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THE INFLUENCE OF HORIZONTAL LAND COVER STRUCTURE CHANGES
OVER THE VALLEY Odra RIVER LANDSCAPE IN THE WROCLAW AREA

WPLYW ZMIAN POZIOMEJ STRUKTURY POKRYCIA TERENU NA KRAJOBRAZ
DOLINY ODRY W REJONIE WROCLAWIA

Abstract

This article concerns the subject of landscape changes based on dynamic changes in horizontal land cover over 20 years (1995–2015). The research area is the Odra valley in Wrocław and its surroundings, which is divided into architectural-landscape units and land structure changes using photointerpretative retrospective analysis. Based on this analysis, a characteristic changeability index was specified, which shows the percentage value of changes in each unit. These changes have direct influences on the visual perception of each landscape.

Keywords: Odra valley, land cover changes, landscape, architectural-landscape units, photointerpretative retrospective analysis, the city of Wrocław

Streszczenie

Artykuł podejmuje temat przemian krajobrazowych na podstawie dynamicznych zmian w poziomej strukturze pokrycia terenu w okresie 20 lat (1995–2015). Obszarem, który poddany został badaniu jest dolina Odry we Wrocławiu i okolice miasta. Wykonano badania dotyczące podziału obszaru na jednostki architektoniczno-krajobrazowe oraz określenia przemian struktury terenu za pomocą fotointerpretacyjnej analizy retrospektywnej. Na podstawie tej analizy określono wskaźniki zmienności cech, które przedstawiają wartość procentową przemian w każdej jednostce. Zmiany te mają bezpośredni wpływ na odbiór wizualny krajobrazu danego miejsca.

Słowa kluczowe: dolina Odry, zmiany pokrycia terenu, krajobraz, jednostki architektoniczno-krajobrazowe, fotointerpretacyjna analiza retrospektywna, Wrocław

1. Introduction

In the preamble of the European Landscape Convention, we read that one of the motives behind the creation of this document is their concern “to achieve sustainable development based on a balanced and harmonious relationship between social needs, economic activity and the environment” [20]. The concerns that the creators of the ECC write about, cover many aspects. One of them is the landscape, or “the area perceived by people whose character is the result of the action and interaction of natural and/or human factors” [20]. It follows that the landscape will always be influenced by both anthropogenic and natural factors that will shape it according to human intentions and legal regulations, but also according to the forces of nature. Thus, the landscape subject to all kinds of changes is a dynamic image that changes over time. In turn, this fact raises the research question: where is the boundary between voluntary shaping of the landscape and its protection, taking into account the principle of sustainable development? In the sense that sustainable development “is socio-economic development in which the process of integrating political, economic and social activities takes place, preserving the natural balance and durability of basic natural processes, in order to guarantee the ability to meet the basic needs of individual communities or citizens of both modern generations as well as future generations” [22].

It is extremely difficult to define the boundary of anthropogenic activities for the landscape based on this principle, because it requires a number of analyses from the border of many different fields of science. Considerations on this subject were undertaken by, among others, Bogdanowski, who made one of the first attempts to organize the concepts related to the landscape, its typology, the division of landscape into architectural-landscape units, and landscape interiors. As a precursor, he highlighted the principles of composition and planning, which he based on an analysis of the factors of many aspects: social, economic, political, natural and historical-cultural [1, 2]. The thoughts of Prof. Bogdanowski in reference to landscape interiors were continued by both Böhm [3] and Patoczka [9, 10]. An important role in this topic was also played by Chmielewski, who widely developed many threads concerning landscape issues. He drew attention to the issue of landscape changes over time based on the analysis of land cover structure, both in function and form [4–6, 8, 12–14].

2. Purpose, materials and methods

The article attempts to draw attention to the pace of change in the horizontal structure of land cover, which has a direct impact on landscape physiognomy. For this purpose, cartographic research was carried out based on methods of architectural and landscape units as well as photointerpretive retrospective analysis. The Odra river valley in the Wrocław region was selected for the research due to the diversity of the landscape in the middle part of the valley. The boundaries of the valley from the east and west side were adopted in accordance with the border of the Odra valley. The area is designated in accordance with the floodplains of the Odra, and thus corresponds to the natural surface of the river flood, i.e. the surface of the

natural zone of influence by the high water levels of the Odra [16]. The northern boundary of the study area is the administrative border of the city of Wrocław, while the southern boundary runs through Nature 2000 protected areas (administratively, the southern boundary is crossed by two Communes: Czernica and Siechnice). The area to be analyzed includes both an anthropogenically transformed area (the city center of Wrocław) and an extremely natural area – Nature 2000 protection areas (Widawa Valley, Pilczycki Forest and Grądy in the Odra Valley). The entire area under study has a total area of about 202 km².

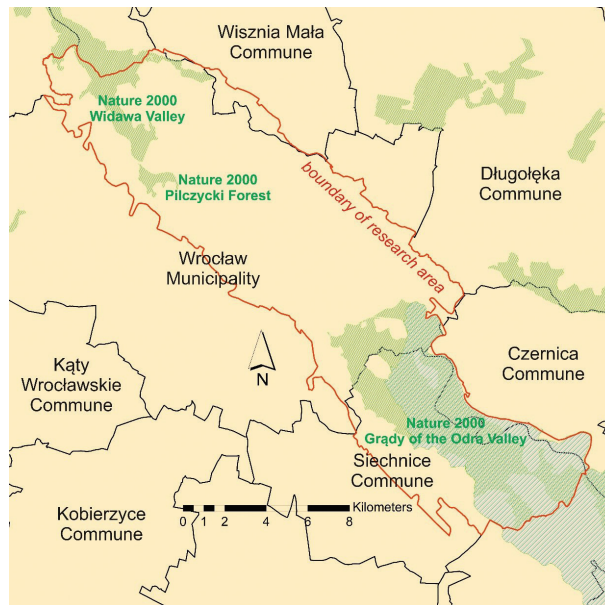


Fig. 1. The research area border

In order to conduct proper analyses, cartographic materials from the Central Geodetic and Cartographic Documentation Center (Centralny Ośrodek Dokumentacji Geodezyjnej i Kartograficznej) in Warsaw, the Provincial Center for Geodetic and Cartographic Documentation (Wojewódzki Ośrodek Dokumentacji Geodezyjnej i Kartograficznej) in Wrocław, and the Regional Water Management Board (Regionalny Zarząd Gospodarki Wodnej) in Wrocław were used. The materials of the Map Archives of Western Poland (Archiwum Map Zachodniej Polski) were also used. The first stage of the research concerned the division of the study area into architectural-landscape units. According to Bogdanowski, this division should be made by designating similar forms of landforms and land cover together by imposing graphically designated areas on each other. It is also important to take into account historical data. [1, 2, 8, 4]. Taking the above into account, the study used the current orthophotomap (2015) and Messtischblatt topographic maps from 1937–1944, to determine spatial layouts, as well as the numerical terrain model and hydrographic map, to determine the relief. The division into units was made on a scale of 1: 50000 using the ArcGIS program.

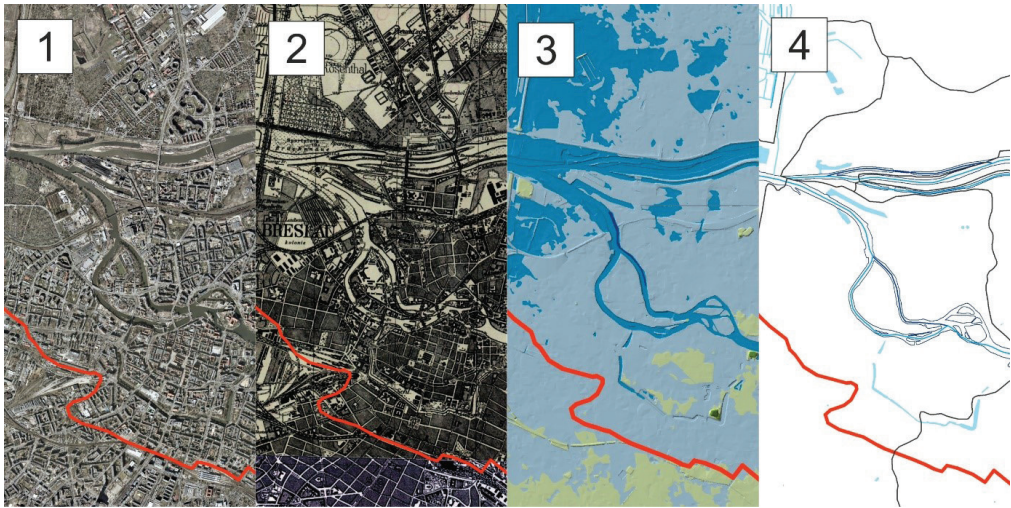


Fig. 2. The fragments of cartographical materials used to create the architectural-landscape units:
 1 – actual orthophotomap, 2 – Messtischblatt, 3 – numerical terrain model, 4 – hydrographical map
 (source: CODGiK and Archiwum Map Zachodniej Polski)

The aim of the second stage of the research was to carry out a retrospective photointerpretative analysis [4–6, 12–14], which was made for designated architectural and landscape units using a 20 year period (1995–2015). The following sources were used for the analysis: orthophotomap (2004 and 2015) and aerial photographs (1995), which were calibrated to the same PL-1992 plane coordinate system (the reference system used to create the Topographic Data Base) [19]. The study was conducted on a scale of 1:10 000 using the ArcGIS program. The result of the retrospective photointerpretative analysis was to show the variability of the land cover data using the Characteristic Changeability Index [4].

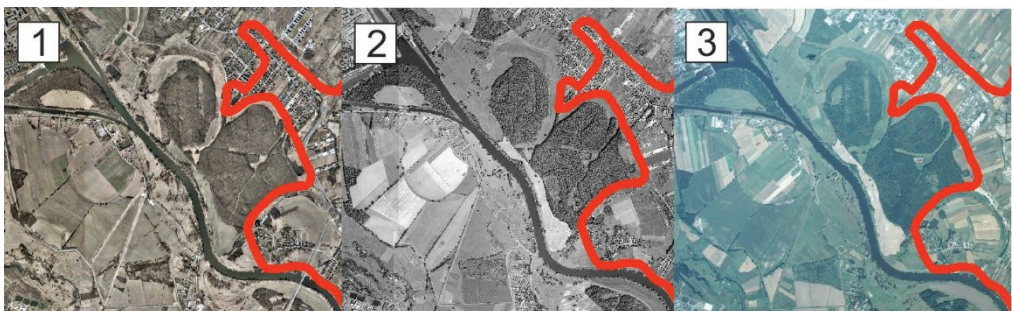


Fig. 3. 1 – 2015 orthophotomap, 2 – 2004 orthophotomap, 3 – 1995 aerial photography (source: CODGiK)

3. Results

The choice of architectural-landscape units was dictated by the benefits of selecting such units, such as the internal landscape uniformity of units, the possibility of obtaining a “natural” image within a unit (comparable to the natural spatial unit) and is considered the best form of land division in landscape analysis [11, 4]. On this basis, a graphic division of the study area into units according to the criteria adopted for each map was made. For the numerical terrain model, the borders were designated based upon estimated differences in height, for the hydrographical map division lines for microcatchments were adopted, historical spatial layouts were recognized for historical topographic maps, and contemporary spatial systems for orthophotomaps. In the following step, the chosen boundaries were imposed and the boundaries of architectural-landscape units were selected according to the principle of choosing the most overlapping lines. Fifteen architectural and landscape units have been distinguished using this method.

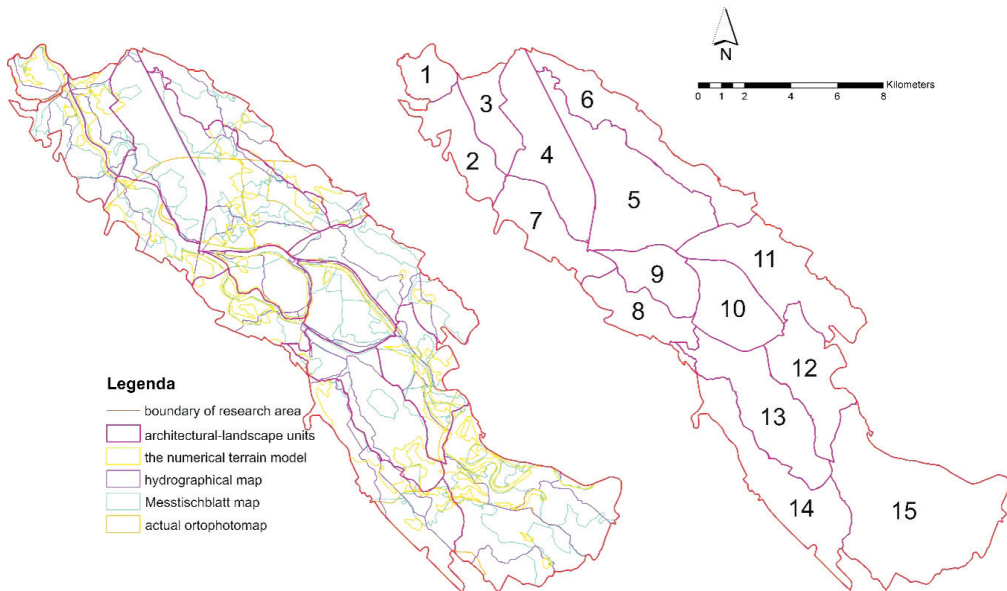
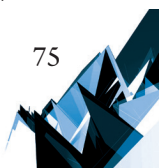


Fig. 4. The border analysis: the numerical terrain model, hydrographical map, Messtischblatt map and actual orthophotomap and the map of architectural-landscape units

Due to the extensive research area, selected land cover forms were analyzed, which are of key importance for landscape analyses in the river valley: surface waters, high greenery, building areas, road and rail transport. The system of watercourses is a characteristic element of the river valley area, hence the decision to choose surface water as an important function of land cover in the research area. Another element is the areas covered with high greenery, and thus all kinds of tree stands (forest complexes, linear systems of trees, groups of trees or single trees). Trees in the landscape are a component of the walls of landscape interiors [1–3, 9,



10]. The number of trees translates into the density of the walls of the landscape interior and influences the assessment of the interior – hence the quantitative analysis of land cover in this form is important for the visual reception of the landscape. In addition, areas covered with a high level of greenery also have a positive impact on the aesthetics of the anthropogenic landscape [17]. A similar situation applies to buildings, which is also a component of the walls of the landscape interior and affects the visual reception of the landscape in the given interior. The last studied form of land cover is road and rail communication. Roads and railways affect the fragmentation of the natural environment and make it difficult to migrate biotic matter in ecological corridors (such as river valleys, among others), which translates into the division of the analyzed landscape and the fragmentation of landscape interiors.

The criteria for the division of selected land cover forms was developed on the basis of the “Technical guidelines for the topographic database” [18] and the study “Cartographic modeling in the suitability tests of areas for afforestation” [15]. Coverage with selected forms is shaped into surface, linear and point objects.

Table 1. The division criteria of the chosen land cover forms

	COVERING	HIGH LEVEL OF GREENERY	SURFACE WATERS	BUILDING AREAS	ROAD TRANSPORT AND RAIL TRANSPORT
1	SURFACE	▶ green areas with an area > 500 m ² (with a width of over 10 m and a length of more than 500 m)	▶ watercourses with an average water table width of over 5 m ▶ water reservoirs (natural and artificial) in the area > 100 m ²	▶ single construction objects with an area of up to 200 m ² ▶ building groups with an area of over 200 m ²	▶ not classified
2	LINEAR	▶ bands and rows of trees up to 10 m wide (distance between trees < than 10 m) and lengths from 50 m	▶ watercourses with an average water table width of up to 5 m ▶ longitudinal water reservoirs (eg oxbow lakes) with an average width of 5 m and a length > 50 m	▶ not classified	▶ road lanes within multi-lane roads, one-way roads, paths, tram tracks, railway tracks up to 5 m wide
3	POINT	▶ single trees and groups of trees up to 200 m ² (0,02 ha)	▶ water reservoirs (natural and artificial) in the area < 100 m ²	▶ not classified	▶ not classified

In order to determine the total area of all studied forms of land cover, the surface and linear objects were given surface forms. These objects were transformed into surface forms using ArcGIS tools: “feature to polygon” for point objects and “buffer” for linear objects. From these

procedures, a surface image was created for all forms of land cover. A photointerpretative retrospective analysis spanning 20 years was carried out for three particular years: 1995, 2004 and 2015, as illustrated in the following maps.

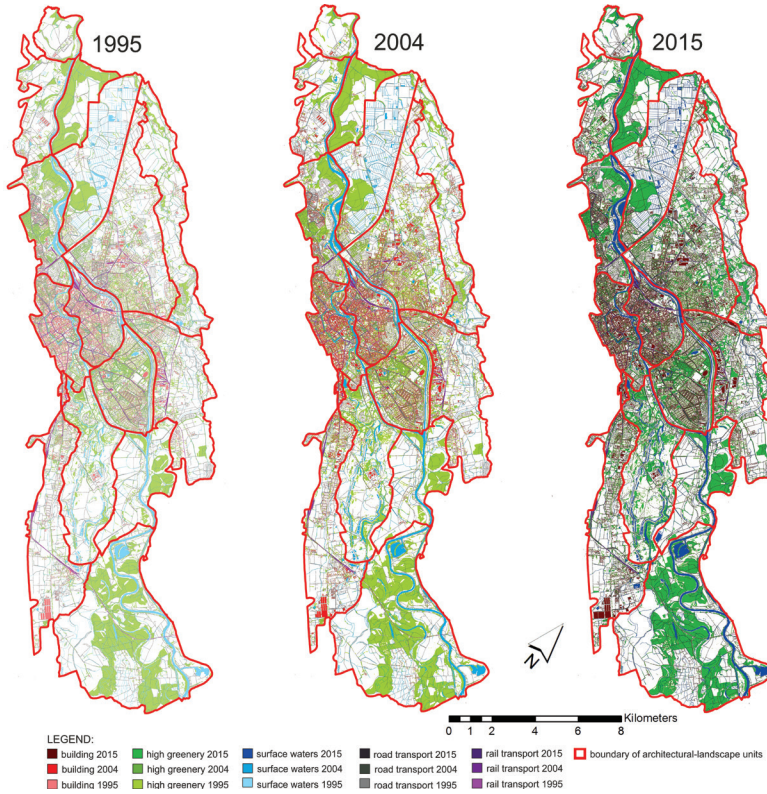


Fig. 5. The photointerpretative retrospective analysis made in 2015, 2004 and 1995 (all research areas)

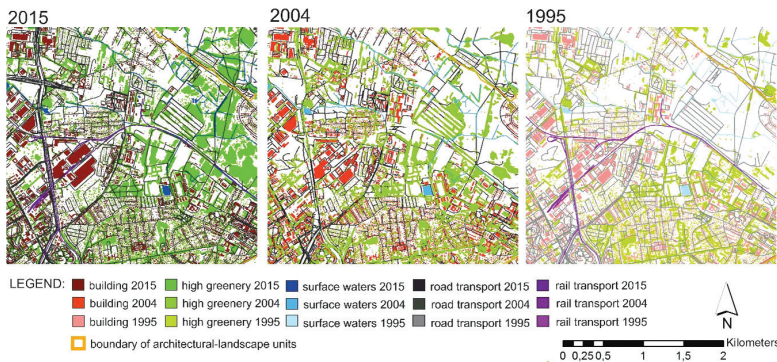


Fig. 6. The photointerpretative retrospective analysis made in 2015, 2004 and 1995 (a part of the research area)

Using the formula for the Characteristic Changeability Index [4] tabulated data on the percentage share of each land cover in all architectural- landscape units is shown.

Table 2. The percentage share in the chosen land cover forms and the characteristic changeability index (CCI) for all architectural-landscape units

A-L UNIT	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
HIGH GREENERY [%]															
1995	15,92	16,27	56,44	13,63	16,07	16,77	35,42	23,4	18,7	36,58	14,66	22,22	19,15	9,7	37,73
2004	15,85	14,78	58,87	13,87	20,01	14,51	31,57	22,19	18,35	34,37	13,11	22,02	22,01	9,71	37
2015	22,17	23,48	61,21	16,55	23,66	19,14	32,3	17,89	15,52	35,66	18,46	25,47	28,66	13,03	37,97
CCI	28,19	30,71	7,79	17,64	32,08	12,38	-9,66	-30,80	-20,49	-2,58	20,59	12,76	33,18	25,56	0,63
SURFACE WATERS [%]															
1995	4,61	7,64	1,45	12,37	2,13	4,28	13,26	8,63	8,23	6,03	2,66	7,85	10,4	2,74	9,22
2004	5,39	8,17	1,59	10,27	2,1	4,57	13,42	9	8,61	5,92	2,74	7,78	10,63	2,87	9,57
2015	6,36	9,09	2,9	12,34	2,39	5,33	14,61	9,1	9,56	6,17	3,22	8,93	11,36	3,13	10,38
CCI	27,52	15,95	50,00	-0,24	10,88	19,70	9,24	5,16	13,91	2,27	17,39	12,09	8,45	12,46	11,18
BUILDING AREAS [%]															
1995	0,41	2,09	0,05	0,59	6,52	0,83	3,7	18,03	17,21	7,93	5,15	0,3	0,64	5,41	0,2
2004	0,39	2,32	0,05	0,57	7	1,04	3,73	18,9	17,44	8,11	5,93	0,28	0,69	6,04	0,22
2015	0,51	2,65	0,05	0,82	7,62	1,19	4	19,83	17,82	8,56	6,93	0,29	0,69	7,68	0,29
CCI	19,61	21,13	0,00	28,05	14,44	30,25	7,50	9,08	3,42	7,36	25,69	-3,45	7,25	29,56	31,03
ROAD TRANSPORT [%]															
1995	6,78	9,23	7,17	7,28	15,64	8,36	20,42	26,65	26,67	26,06	13,13	6,66	8,17	12,15	6,51
2004	5,74	10,42	7,43	7,1	16,01	8,82	20,97	26,74	25,81	25,73	13,65	7,09	8,24	12,63	6,4
2015	8,22	10,35	7,52	8,35	17,28	9,06	21,51	26,76	25,25	25,7	13,98	8,68	8,16	13,34	6,27
CCI	17,52	10,82	4,65	12,81	9,49	7,73	5,07	0,41	-5,62	-1,40	6,08	23,27	-0,12	8,92	-3,83
RAIL TRANSPORT [%]															
1995	0	0	0	0,42	1,27	0,17	1,19	2,68	5,43	0,87	1,71	0,05	0,03	2,49	0,16
2004	0	0	0	0,42	1,26	0,17	1,19	2,68	5,43	0,87	1,71	0,05	0,03	2,49	0,16
2015	0	0	0	0,42	1,26	0,17	1,66	2,7	5,46	0,87	1,71	0,05	0,03	2,56	0,16
CCI	0,00	0,00	0,00	0,00	-0,79	0,00	28,31	0,74	0,55	0,00	0,00	0,00	0,00	2,73	0,00

The percentage share of the variability of a given feature is shown in the bar graph. On the basis of the results of the variability of a given land cover form, conclusions were formulated in each of the architectural-landscape units.

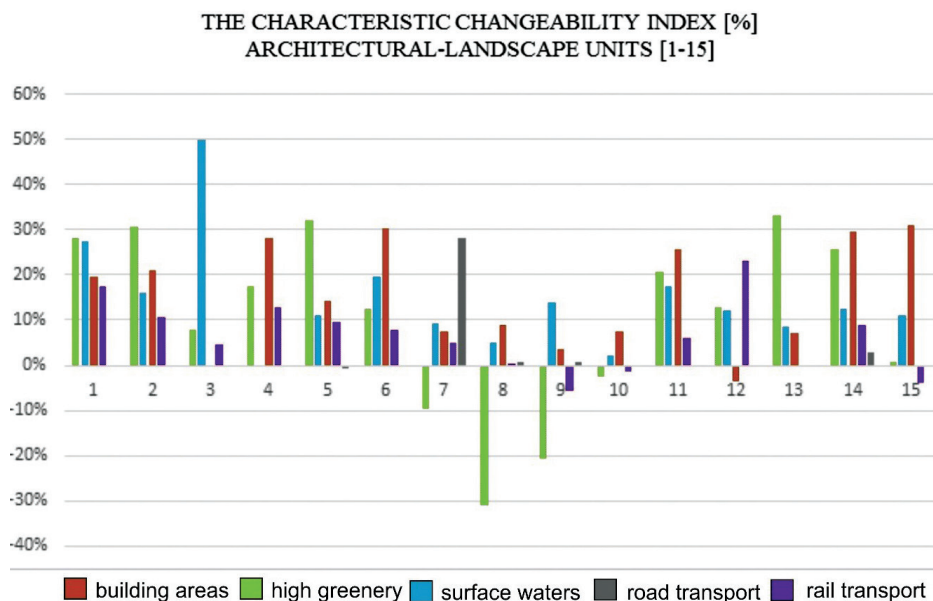


Fig. 7. The characteristic changeability index

The characteristic changeability index clearly showed that the dynamics of changes in individual forms of land cover within 20 years is significant. Most of the surveyed land cover forms showed an upward trend, which means that over time, the analyzed land cover forms grew in each of the architectural-landscape units. Only in units 7, 8, 9 and 10 can downward trends be seen, which is associated with the stronger anthropogenic impact on the cultural landscape of these units. Reading the data from the graph, it can also be seen that in each unit (except unit 15, where most of the area is protected – Nature 2000) there are changes in the level of greenery. The more natural the landscape and the smaller the impact of anthropogenic activities, the greater is the growth of areas covered by greenery, greenbelts or groups of trees. On the other hand, the more cultural and anthropogenic the unit was, the greater the decrease in greenery (this is especially visible in the very center of Wrocław in units 8 and 9). It is also interesting to note that in most units there is an increase in the amount of surface water. This applies to waters flowing in the I, II and III order watercourses (along with drainage ditches), as well as stagnant waters in natural and artificial reservoirs. The study area lies in the Odra valley, so the main riverbed flows along the center of the area. The changing shape of the Odra coastline can be observed, especially in areas that are considered most natural. In addition, new artificial reservoirs appear in the form of ponds and small water reservoirs in private properties near detached family houses. Hence the significant increase in the amount of water. The exception is unit 4, where there are extensive drainage fields that

maintain their form as a system of drainage ditches. In this space, a slight decrease in surface water is observed, which is related to periodic droughts in the system of drainage ditches. The characteristic changeability index showed that only unit 3 lacked noticeable changes in the number of built-up areas within the unit (this is the area where a high level of green cover is the dominant form of land cover). The remaining units show the dynamics of the change, which in most cases shows building development in each unit. The exception is unit 12, in which a slight decrease is noticeable, which may be due to the fact that according to the Local Development Plan, this area (Opatowice) is a designated area for polders of the Odra river as well as having a rather inconvenient transport connection to the center of Wrocław, which is an obstacle to the development of the settlement. We also read from the chart that there are slight fluctuations in the increments and losses of areas related to road transport throughout the study area. Units 9, 10, 13 and 15 show declines, while in the rest of the units there is an increase in road transport. The largest increase is visible in unit 12, which results from the previously mentioned shortage of appropriate transport infrastructure. Expansion of roads in this place may cause an increase in the number of buildings in the future, at the expense of other forms of land cover. The first three units do not have rail transport within their area, while in the rest of the units the occurrence of this form of land cover is noticeable. The number of railway lines in most units has not changed (in 7 of the units this area has been constant over the last 20 years). The high variability of this feature can only be seen in unit 7, which was dictated by the construction of the stadium for EURO 2012 in Wrocław, the expansion of the Kozanów and Pilczyce housing estates and the development of railway infrastructure in this area of the city (railway and tram transport).

4. Discussion of the results

Changes in the horizontal land cover structure are inevitable. However, each transformation of the smallest section of space has a direct impact on the appearance of the landscape, which translates into the visual reception of the place. If such significant increments and losses of land cover forms can be seen in just 20 years, what will the landscape look like after 50 or 100 years? The current rate of change would indicate a drastic transformation of the landscape. Most of the changes in the studied area of the Odra River valley are of an anthropogenic nature, which is the result of inapt planning decisions and numerous investments. This is evidenced by, for example, statistics showing the number of construction projects in Wrocław in proportion to investment in urban green areas. In the ranking of 152 investments, we can find only 6 which concern the revitalization of the Odra areas (implemented as part of the long-term Program for the Odra 2006), expansion of recreational areas within the city's limits or the construction of a new cemetery. Investments concerning the reconstruction of roads and existing buildings with residential and utility functions as well as new road, residential and service investments dominate [21]. We can also see the transformation of the landscape in suburban areas near Wrocław, where the spatial policy of communes affects the development of built-up areas even at the expense of protected areas [7].

The presented research results allow the formulation of general guidelines for the entire area where changes in land cover occurred.

- 1) High level of greenery:
 - ▶ protection of green areas with high natural and landscape value spaces,
 - ▶ limiting the possibility of tree felling in highly urbanized areas,
 - ▶ introduction of new green spaces in areas that have been heavily anthropogenically transformed (biologically active areas).
- 2) Surface waters:
 - ▶ protection and maintenance of irrigation fields,
 - ▶ protection of surface waters with high natural and landscape value,
 - ▶ applying the principles of sustainable development when creating new artificial reservoirs.
- 3) Buildings:
 - ▶ limiting the possibility of introducing new construction projects in highly urbanized areas,
 - ▶ limiting the possibility of building in valuable natural areas,
 - ▶ applying the principles of sustainable development while expanding Wrocław and neighboring towns and villages.
- 4) Road transport:
 - ▶ prudent road planning based on the principles of sustainable development,
 - ▶ limiting the possibility of extending road communication to valuable natural areas.
- 5) Rail transport:
 - ▶ prudent planning of railway routes based on the principles of sustainable development.

5. Final remarks

In accordance with the principle of sustainable development, the shaping of space should take into account human needs, but with respect for the laws of nature. Only then will it be a guarantee for present and future generations, so that they have a chance to live in a harmoniously formed space in which the proportion of natural areas balances with areas that have been strongly anthropogenically influenced. Therefore, it is important to create parametric standards of possible anthropogenic actions and protective measures that would be the basis for creating planning documentation. In order to objectively set such standards, it is necessary to introduce a system of monitoring changes in the landscape and to determine the type of landscape and character of a given place. Based on the rate of landscape change, it is recommended that this kind of analysis should take place at least once every 5 years. The research methods used can apply to the entire country of Poland irrespective of the extent of anthropological changes (environmental, environmental-cultural and cultural).

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