

OPEN LANDSCAPES STRUCTURE AND THEIR OPTIMISATION IN THE CONTEXT OF SUSTAINABLE DEVELOPMENT

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Abstract

This article attempts to assess the landscape structure of the open landscape of the Ustka municipality for the design and development of sustainable landscapes, ensuring environmental safety and the quality of human life. The analysis of the area's natural conditions has been made, i.e. abiotic components: relief, water conditions, soil, and biotic: real vegetation, the existing anthropogenic objects, their scale and location in the landscape have been recognized, as well as the basic elements of landscape environmental structures such as environmental corridors and nodes. A quality and quantity characteristics of selected elements of the landscape structure of the research area have been presented and in the final stage of the study the most important directions for changes to optimize the rural landscape of the municipality of Ustka have been shown.

Key words: sustainable development, landscape structure and functioning, optimisation of rural landscapes, Ustka municipality

INTRODUCTION

In line with the idea of sustainable development the natural conditions determine the development of social and economic functions and account for the potential for development of the area. One of the instruments to optimize the development of a specific area in the local and regional scale is a so-called "smart growth" that combines the principles of sustainable land use, controlled sprawl and space order (Degórski 2006). Recognition of environmental resources and values is a priority task, the implementation of which subsequently allows the creation (organizing) of landscape area ensuring environmental safety and proper quality of human life.

The above assumptions relate to areas of different levels of anthropogenic pressure: the ones transformed by men in the highest degree, such as urban and industrial ar-

eas, these partially transformed, being a mosaic of different proportions of natural and artificial elements, like suburban areas, areas dominated by natural elements in the landscape, as rural areas of different functions (agricultural, recreational, et al.) or finally the areas of minor or negligible anthropogenic pressure, often subject to the highest form of protection.

In the contemporary meaning the landscape is treated as a multi-dimensional and multi-feature system changing in time and space. Inherent in the landscape is the man, so the landscape is subject to various anthropogenic influences. According to the European Landscape Convention, the landscape is an area "as perceived by people, whose character is the result of the action and interaction of natural and / or human" (J. o L. of 2006...). Changes in the landscape are held mostly by changing elements of its structure (Pietrzak 1998). The structure of the landscape indicates the spatial (component and territorial), temporal and functional diversity.

In this paper, focusing on the study of the structure of the open landscape of a chosen territorial subdivision, the analysis was performed on spatial differentiation of landscape, that is its component structure and its territorial configuration. In the later stages of work the environmental landscape structure was also taken into account, which, according to Zarska (2005) should be analysed in three aspects: quality, quantity and spatial.

The concept of the open landscape by Bogdanowski (1976) is defined as follows: "An open landscape has a natural, broad horizon, within which most predominant forms are made by man (crops, orchards, forests), but natural in their material. This should also include the cultural landscape (rural-type settlement, monuments and roads) consisting of open interiors, formed by man mainly from natural elements being natural resources." An open landscape is thus identified with rural landscape and it will be used in this study in this sense.

Optimisation is a process of finding the best solution to a problem, determining the best solution of all allowed ones, basing on a chosen criterion. Optimisation can be made basing on one chosen criterion (single criterion) or on a specific set of criteria (multi criteria optimisation). As a research method, optimisation is used to solve problems of economic nature, in business programming and in very many fields, concerning planning and development of various aspects of human activities. Increasingly, optimisation is talked about in the context of architecture and urban planning in relation to developing investments of various functions, with regard to the fundamental principle of sustainable development, i.e. the principle of triple responsibility (environmental, economic and social) in so called sustainable design (*Zawód Architekt...* 2010).

The issue of optimizing the landscape structure appears more and more often in modern research work and scientific studies. Solon (2006) writes about so called concept of optimal landscape conditions, according to which for each landscape there is one optimal spatial configuration of ecosystems and land use, which corresponds with maximum landscape integrity while maintaining the possibility of sustainable development and ensuring the fulfillment of social and economic functions. The need to rebuild (restructuring) a significant part of the existing territorial and landscape structures in order to improve the quality standards of the landscape space is also noticed by Klimko (2006), who emphasizes on development of criteria and methods for as-

sessing the current and future functions of landscape units. Search for methods to assess rural landscapes of Pomerania in the context of their optimisation was also dealt with by the author of this article (Flis 2006), recognizing an urgent need to confront functional and spatial structure of rural areas with their natural conditions.

An important assumption of many environmental decisions is that some patterns or combinations of land cover are optimal or more preferable to others. Management plans frequently seek to change the structure of a landscape to realise particular management goals, because it is recognized that the spatial arrangement of elements in a land cover mosaic control the ecological processes which operate within it (Haines-Yuong and Chopping 1996).

It seems obvious that planning of sustainable development of open landscapes requires a good recognition of the environment, the value of which is the result of its internal structure and the status, resulting from human activity (German 2004, Nikodemus et al. 2010, Pauditsova and Rehackova 2010, Gruehn 2010 and others).

MATERIAL AND METHODS

This paper focuses on the analysis and recognition of the natural structure of open landscapes, which have different social and economic functions, due to their location, natural potential and social, economic or cultural factors.

The main research problem and the purpose of this study is to get an answer to the question: what is the landscape structure of the examined area like and what features of it can be regarded as crucial for forming a sustainable (smart) landscape. This is about maintaining or obtaining, by taking specific actions, an optimal system of functional and spatial landscape, while taking into account the existing structure of nature and environmental processes occurring in the studied area.

As the sub-goals that make up the problem of this study, the following research tasks can be listed:

- a) recognition of the current territorial and landscape structure of the studied area, characteristics of local features – features of the landscape that identify its natural conditions,
- b) characteristics of anthropogenic influence on the landscape by analysing the land use structure; recognition of land cover forms and their classification according to the European CORINE Land Cover system,
- c) identifying the basic elements of the landscape structure characteristics of such elements as environmental corridors and nodes, analysis of their density and mutual relations,
- d) attempt to assess the existing functional and spatial structure from the perspective of the functioning of natural processes,
- f) optimisation – identifying the courses of actions aiming at optimisation of the landscape structure of the studied local government subdivision.

What transforming and corrective actions should be taken to optimize the current landscape structure of this area from the perspective of natural and environmental criteria? In the course of the research, three stages of actions have been distinguished, which are presented in the diagram below (Fig. 1).

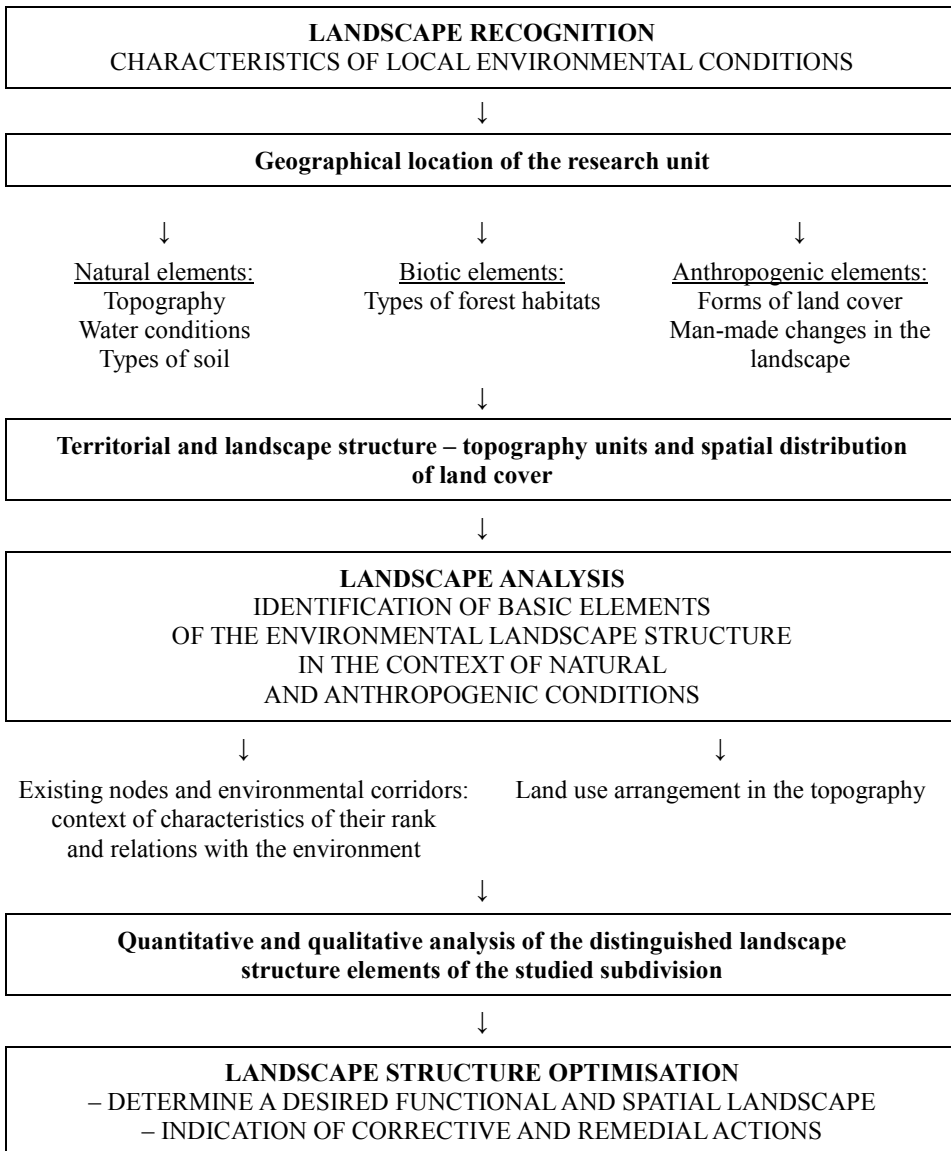


Fig. 1. Stages of the research in optimising the open landscape structure of the research unit (municipality of Ustka)

At the stage of landscape structure recognition its features have been taken into account: abiotic – relief, water conditions, soil types; biotic – types of forest habitats as well as anthropogenic – types of land cover. The key role in recognizing the natural conditions was the relief, considered to be leading component, a dominant, which determines the system of remaining elements – soil, water and vegetation. At this stage, the land topography units have been isolated by adopting two criteria: absolute height above sea level and forms of relief. The characteristics of distinguished

Table 1

Land cover classes distinguished in the CORINE Land Cover program

Level 1	Level 2	Level 3	
1. Artificial surfaces	1.1 Urban fabric	1.1.1 Continuous urban fabric	
		1.1.2 Discontinuous urban fabric	
	1.2 Industrial, commercial and transport units	1.2.1 Industrial or commercial units	
		1.2.2 Road and rail networks and associated land	
		1.2.3 Port areas	
		1.2.4 Airports	
	1.3 Mine, dump and construction sites	1.3.1 Mineral extraction sites	
		1.3.2 Dump sites	
		1.3.3 Construction sites	
	1.4 Artificial, non-agricultural vegetation areas	1.4.1 Green urban areas	
		1.4.2 Sport and leisure facilities	
	2. Agricultural areas	2.1 Arable land	2.1.1 Non-irrigated arable land
			2.1.2 Permanently irrigated land
2.1.3 Rice fields			
2.2 Permanent crops		2.2.1 Vineyards	
		2.2.2 Fruit trees and berry plantations	
		2.2.3 Olive groves	
2.3 Pastures		2.3.1 Pastures	
2.4 Heterogeneous agricultural areas		2.4.1 Annual crops associated with permanent crops	
		2.4.2 Complex cultivation patterns	
		2.4.3 Land principally occupied by agriculture with significant areas of natural vegetation	
		2.4.4 Agro-forestry areas	

3. Forests and semi-natural areas	3.1 Forests	3.1.1 Broad-leaved forest
		3.1.2 Coniferous forest
		3.1.3. Mixed forest
	3.2 Shrub and/or herbaceous vegetation associations	3.2.1 Natural grassland
		3.2.2 Moors and heathland
		3.2.3 Sclerophyllous vegetation
		3.2.4 Transitional woodland scrub
	3.3 Open spaces with little or no vegetation	3.3.1 Beaches, dunes, sand plains
		3.3.2 Bare rock
		3.3.3 Sparsely vegetated areas
		3.3.4 Burnt areas
		3.3.5 Glaciers and perpetual snow
	4. Wetlands	4.1 Inland wetlands
4.1.2 Peat bogs		
4.2 Coastal wetlands		4.2.1 Salt marshes
		4.2.2 Salines
		4.2.3 Intertidal flats
5. Water bodies		5.1 Continental waters
	5.1.2 Water bodies	
	5.2 Marine waters	5.2.1 Coastal lagoons
		5.2.2 Estuaries
		5.2.3 Sea and ocean

Source: (<http://ec.europa.eu/agriculture/publi/landscape/imag11.jpg>) (access on: 10/12/2012)

units have been supplemented with information on hydrography, soil types and forest habitats.

Another important issue of the recognition stage was to identify landscape cover forms, which were classified according to the CORINE Land Cover system (Table 1). A spatial landscape use distribution in the studied area has been obtained and calculations have been made, leading to the quantitative data.

The analysis stage was preparing quantitative and qualitative characteristics of the landscape structure elements and complementing it with information concerning functioning of the landscape from the natural processes' point of view. An identifica-

tion of basic elements of the environmental structure of the landscape, such as nodes and environmental corridors was made, followed by determining their meaning for the examined area and its surroundings.

At this stage, a detailed characteristics of distribution of land use forms is presented, according to the distinguished topography units. An attempt was made to determine in what way the existing spatial arrangement can influence the course of natural processes and possibilities of functioning of the environmental open landscape of the Ustka municipality.

Optimization is an integral part of the process of shaping the landscape, while matching the basic principles of sustainable development, concerning preserving of the natural resources of the rural areas at the local and regional levels. At the optimization stage a proposal of remedies and corrective actions to achieve the desired state of the landscape and the functional and spatial system was made. The directions of changes in the land use, most desired for maintaining the favourable landscape structure or those that are necessary to improve it, were indicated.

In the research work on the open landscape structure of a municipal unit, the cartographic analysis method was applied, using a set of topographic maps of Ustka (1:25 000) as well as the thematic maps: hydro-graphic, soil and agricultural, forest habitats and zoological maps. Field mapping for land cover in the spring and summer of 2011 was also done.

The study site

For the purpose of conducting the research on the open landscape optimization, the municipality of Ustka was chosen, which is located in the central part of southern coast of the Baltic Sea, at the mouth of the river Słupia, in the city-resort of Ustka. The Ustka municipality is located in the north-western part of Pomorskie voivodship. In the west it borders with the Postomino municipality (Zachodniopomorskie voivodship), in the east with the Smołdzino municipality and in the south with the rural municipality of Słupsk. The north boundary of the municipality is the Baltic Sea coastline with a length of 25 km (Fig. 2).

According to the physical and geographical division (Kondracki 1988), the discussed area unit consists of three mesoregions: the Słowińskie Coast, the Słupsk Plain and the Damnica Upland. In terms of hydrography, its area is located within three rivers catchments: in the western part of the Wieprza River, in central part of the Słupia River and in the west of the Łupawa River. Along the Baltic coast, there are also distinguished the smaller hydrographic units as catchments of the Potynia Canal and the Orzechówka River.

The Ustka municipality covers an area of 21 746 ha. Its population at the end of 2006 amounted to 7,367 inhabitants and a population density was 34 people/km², with an average population density for the county of Słupsk of 40 people/km² and for Pomorskie voivodship of 120 people/km² (Strategia... 2009). The settlement network of the municipality consists of rural locations of tourist and recreation nature, located within the coastal zone (Dębina, Rowy, Poddąbie, Orzechowo), rural centres well communicated with the spa of Ustka (Duninowo, Zaleskie, Grabno, Przewłoka) and with the city of Słupsk (Objazda, Machowino, Wotywno).



Fig. 2. Location of the Ustka municipality within the Poland area

Among road and rail routes run through the Ustka municipality: the provincial road Słupsk – Ustka No. 210, Darłowo – Ustka No. 203 and a rail road Słupsk – Ustka, are the most important transport and communication trails.

The dominant economic function of the Ustka municipality is agriculture, with its accompanying functions: industry and services, tourist, recreational and residential. Numerous forms of nature and landscape protection existing in this area, have a considerable meaning, as a part of the regional system of conservative areas of the Pomeranian voivodship.

RESULTS AND DISCUSSION

The open landscape structure of the Ustka municipality consists of elements of abiotic and biotic character. Their functionality structure and spatial diversity result from numerous physical and chemical processes, topography and geology, soil, sur-

face, ground water and vegetation, they create a system of interrelated components of the environment, which can be seen in the form of the landscape.

The research area, located in the coastal lowlands is characterized by a high diversity of relief forms. By their origin, we can distinguish here forms related to the coast line, shaped by wind, waves and offshore currents. These includes: dunes, eolian sand fields, beaches and cliffs, located along the coast of the Baltic Sea. The most developed zone of dunes occurs in the area of Ustka – Poddąbie, east from Dębina and west from Ustka, these are so called the Łędowskie and Zaleskie Dunes, where the dune hills altitudes exceed 40 m above the sea level. The sandy beaches of varying width (the widest is in the Ustka spa area, the width is in the range from 40 to 100 m) stretch along the whole coast within the area of interest. The narrowest part of the beach with a width of just a few meters is west from the mouth of the Orzechowski Creek, backed by a 14 m high cliff and 12 m high dunes. The cliffs extend from Ustka to Rowy. In Ustka, the cliff height reaches 3-5 m, in the region of Orzechowo – Poddąbie 12-15 m, in Dębina 40 m and in Rowy 4-5 m, respectively (Florek 2001).

The forms of *glacial origin*, typical for this area, include: flat, undulating, sometimes hilly moraine plateaus, composed of sandy clay, glacial till, covering sands and clay-silt. They are present in the central and south part of the municipality. The heights range between 10 to 50 m above sea level. The central part of the area is dominated by flat areas up to 20 m above sea level; in the south, the heights and diversities of relief become higher.

A significant area of the Ustka municipality are dammed glacial plains, built of clay, mud and dammed sands. They are present in the central part of the area in the regions of Machowino, Wytowno, Grabno, Charnowo and Peplino. An example of a vast plain of mineral and organic accumulation is the bottom of lake Modła, located in a huge cavity in the plateau, consisting of laminated mineral mud mixed with some organic substance. A vast plain of lake and peat accumulation is also present in the east of Dębina and Objazda, in the surroundings of the Gardno Lake. Common to this area are also kettle cavities, scattered throughout the whole area as contained catchment cavities, dry or wet, filled with alluvial sediments or peats.

The valley of the Słupia within the research area belongs to the *forms of fluvial origin*. There are distinguished slopes of the valley at low altitudes (from several to 3 m) and variable slopes. Along the valley there are erosion and accumulation floodplains (in the region of Ustka, Grabno, Charnowo and Wodnica). In the vicinity of Wodnica there are also dry oxbow lakes, filled with young alluvial sediments.

The visual reflection of these genetic features of the relief are the morphometric properties (absolute heights, height differences, form types). The analysis of the topography of the researched municipality was made in order to identify the spatial (territorial) diversity of the area, in terms of defining its importance for the functioning of natural processes but also the usability and suitability of these areas for economic purposes of man. Therefore, while distinguishing the topography units, the hypsometric conditions, that is altitude above sea level and existing forms of relief, which reflect the physiognomy of the open landscape features of the researched area, were also taken into account. The units of topography of the Ustka municipality are presented in Fig. 2, while their contribution to the total surface area is specified in Table 2.

Table 2

Units of topography in the Ustka municipality
(values given in %, based on own cartometric measurements)

Forms of topography	The percentage of the municipality area
Flat plains landscape	53.73
Undulating landscape	22.48
Dune hills landscape	5.56
Hilly landscape	17.76
Valley slopes landscape	0.47

The largest area taking more than 50% of the municipality area is the flat plains landscape with altitude up to 20 m above sea level. It covers the central part of the research area extending parallel to the coast line in the direction south-west to the north-east, as well as the eastern part of the municipality, along its border and a lake of the Gardno Lake, already beyond the borderline. Flat plain landscape can be found also at the mouth of the Gnilna River in the lower section of the Słupia floodplain.

The undulating landscape with altitude from 20 to 30 m a.s.l. covers slightly more than 22% of the research area. They are mainly present along the southern border of the municipality, from south-west to north-east, then turn north and become meridional-oriented: Redwanki, Machowinko, Objazda and Poddąbie, reaching the sea coast.

The hilly landscapes cover less than 18% of the area. They consist of small surface elevations with altitudes greater than 30 m above sea level and sometimes even 55 m above sea level. They are located at the south-western border of the municipality, in the region of Zaleskie and Możdżanowo and in the north- and south-eastern part of the area in the east from Poddąbie and in the south-east from Gąbino.

The dune hills landscape is dominates along the sea coast border of the municipality, embracing 5.5% of its total area. In the west from the Słupia River mouth these are groups of dunes like Zaleskie Wydmy, Modelskie Wydmy, Łędownskie Wydmy, of which is the highest peak Góra Ognica with a height of 40.4 m a.s.l. To the east of river Słupia, from Ustka to Rowy, there are groups of less diverse and lower dune hills of max. altitude of 32.5 m a.s.l. in the region of Dębina.

The share of lowland landscape is relatively small in the analysed area, as it takes less than 0.5% of the municipality area. It is a steep slope, running along the valley of river Słupia, falling from a height of 45 m above sea level towards the river, with altitude differences of 25 m. It is located in the south part of the research area (Fig. 2).

On such relief, certain types of soil formations have developed. The research area is dominated by soils formed of glacial till: proper brown soil, leached and acid brown soil and black soil. These are complexes of agricultural usability of 2, 4 and 8, referred to as suitable for agricultural production. In the central and eastern part of the Ustka municipality there is also a mosaic of sand soils of various genetic types (e.g.

pseudo podzolic) of agricultural usability of 6 and 7, of a low suitability for crop production. Some of the poorest soils, especially in the northern part of the area have been forested. Vast areas are covered by organic sedimentary soil located in the area of Modła and Gardno lakes, where lowmoors, transitional moors and highmoors have created. Lowmoor is used in agriculture as a permanent pasture of medium quality. In the valley of the Słupia River and its tributaries there are moor soils: silt-peat and alluvial soils, classified as permanent pasture of medium and poor quality.

The soil conditions of the studied municipality are described as quite favorable, with an agricultural production space index of 67.5, which represents average conditions for agriculture within the county (Grabowski et al. 2003). Best and very good soils are 0.4% of the arable land, good and average soils are 74.2% while poor and very poor soils are 25.4% of the arable land.

The hydro-graphic network of the research area is in the following sub-catchments: the catchment of lower Słupia River (the central part of the area with the biggest right tributary, the Gnilna River), Przymorze catchment (the western part of the area: lake Modła and the Potena Canal, taking water from it and ending at the sea, with its tributaries Pogorzeliczka and Kawia rivers), direct Baltic catchment (central-eastern part of the area with the Orzechówka River), the catchment of the Łupawa River (eastern part of the area with rivers of Bagienica and Grabownica, ending in the Gardno Lake, located beyond the border of the municipality of Ustka) and the catchment of the Wieprza River (south-western part of the municipality with the tributary of the Wieprza River – the Pijawica River).

In the landscape of the Ustka municipality an important hydro-graphic element are canals and drainage ditches, regulating water levels of the grasslands and acting as flood protection. Drained areas cover 8 649 ha and are present in the area of Objęskie Łąki near the Gardno Lake and Zaleskie Marshes near the Modła Lake. Flood risk results from periodically excessive precipitation, storms and so called backwaters, when water is backed up to the river by north or north-western wind to the mouth of Słupia, Orzechówka, Potena or Łupawa, as well as the lakes Modła and Gardno. The flood protection elements are the embankments and pumping stations.

The only big lake in the research area is the Modła Lake – a coastal lake with an area of 41 ha, maximum depth of 2 m and average depth of 0.5 m (Wojterski and Bednorz 1982). The lake is located at an altitude of 0.4 m above sea level but still its cavity is considered to be a crypto depression type (1.6 m below the surface), (Cieśliński 2006). There are some minor lakes, ponds located in some kettle cavities.

The forest habitats and vegetation arrangements reflect the diversified hydrographic and soil morphology conditions. The municipality of Ustka has a high diversity of habitats, from aquatic and wetlands, associated with peat bogs, lakes and creeks to extremely dry, typical for sand dunes and the sea shore. We can distinguish here the following types of plant communities (by Grabowski et al. 2003):

- communities of coastal dunes and cliffs: white dunes, grasslands, fertile lowland beech, coastal beech and beech-oak forests,
- communities of high peat bogs, like swamp forest and bog birch,
- communities of hydrophytes with floating leaves and bog plants typical for Słupia oxbows, natural and man made lakes, drainage ditches and cavities with high levels of ground water,

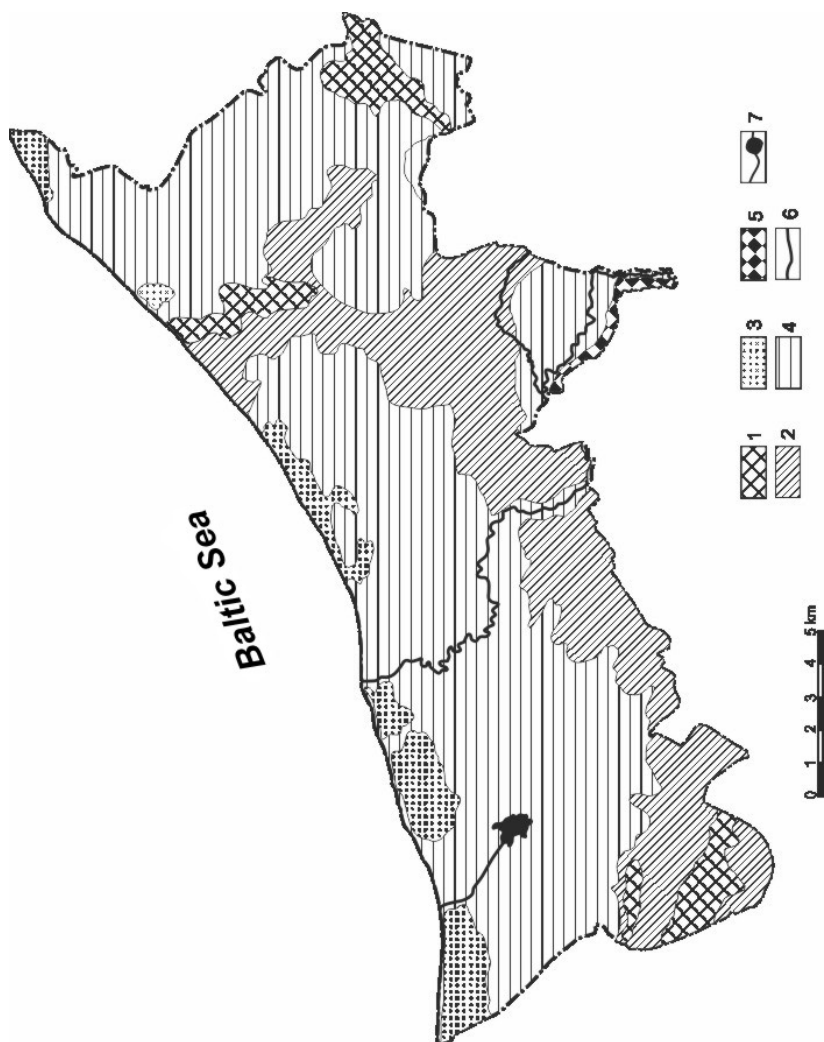


Fig. 3. Units of the land shape in the Ustka municipality (own work)

1 – hilly landscapes with a height of 30-55 m above sea level, 2 – undulating landscapes with a height of 20-30 m above sea level, 3 – dune landscapes of hills with a height of 40 m above sea level, 4 – flat plains landscapes to a height of 20 m above sea level, 5 – landscapes of valley slopes, 6 – natural watercourse, 7 - lake

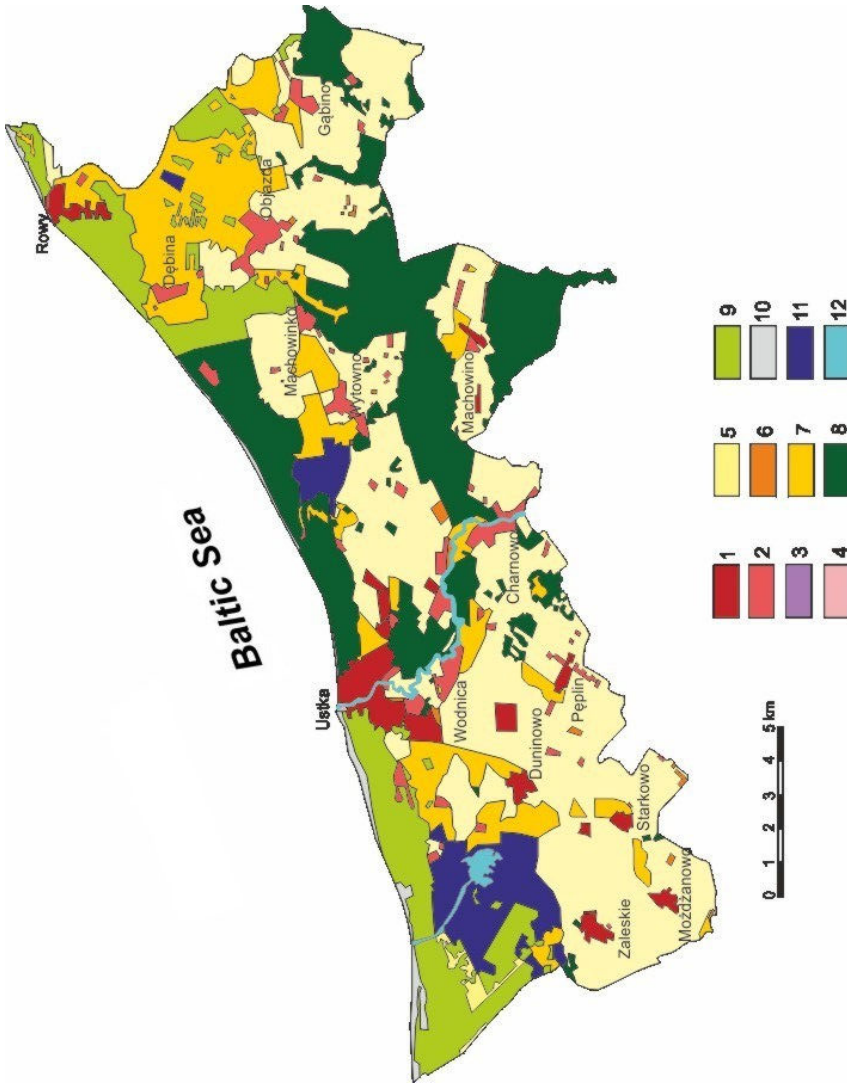


Fig. 4. The spatial distribution of land use forms within the municipality of Ustka (as of the year 2010, own work)
 1 – compact development, 2 – scattered development, 3 – communication facilities areas, 4 – sea and river ports, 5 – arable land, 6 – plantations and orchards, 7 – meadows, 8 – coniferous forests, 9 – mixed forests, 10 – dunes, sand and beaches, 11 – inland wetlands, 12 – inland waters

- communities of scrub: withy and willow communities along the banks of rivers, creeks and communities of shrub: broom,
- meadows and grasslands, typical for permanent pasture,
- communities of forests of habitats like: alder, ash alder riparian, acid lowland beech, swamp forests, pine forests and
- synanthropic communities associated with agricultural fields, developed areas, communication facilities areas, where weeds and ruderal can be distinguished.

Table 3

Land cover forms of the Ustka municipality classified by the CORINE Land Cover system (as of the year 2010)

Land cover categories by CORINE Land Cover		[ha]	[%]
Anthropogenically transformed areas	compact development	773	3.5
	distributed development	547	2.4
	communication facilities	573	2.6
	sea harbors and river ports	12	0.1
Agriculture areas	arable land	8804	39.3
	orchards and plantations	45	0.2
	grasslands	2863	12.8
Forests and semi-natural ecosystems	coniferous forests	790	3.5
	mixed forests	6392	28.5
	beaches, dunes, sands	358	1.6
Wetlands	inland marshes	1057	4.7
Water Areas	surface water	48	0.2
	creeks and rivers	127	0.6
Total		22 389	100

Source: own work

The consequence of the existing biotic and abiotic elements in the open landscape of the research area is the spatial distribution of land use. They reflect anthropogenic human impact on the landscape, leading to modification of specific features and properties of the natural environment. In order to recognize how intense this activity is and how it influences the change of functioning of the natural processes, a detailed analysis of the land cover forms in this area has been made. Their quantitative characteristics is shown in Table 3, while its spatial distribution is shown in Fig. 4.

As it can be seen in Table 3, the anthropogenically transformed areas occupy 8.6% of the research area, agricultural land 52.3%, forests and semi-natural ecosystems 33.6%, wetlands 4.7% and water areas 0.8% of the total area of the municipality.

Analysing the spatial system of the land use in accordance to the distinguished types of the relief, one must pay attention to the existing mutual relationships between these elements of the landscape. The forests extend along the whole coastal border of the municipality in a strip of the average width 2 to 4 km inland (Fig. 4). They cover 100% of the dune hills and some undulating and plain areas between them. The other “zone” of the forest areas is in the south-eastern part of the research area and it is associated with undulating and hilly relief. Only in the southern part, along the Słupia River, there is a compact forest on flat areas above the river. Forests on the plains are fragmented: at the north-western border of the municipality, along river Słupia to the developed areas of Ustka and Wodnica village and in the east near the lake of Gardno and a town of Rowy.

Most of the flat and plain forms in the centre of the Ustka municipality are used as farmlands: mostly used as arable land, some smaller areas are occupied by meadows and pastures. Quite a large area is also covered with swamps and waterlogged areas: in the western part of the Modła Lake, but in the eastern part, by the borderline around lake Gardno. It should be noted that in the western part of the municipality near the villages of Peplin, Duninowo, Zaleskie, Starkowo and Możdżanowo, there are vast areas of arable land on hilly and undulated forms, virtually devoid of permanent vegetation.

Settlement areas, which include villages, mainly single-street ones, form a mosaic arrangement in the landscape space and are located both on flat land as well as on hilly and undulated areas. The largest villages, with population over 450, are Duninowo, Przewłoka and Machowino (Fig. 4).

The above characteristics of the basic elements of landscape structure and of the existing arrangement of forms of land use makes it possible to analyse so called *environmental structure of the landscape*, which is essential for the protection of the nature and landscape values. The widespread contemporary processes of “fragmentation” of the natural ecosystems in the landscape, due to the ongoing creation of the so called environmental barriers and improper activities related to the use and development of the landscape are “one of the most important causes of mass disappearance of species and ecosystems of natural character” (Żarska 2005). A special role in preserving biodiversity are the environmental corridors, which are roads connecting the specified elements. Their presence decides on possibilities for the species to move around within the area, as well as to migrate from the surroundings. The areas to which the corridors lead are so called nodal areas, i.e. places of highest biodiversity, habitats for many species of fauna and flora.

The most important elements of the ecological structure of the landscape which are present in the research area are:

- the Słupia River, the environmental corridor of regional value,
- Baltic coastal zone with groups of dunes and beaches being a part of the environmental structure of national and transnational value,
- valleys of smaller creeks and streams (e.g. Pogorzeliczka, Potynia, Struga Łędowska, Orzechówka, Grabownica, Gnilna etc.),
- compact forests,
- bogs, marshes and swamps, including the largest Reserve “Zaleskie Marshes” and “Modła Lake” with the Potynia canal leading to the sea,

- small forest ponds and lakelets with associated vegetation,
- ecotones, i.e. contact zones of different ecosystems with higher biodiversity,
- mid-field trees and shrubs of various shape and structure of the species,
- steep slopes, occurring mainly in the southern part of the area, on the slopes of the Słupia stream channel.

Spatial configuration of the elements of the environmental structure within the Ustka municipality is presented in the Fig. 5.

The analysis of the spatial arrangement of these listed elements makes it possible to conclude that the greatest concentration of elements of the environmental structure is present in the coastal strip, in the north-western part of the area, in the region of the Modła Lake, along the Słupia valley extending from the southern border to the river mouth in Baltic and in the south-eastern part of the municipality, where there are quite extensive and compact forests from Charnowo to Gąbino (Fig. 5). These are spatially coherent areas and environmental corridors demonstrating spatial continuity and extending also beyond the administrative border of the Ustka municipality. In the south-eastern and eastern part of the Ustka municipality there are also numerous mid-forest waterlogged areas as well as ponds; the degree of border development of these complexes is significant, there is a network of small rivers and creeks through the forests, meadows and fields. Boundaries of individual habitats is much varied, the so called ecotone zones are an important element of the landscape space.

The areas with relatively simplified environmental structure, where the share of the elements making the landscape various is small, the areas that are monotonous in terms of land use include: south-western and central part of the municipality: the villages of Zaleskie, Możdżanowo, Starkowo, Peplin, Duninowo, Wodnica and the area between Przewłoka and Wytowno. They are dominated by large areas of farmland, mostly devoided of such elements as mid-field trees, shrubs along field borders, ponds etc.

It is worth noting that the elements that are most meaningful for functioning of the landscape have been subject to various forms of preservation. In the research area, 6 373.7 ha are subject to legal preservation (Strategia... 2009) which is 28% of the total municipality area. The following forms of legal preservation should be mentioned:

- a part of the Slovinski National Park with an area of 288.7 ha (that is 1.3% of the municipality area),
- nature reserves: “Zalewskie Marshes”, “Modła Lake” and “Beech at the Słupia River” with an area of 615.7 ha, that is 2.8% of the municipality area (Fig. 6),
- areas of the preserved landscape “Coastal strip west from Ustka” and “Coastal strip east from Ustka” with a total area of 5 836 ha, that is 26.8% (Fig. 6),
- environmental areas: 59 objects of total area of 229.9 ha, including the mid-forest waterlogged areas and habitats of preserved and rare species of plants and animals,
- natural monuments: 87 objects, mostly single trees.

In the area of the Ustka municipality there are also zones of the resort-related protection. In these areas, certain rules of land management are required, as stated in the Law on resorts and the resort statute (J. o L. of 2005...).

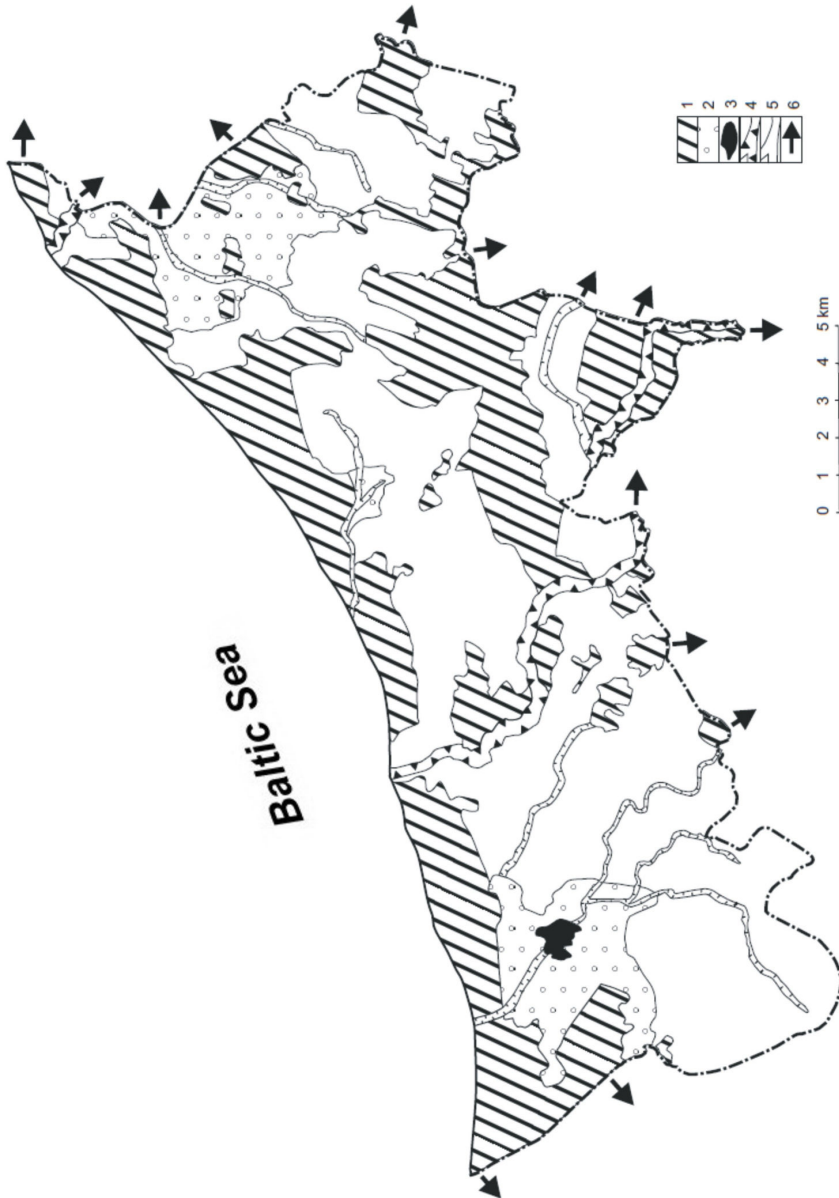


Fig. 5. Elements of the environmental structure of the Ustka municipality (own work)
 1 – compact forest complexes, functioning as ecological corridors and nodes, 2 – the vast swamps and marshes, 3 – natural lakes, 4 – regional corridors of the Stupia and Lupawa rivers, 5 – local environmental corridors, 6 – existing lines of relations between the elements

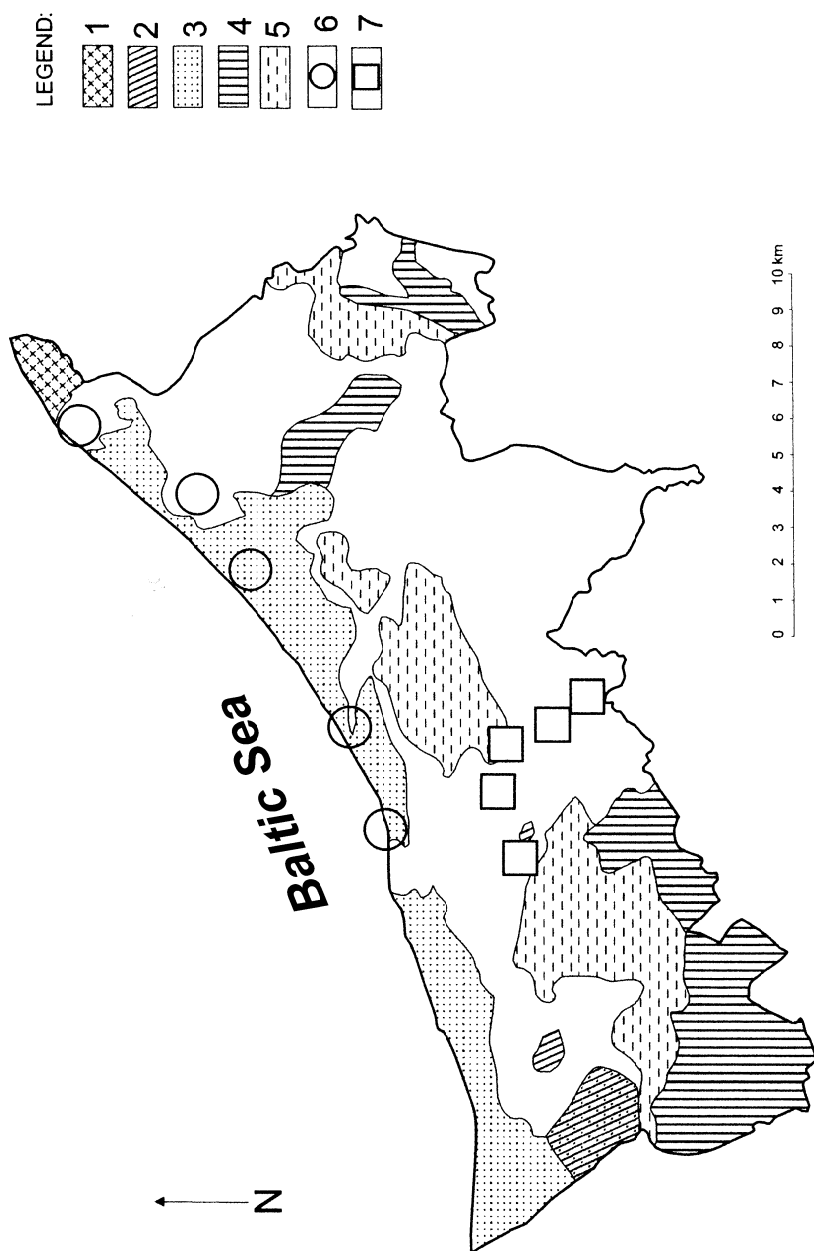


Fig. 6. Environmental protection of the Ustka municipality and the main areas that require adjustments in the structure of land use (own work)
 1 – a part of Slovinski National Park, 2 – nature reserves, 3 – areas of preserved landscapes, 4 – arable lands highly endangered by erosion, 5 – developed areas or areas planned for development in the coastal zone which have low resistance for human pressure, 6 – rural settlement areas where a large scattering of the new developments is observed

The presented analysis of the open landscape of the Ustka municipality, especially the characteristics of the spatial configuration of the land use forms allows to identify positive and negative features of the existing functional and spatial arrangement of the landscape. From the point of view of the natural processes, the key, positive features of the current open landscape structure of the research area include:

- location of the area along the coast of the Baltic Sea, being a zone of high biodiversity in terms of ecosystems, habitats and landscapes in the supra-regional scale, as well as being a zone of relatively small anthropogenic changes and of seasonal tourist pressure towards the landscape,
- a significant share of forests (33%) and wetlands (4.7%) in the total area of the studied municipality,
- presence of a regional environmental corridor in the form of the Słupia River valley and a quite dense network of small rivers and creeks, forming environmental corridors at the local level,
- a high diversity of forest habitats and plant communities, reflecting the various hydro-graphic and soil morphology conditions,
- a relatively small share of anthropogenically transformed areas: developed and communication facilities areas (8.6% of the municipality area) and their quite compact spatial arrangement.

On the other hand, the negative factors that can make the environmental processes difficult, we can specify:

- a large share of agricultural land: more than 50% of the municipality area, of which an incredible part is heavily utilized as arable land (more than 39% of the municipality area),
- dominance of flat plains in the open landscape, exposed to wind erosion in the absence of permanent vegetation as well as an absence of elements that could provide shielding or making the landscape more various,
- an intense crop production in the undulating and hilly areas and lack of facilities controlling the erosion and improving the biodiversity of the agricultural landscape (especially in the western part of the municipality),
- an uneven distribution of forest areas: their total absence in the south-west of the studied area and a simplified, contrary to some of the habitats, composition of species in some forest areas,
- lack of coherence and connection between small forest surfaces and areas with non-forest vegetation and creeks, especially in the central and eastern part of the studied area,
- development pressure related to the recreational and tourism function on the dunes areas and on forest strips along the coast (especially in Przewłoka, Poddąbie, Dębina and Rowy),
- ongoing process of deconcentration of developed areas: chaotic expansion of housings for residential or service functions beyond the borders of compact developed areas (e.g. around the settlements of Wodnica, Duninowo, Grabno, Charnowo or Niestkowo),
- presence in the open landscape of so called environmental barriers in the form of communication facilities and areas permanently developed, causing cutting

the ecosystems separate, isolating them and making them smaller, as well as making it difficult for the natural resources to move around.

Going back to the fundamental problem of this research, which was defined at the beginning of this paper, an attempt should be made to define an optimal functional and spatial arrangement of the open space in the studied area, taking into account its natural conditions and the existing environmental structure.

An optimal planning of sustainable open landscape in the studied area, i.e. the municipality of Ustka, requires certain changes in the existing landscape space management to be introduced, meeting the basic concepts of sustainable development and the challenges of the future. The appropriate lines of actions aiming to preserve and to restore the natural resources as well as protection of the biological diversity of this area should focus on two issues:

- maintaining and strengthening the existing positive properties and features of the current landscape of the Ustka landscape,
- elimination or reduction of the scope of impact of the negative features and introduction of corrective actions against the detrimental functional and spatial arrangements on chosen parts of the area.

The most important corrective actions relevant to shaping of the optimal spatial and functional structure of the multifunctional landscape of the Ustka municipality should be considered:

- a) changes in methods of land use, aiming to improve the conditions (for example: water circulation, local climate, condition of animal migration etc.) of functioning of natural systems, such as:
 - introduction of permanent vegetation *of water and soil protecting impact* along the small creeks, field borders, mid-field roads, around the developed and industrial areas,
 - introduction of compact enclaves in vegetation of various forms and spatial structure with the *erosion protection function* on the hilly and undulating areas,
 - creating a coherent system of middle-field trees in the western part of the municipality (west from the Słupia River valley), intensively used for agriculture due to the fertile soils,
 - quitting the intensive crop production on the poorest soils (complexes 6 and 7 of agricultural soil suitability) and implementing afforestation on these areas,
 - optimization of the spatial structure of the forest areas by: implementation of afforestation by the existing forests bordering the agricultural landscape, improving the species composition of the forest and its bordering (so called ecotones), improving their shape in order to enlarge the forest interior habitats (by Cieślak 1996), increasing the number of connections between forest surfaces, including them in the system of mid-field afforestations and valleys of creeks, creating *the environmental corridors*, as well as connecting them with the strap of the coast, afforestation of the slopes (river banks, hill sides and erosion undercuts),
 - creating the buffer zones around the areas of natural value with the greatest value for the course of natural processes (e.g. animal food and cover sites, bird breeding sites, species migration routes etc.),

- b) optimization of activities *in the sphere of human-environment relationship* aimed at slowing the process of detrimental development pressure on valuable natural areas in the coastal zone as well as controlling the spatial expansion of the settlement zones outside the rural developed areas.

By analysing the spatial configuration of the natural conditions, elements of the environmental structure and area development in the municipality of Ustka, two categories of areas have been distinguished, on which there are different guidelines for the proposed transformations or changes in the method of use of the landscape space. These are the following types of areas:

- I. **Areas that require no major changes in land use**, where the main priority is to preserve the existing functional and spatial structure, in accordance with the natural conditions and beneficial from the point of view of ongoing ecological processes. They require only caring activities to maintain the desired state of the landscape. These are the areas of forests in the landscape of dune hills along the coastal line, forests on the undulated areas in the eastern and south part of the municipality, extensive wetlands associated with Modła and Gardno lakes, forest areas along the Słupia River valley, as well as the valleys and flat plains used as grasslands.
- II. **Areas that require adjustments in the structure of land use in order to improve the performance from the natural properties and their environmental functions point of view**. Proposals for corrective actions on land cover of certain areas are different, depending on natural conditions and their economic significance. In this category we find the following areas: undulated and hilly areas, used as arable land located mainly in the south-western part of the municipality, which, due to intensive crop production, and partially highly endangered by erosion, require partial changes in the direction of improving the landscape structure of the agricultural landscape; plain and flat areas of the vast agricultural use, extending from west to east in the middle of the community, requiring the introduction of the afforestation system which would protect the soil and water as well as the landscape; areas of arable land on the poorest soils (6 and 7 complex), located in the contact zones with the existing forest complexes or in the vicinity of the river valley – it is highly recommended to perform the afforestations in accordance with the habitats or permanent grasslands; developed areas or areas planned for development in the coastal strip, located on habitats susceptible to degradation – the desired actions there would be reducing the development pressure in the process of spatial planning at the municipal level and directing the development of the buildings to the areas different than the environmentally valuable areas which have low resistance for human pressure; rural settlement areas, where a very large scattering of the new developments is observed – activities at the level of the municipal spatial planning, limiting expansion and excessive scattering of buildings at the cost of biologically active sites. The largest of them are presented in Figure 6.

It must be noted that the above analysis of the open landscape structure was carried out in the scale 1:25 000 with a level of details covering the area of the Ustka municipality which has an area of 22 384 ha. Implementation of measures to optimize the landscape structure at different parts of the municipality of Ustka requires more thorough analysis of these areas in the scales larger than 1:25 000. To determine the

optimal use and management of some areas it will be necessary to perform more detailed studies concerning their natural and landscape structure, environmental functions and economic importance.

CONCLUSIONS

In the analysis of the open landscape structure of the municipality of Ustka, the characteristics of the natural conditions of this area was made and the current spatial and functional structure was distinguished, basing on the map of land cover and identifying the essential environmental elements like nodes and environmental corridors, relevant from the point of view the natural environment functioning. It made it possible to indicate the areas of favourable functional and spatial arrangement for the ongoing natural processes, which form a significant part of the studied area (according to the author's calculations, about 58%) and areas that require corrective actions for the current functional and spatial structure, with a view towards the optimization for the benefit of the natural and environmental processes. Specified areas within the studied area which require an improvement of the functional and spatial arrangement occupy approximately 42% of its surface. The proposed corrective actions are primarily related to the change of land use on small areas, to increasing of biodiversity of the arable land or inhibiting and excessive settlement pressure on the areas which are biologically active or have high natural value.

The essence of the sustainable development is to preserve the local values of the landscape, primarily its structural, spatial and biological diversity. The concept of the sustainable development is fundamentally anthropocentric (Kistowski 2008) which means, the man is assigned to the natural system as its permanent element. In case of a chosen area of the municipality, where a large area is used for economy, the tendency is to take an option of shaping the multifunctional sustainable landscape, fitting the local natural features but also making it possible to perform the social, economic and cultural role.

It is worth noting that some parts of the studied area, for which the optimization is suggested, require additional, more detailed studies on the soil, water, phytosociological or zoological conditions, describing the qualitative state of each environmental component. Therefore it seems advisable to take further studies on chosen places within the research area in a much greater scale than 1:25 000, providing the more-in-depth analysis of their state, properties and environmental meaning as well as providing the guidance on how to use and manage them in an optimal way.

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STRUKTURA KRAJOBRAZÓW OTWARTYCH I ICH OPTYMALIZACJA W ŚWIETLE ROZWOJU ZRÓWNOWAŻONEGO

Streszczenie

W artykule podjęto próbę oceny struktury krajobrazu otwartego gminy Ustka na potrzeby projektowania i kształtowania krajobrazów zrównoważonych, zapewniających bezpieczeństwo ekologiczne i odpowiednią jakość życia człowieka. Problematyka badawcza obejmowała zarówno analizę uwarunkowań przyrodniczych obszaru, tj. komponentów abiotycznych: rzeźby terenu, warunków wodnych, gleb oraz biotycznych – roślinności rzeczywistej, jak również identyfikację występujących obiektów antropogenicznych i ich rozmieszczenie w przestrzeni krajobrazowej, a także rozpoznanie podstawowych elementów struktury ekologicznej krajobrazu, takich jak korytarze i węzły ekologiczne. Etapy pracy prezentuje Ryc. 1. W końcowym etapie pracy wskazano najistotniejsze kierunki zmian służących optymalizacji krajobrazów wiejskich gminy Ustka. Analizując konfigurację przestrzenną uwarunkowań przyrodniczych, elementów struktury ekologicznej i zagospodarowania terenu na obszarze gminy Ustka, wyróżniono dwie kategorie powierzchni, co do których istnieją odmienne wytyczne odnośnie do propozycji przekształceń lub zmian w sposobie użytkowania przestrzeni krajobrazowej. Są to następujące rodzaje powierzchni:

- **obszary niewymagające zasadniczych zmian w użytkowaniu terenu**, na których priorytetem jest zachowanie istniejącej struktury funkcjonalno-przestrzennej, zgodnej

z uwarunkowaniami przyrodniczymi i korzystnej z punktu widzenia zachodzących procesów ekologicznych. Wymagają one jedynie działań pielęgnacyjnych, umożliwiających utrzymanie pożądanego stanu krajobrazu.

- **obszary wymagające korekty w strukturze użytkowania ziemi w celu jej poprawy z punktu widzenia właściwości przyrodniczych oraz funkcji ekologicznych.** Propozycje działań naprawczych odnośnie do przekształceń w pokryciu terenu poszczególnych powierzchni są zróżnicowane w zależności od uwarunkowań przyrodniczych oraz znaczenia gospodarczego tych terenów. Wymagają one częściowych zmian w kierunku poprawy struktury ekologicznej krajobrazu np. wprowadzenia roślinności o funkcji przeciwoerozyjnej na gruntach rolnych, wykonania zalesień zgodnych z siedliskiem, ograniczenia presji inwestycyjnej na terenach cennych przyrodniczo o niskiej odporności na antropopresję, ograniczenia ekspansji i rozproszenia zabudowy kosztem terenów biologicznie czynnych w obrębie jednostek osadniczych.

Warto podkreślić, iż niektóre fragmenty analizowanych obszarów, dla których sugeruje się ich optymalizację, wymagają dodatkowych, bardziej szczegółowych badań odnośnie do ich warunków glebowych, wodnych, fitosocjologicznych czy też sozologicznych, określających stan jakościowy poszczególnych komponentów środowiska. Dlatego też celowe wydaje się podjęcie dalszych badań na wybranych powierzchniach tego obszaru w znacznie większej skali niż 1:25 000, umożliwiających bardziej wnikliwą analizę ich stanu, właściwości i znaczenia ekologicznego oraz sformułowanie wytycznych co do sposobu ich optymalnego użytkowania i zagospodarowania.

