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Full Length Research Paper

Research of significant anthropogenic changes in Ostrava city area (Czech Republic)

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This study aimed to widen the knowledge on landscape element changes in areas exposed to the effects of mining and other industries, which represent one of the most affected types of landscape in terms of environmental changes. It provides results of analyses of landscape element changes in the selected area of Ostrava Basin (city of Ostrava) in the North-east of Czech Republic. The study was compiled for nine model areas. All the analyses of landscape element changes were executed on the basis of geographical information systems, study of archives and terrain observation. In the monitored area, there were significant changes in the landscape character. Four landscape elements increased (built-up area, forests, anthropogenic shapes and water areas) and two elements lost their percentages (fields and meadows, and water courses). The surface area of the built-up area grew by 44 km^2, which represents a rise of 99.7%, though the anthropogenic shapes enlarged by 160%. Both the largest surface area and the most significant percentage drop were registered with the landscape element of fields and meadows (decrease of 59 km^2, that is, of 48%). The main cause of this was expansion of the built-up area.

Key words: Landscape elements, anthropogenic changes, mining, aerial photos, geographic information system (GIS).

INTRODUCTION

The purpose of this study is evaluate the results of the analysis of landscape element changes, such as forests, water areas, agricultural areas, and built-up areas, in a selected area (Balaga, 2007; Jankauskaite and Veteikis, 2010; Jones et al., 2010; Tempesta, 2010).

The applied method makes use of the possibilities of Geographical Information Systems, terrain observation, documentation and study of archives. The starting time period for which the landscape character analysis was carried out is the year of 1946 (military aerial photos) and the present time (maps).

The research is localized in the selected area of the city of Ostrava (Figure 1), which has been affected by former mining of black coal (Cala, 2007; Kalisz, 2009). Ostrava,

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Figure 1. Location map of the study area.

Table 1. Basic characteristics of the monitored model territories.

Type of area	Area (km^2)	Limitation
1a	11.93	Lhotka u Ostravy, Petřkovice u Ostravy, Koblov, Hrušov, Přívoz, Mariánské Hory a Nová Ves u Ostravy
1b	12.9	Vrbice nad Odrou a Pudlov, Šilheřovice a Antošovice
1c	12.4	Ostrava -.Jih
2a	21.04	Přívoz, Muglinov, Heřmanice, Michalkovice, Petřkovice
2b	20.2	Slezská Ostrava, Moravská Ostrava, Mariánské Hory a Hulváky
2c	29.79	Ostrava-Jih, Moravská Ostrava a Přívoz a Slezská Ostrava
3a	28.39	Poruba, Svinov, Zábřeh a Třebovice
3b	26.72	Hlučín, Bobrovníky, Martinov, Ludgeřovice
3c	26.73	Polanka nad Odrou, Svinov, Stará Bělá, Hrabová, Vítkovice

which is situated in the north-east of Czech Republic, is among the worst affected European regions, with regard to landscape and environmental changes, and thus it is suitable for the above-mentioned research. The overall project was divided into nine model areas (1a, 1b, 1c, 2a, 2b, 2c, 3a, 3b, and 3c). The study used applied experiences from previous studies related to land use, planning, hazard, susceptibility, etc. (Bednarik et al., 2010; Marschalko and Duraj, 2009; Marschalko et al., 2008a-e; Marschalko and Juris, 2009; Marschalko et al., 2009; Marschalko and Treslin, 2009; Yilmaz and Yavuzer, 2005; Yilmaz and Bagci, 2006; Yilmaz and Yildirim, 2006; Yilmaz, 2009a, b; Yilmaz, 2010; Yilmaz et al., 2011).

EVALUATION OF LANDSCAPE ELEMENT CHANGES

In the interest area, six landscape elements were examined and analyzed (anthropogenic shapes, water areas, water courses, forests, fields and meadows and built-up area).

The interest area comprises nine smaller model territories that were gradually examined in nine studies between 2004 and 2006. The surface area and the determination of the individual separate territories are outlined in Table 1.

The overall surface area of the monitored locality is 190.1 km^2. The areas of the individual landscape elements in both time profiles along with their percentages to the overall surface area are given in Table 2.

As for the percentages of the individual landscape elements with regard to the total area in 1946, the most abundant was the element of fields and meadows, that is, 64.7%. The second most prevalent landscape element was the built-up area, which took up nearly a quarter of the monitored area, followed by forests, water courses and anthropogenic shapes. The smallest landscape element in 1946 was the water area (Figure 2).

Currently, the largest landscape element is the built-up

Table 2. Surface areas of the landscape elements and their changes.

Landscape element	Area in 1946		Present area		Change	
	km^2	%	km^2	%	km^2	%
Bulit-up area	43.71	23	87.28	45.91	43.57	99.68
Fields and meadows	123.18	64.7	64.2	33.87	-58.98	-47.88
Forested area	18.74	9.86	29.04	15.28	10.3	54.95
Anthropogenic shapes	1.85	0.97	4.81	2.53	2.96	159.74
Water areas	0.77	0.4	2.74	1.44	1.97	256.7
Watercourses	2.03	1.07	1.85	0.97	-0.18	-9.06

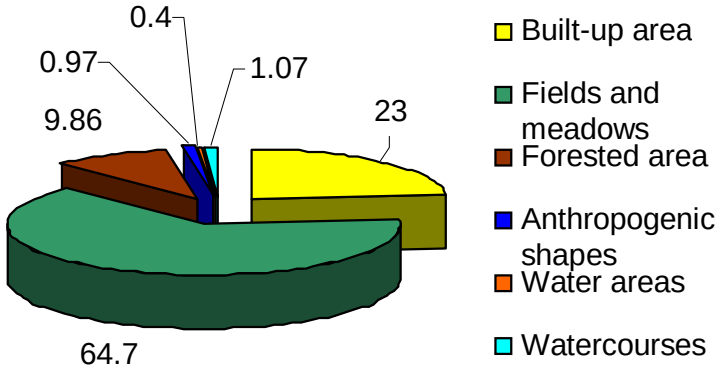

Figure 2. Chart of landscape element percentage representation in 1946.

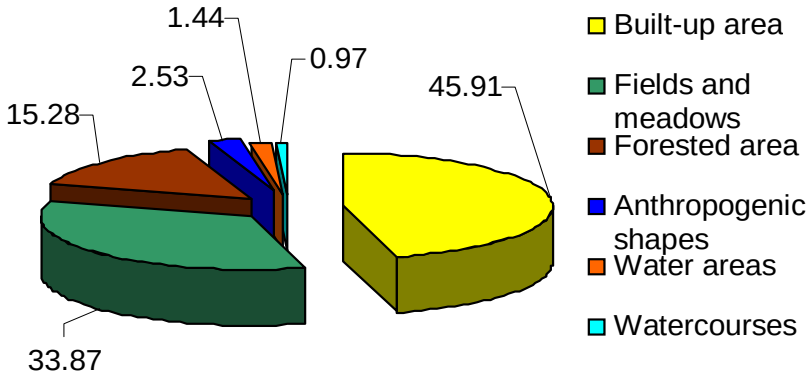

Figure 3. Chart of current landscape element percentage representation.

area, followed by fields and meadows, forests, anthropogenic shapes, and water areas. However, they are water courses that are currently the smallest landscape element (Figure 3).

The changes in the individual landscape elements are well arranged in the following chart (Figure 4). More detail of the landscape elements that are not distinguishable in Figure 4 are represented in Figure 5. It is apparent from the charts that the landscape element of fields and meadows and the landscape element of water courses decreased in the course of time. However, there was an increase in the areas of the other landscape elements.

CHANGES IN THE BUILT-UP AREA

In 1946, the element of the built-up area was the second most prevalent landscape element and currently it is the largest with the surface area of 87.28 km^2. To date, the surface area of the built-up area has undergone dynamic

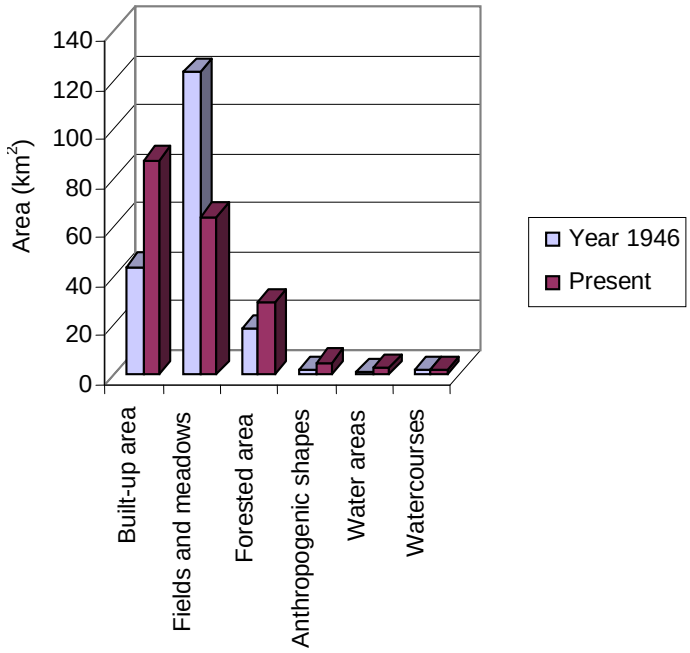

Figure 4. Chart of landscape element changes.

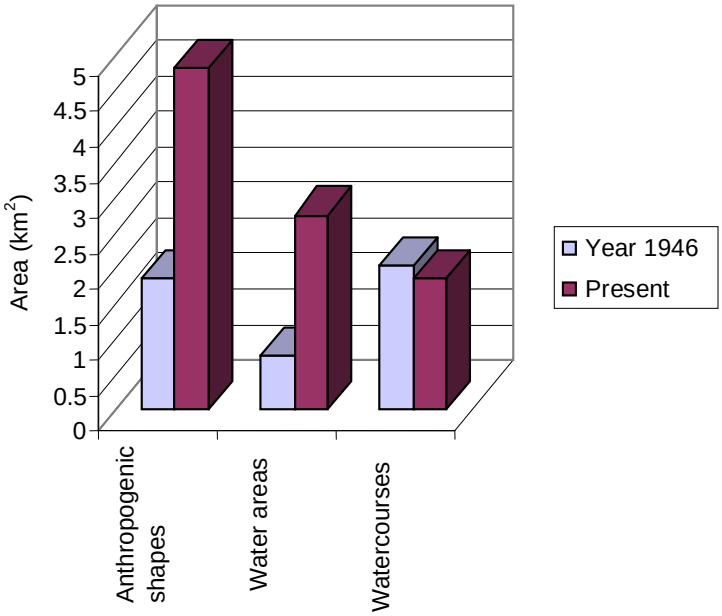

Figure 5. Chart of changes in the selected landscape elements that are not distinguishable in Figure 4.

changes in the course of time and its area has almost tripled.

In 1946, the built-up area was about 43.71 km^2, which represented 23% of the monitored area. By 2001, it had expanded to 87.28 km^2, which meant 45.91% of the total area. Therefore, the built-up area increased by 43.57 km^2, which represents an increase of 99.68%. The changes in the built-up area in the individual model territories (1a to 3c) are given in Table 3 and charted in Figures 6 and 7.

In the entire model territories there was an increase in the built-up area for various reasons (Figures 6 and 7). A very important factor which affected the changes in the built-up area in all the model territories was migration of

Table 3. Changes in the surface areas and percentage representations of the built-up area in the individual model territories.

Type of area	Bulit-up area (km^2)		Bulit-up area (%)	
	Year 1946	Present	Year 1946	Present
1a	1.87	3.97	14.6	31.8
1b	0.94	1.8	7.3	13.91
1c	1.76	4.54	14.17	36.61
2a	10.06	12.65	47.81	60.13
2b	8.05	12.32	40.25	61.6
2c	9.59	17.94	32.2	60.23
3a	4.33	13.91	15.25	49
3b	1.54	5.17	5.77	19.36
3c	5.57	14.98	20.82	56.01

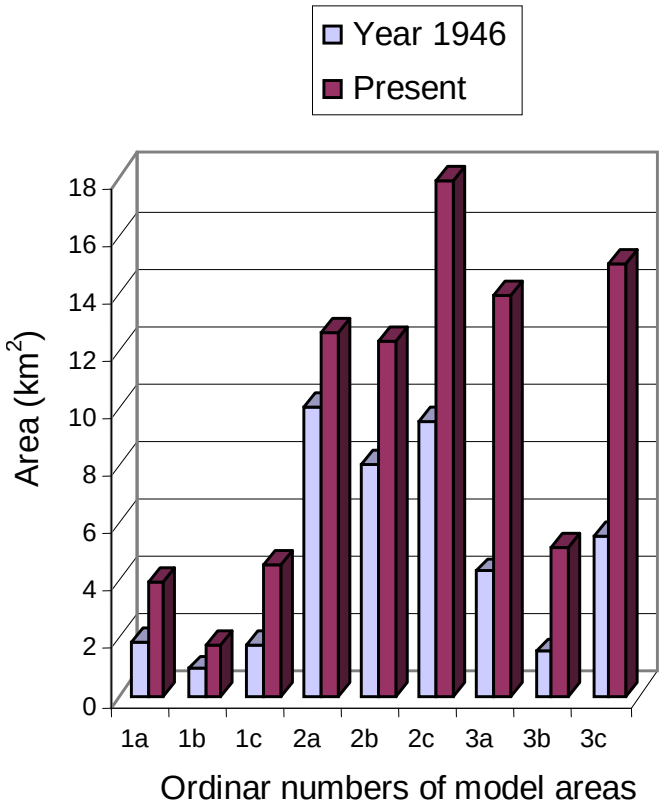

Figure 6. Chart of area changes (in km^2) of the built-up area in the individual model territories.

inhabitants into the agglomeration of Ostrava, which has resulted in a rise in the number of inhabitants both in Ostrava City and its surroundings. The main reason for the migration of inhabitants into the Ostrava region was shortage of labour due to expanding industries. It was the mining industry that had the decisive influence on the influx of labour in the past. Among the busiest mines there were Odra Mine, Heřmanice Mine, Michal Mine and Eduard Urx Mine (model territory 2a), Hlubina Mine, Šalamoun Mine, Jakub Mine, Jan Maria Mine, Trojice Mine and Zárubek Mine (model territory 2b), Jeremenko Mine, Alexander Mine and Ludvik Mine (model territory 2c) and Šverma Mine (model territory 3a). The chronology of name development and organizational structures, especially in terms of mine mergers, is apparent from Figure 8.

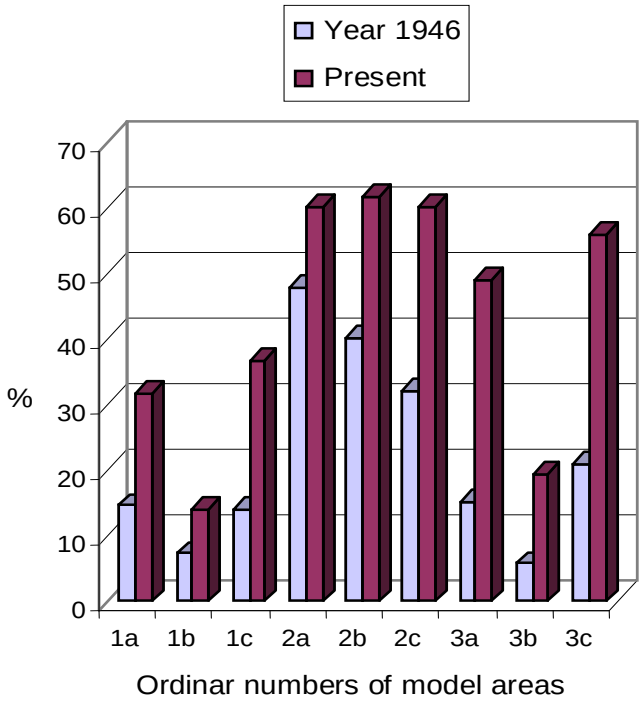

Figure 7. Chart of area changes in percentage representations of the built-up area in the individual model territories.

Apart from the mining industry, there were also other industries, such as the metallurgical industry represented by the plants of Nová Huť a.s., Vysoké pece Ostrava a.s. and Vítkovice Steel (model territory 2c and 2b). In the model territory labelled 2a it was the case of the chemical plant Hrušov, and OKD – Doprava, a.s. In the model territory 2b there were or have been Ostravar Brewery and Teplotechna Ostrava. The industries have not only contributed towards the industrial constructions but also towards related civic amenities such as housing development, office buildings and other facilities. Among the largest housing estates built in the monitored area there are the prefabricated housing estates of Dubina, Hrabůvka, Buškovice and Pískové doly, belonging to the model territory 1c, or the housing estate of Fifejdy that belong to the model territory 2b. In the past, the so-called miners' housing estate of Poruba had a special status as it used to be the largest housing estate in the former Czechoslovakia (model territory 3a). The rise in the built-up area was noticed especially at the expense of the element of fields and meadows. The most significant increase was registered in the aforementioned localities where housing estates had been constructed (model territory 1c, 2b and 3a).

CHANGES IN THE FIELDS AND MEADOWS

In 1946, the landscape element of fields and meadows was the largest. Currently, it is the second largest landscape element, having lost on its surface area due to the increase in the built-up area. In 1946, fields and meadows had 123.18 km^2, which represented 64.7% of the monitored area, that is, almost two thirds of the area. At present, fields and meadows take up 64.2 km^2, which equals 33.87%. The drop in this landscape element embodies 47.88%, that is, 58.98 km^2. The changes in the area of the fields and meadows landscape element in the individual partial territories (1a to 3c) are displayed in Table 4 and charted in Figures 9 and 10.

Contrary to the built-up area, where an increase was registered with all the model territories, in the case of the fields and meadows landscape element there was a drop in the surface area, namely in all the model territories. As mentioned earlier, the main reason for the decrease in the fields and meadows landscape element was the expansion of the built-up area (the most significant changes were in the model territories 2c, 3a, and 3c). Another reason for the drop were new anthropogenic shapes (dumps), which were predominantly formed at the expense of the fields and meadows landscape element (e.g. in the model territory 1b, during gravel extraction). The next reason for the area drop was gradual forestation of Ostrava (e.g. the model territory 1c and 2a).

CHANGES IN THE FOREST PERCENTAGE

Since 1946, the landscape element of forests has been the third largest landscape element in the monitored

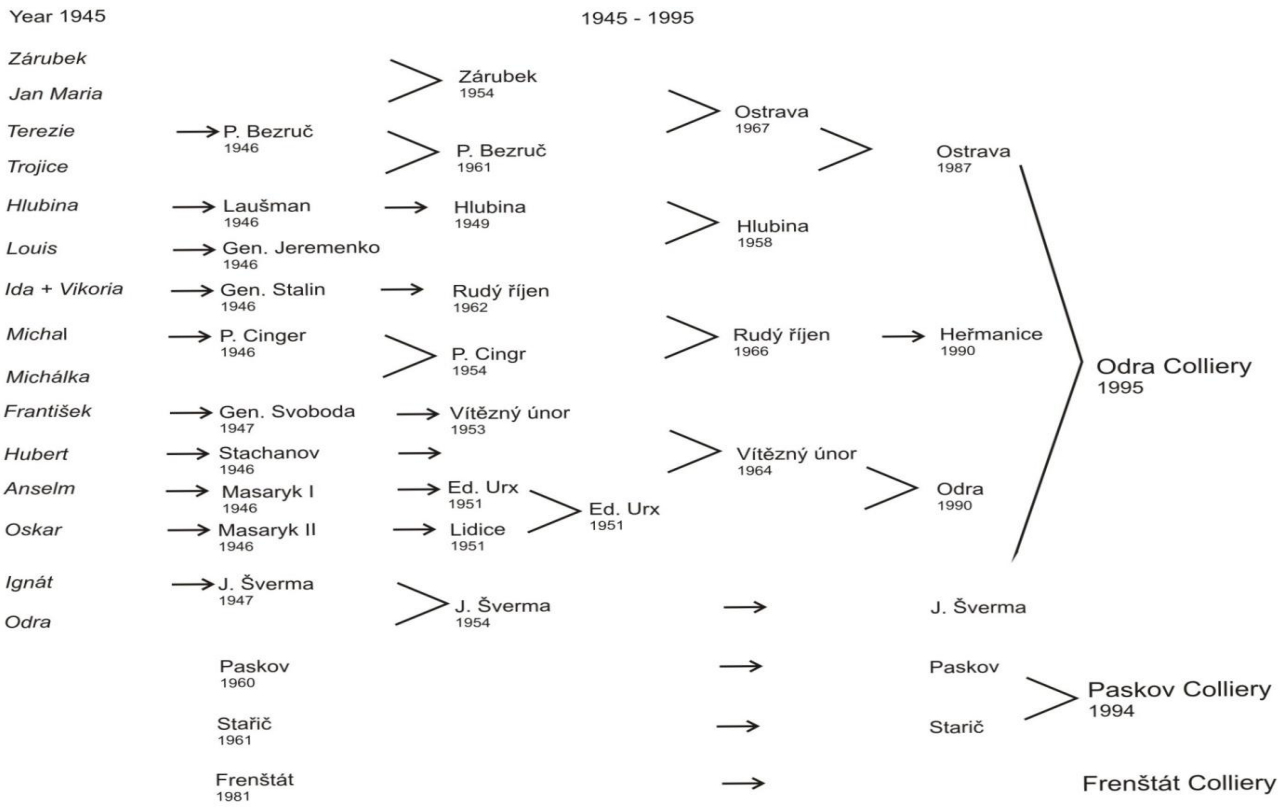

Figure 8. Chronology of names and organizational structures of Ostrava Mines (Dopita, 1997).

Table 4. Changes in the surface areas and percentage representations of the fields and meadows landscape element in the individual model territories.

Type of area	Fields and meadows (km^2)		Fields and meadows (%)	
	Year 1946	Present	Year 1946	Present
1a	8.24	5.67	69	47.5
1b	10.15	6.72	78.52	51.96
1c	8.74	5.06	70.5	40.8
2a	9.28	4.3	44.08	20.43
2b	11.11	4.18	55.55	21
2c	17.69	5.79	59.4	19.45
3a	21.46	10.29	75.59	36.23
3b	19.2	15.14	71.86	56.67
3c	17.31	7.05	64.73	26.36

area. Moreover, there was an increase in the surface area in the monitored period.

Back in 1946 forests took up 18.74 km^2, which represented 9.86%. Due to the expansion of the built-up area and growing industries, the surface area of forests could have been expected to decrease with time. However, the reverse is true. Currently, the forests take up 29.04 km^2, which equals 15.28% out of the total area. This represents an increase of 10.3 km^2, that is, 54.95%. The changes in the surface area in the individual partial territories (1a to 3c) are given in Table 5 and charted in Figures 11 and 12.

Since 1946 there has been a rise in the surface area of forests in all the model territories, which is a positive trend. The most significant increase was registered in the model territories 2a, 2b and 2c, namely because of forestry reclamation of dumps or due to a growth in the existing forest areas (e.g. the premises of the Zoological

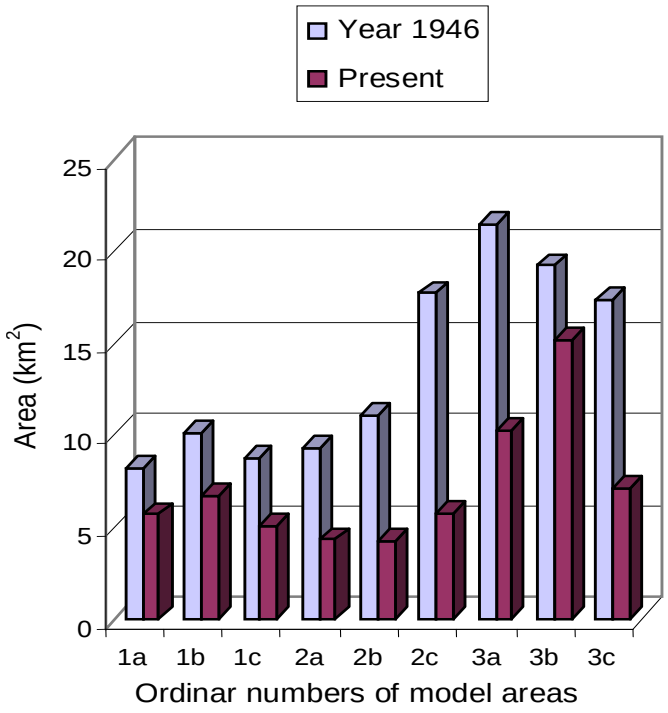

Figure 9. Chart of area changes (in km^2) representations of the fields and meadows landscape element in the individual model territories.

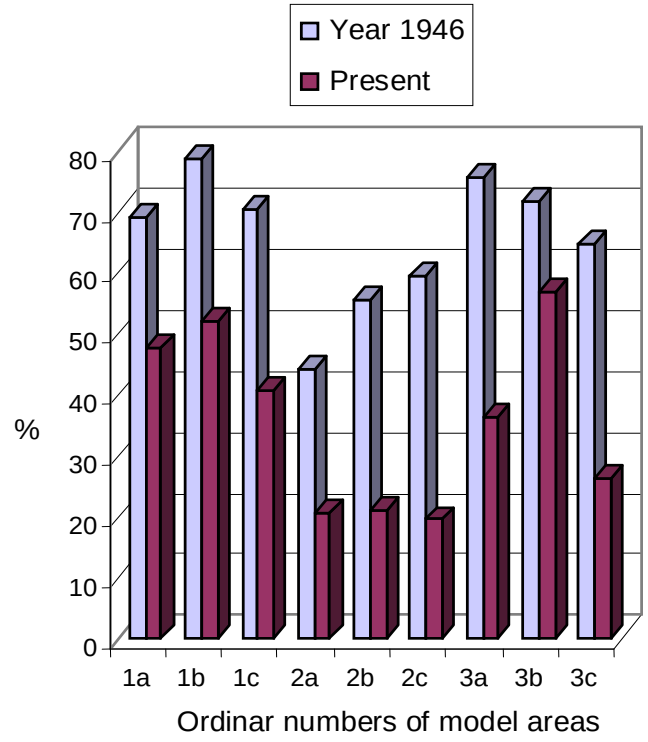

Figure 10. Chart of area changes in percentage representations of the fields and meadows landscape element in the individual model territories.

Table 5. Changes in the surface areas and percentage representations of the forest landscape element in the individual model territories.

Type of area	Forested area (km^2)		Forested area (%)	
	Year 1946	Present	Year 1946	Present
1a	1.1	1.35	9.2	11.3
1b	1.51	2.16	11.68	16.7
1c	1.79	2.14	14.4	17.3
2a	1.26	3.33	5.98	15.8
2b	0.81	2.56	4.05	12.8
2c	1.78	4.78	5.98	16.08
3a	2.14	2.97	7.54	10.46
3b	5.53	5.95	20.69	22.28
3c	2.82	3.79	10.55	14.19

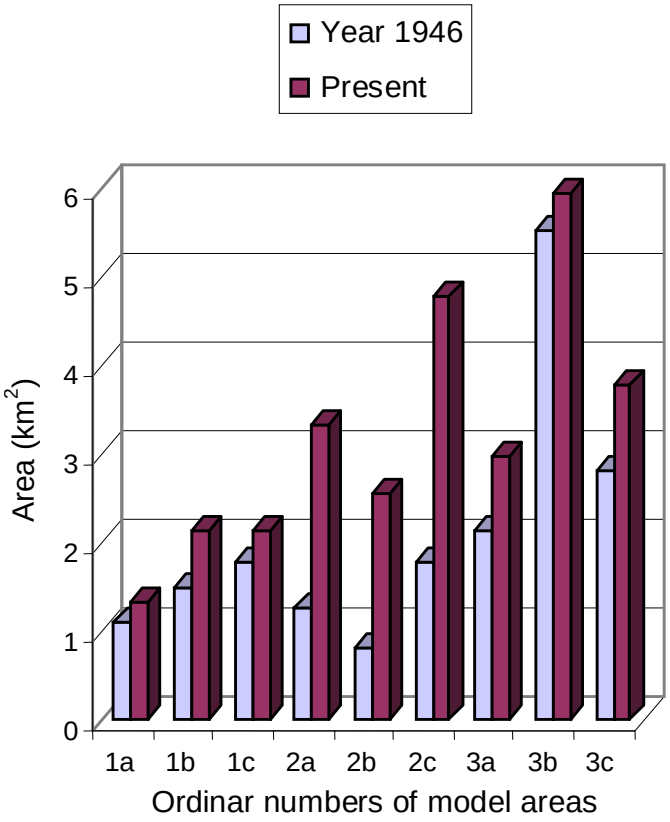

Figure 11. Chart of area changes (in km^2) representations of the forest landscape element in the individual model territories.

Garden, Černý les). On the other hand, the smallest increase in the forest percentage was noticed in model territories 1a and 3b, that is, in the suburbs of Ostrava, where the forest percentage had represented a significant landscape character even before 1946, and thus there was no need to improve such state (e.g. Bobrovnícký les, Ludgeřovický les). There was also a rise in the forest percentage along water courses, which is related to tree plantation following stream regulation.

There are two reserves in the monitored area. In the south-west of model territory 1c, there is Polanský les, which belongs to the CHKO Poodří Reserve. There is also Rezavka Reserve with a rich range of various biotope types – bottomland forests with crescentic lakes and pools, water and wetland areas, meadows with bosks facilitating life to a wide number of living organisms. In the model territory 2a, there is a national monument of Landek with an adjacent Mining Museum.

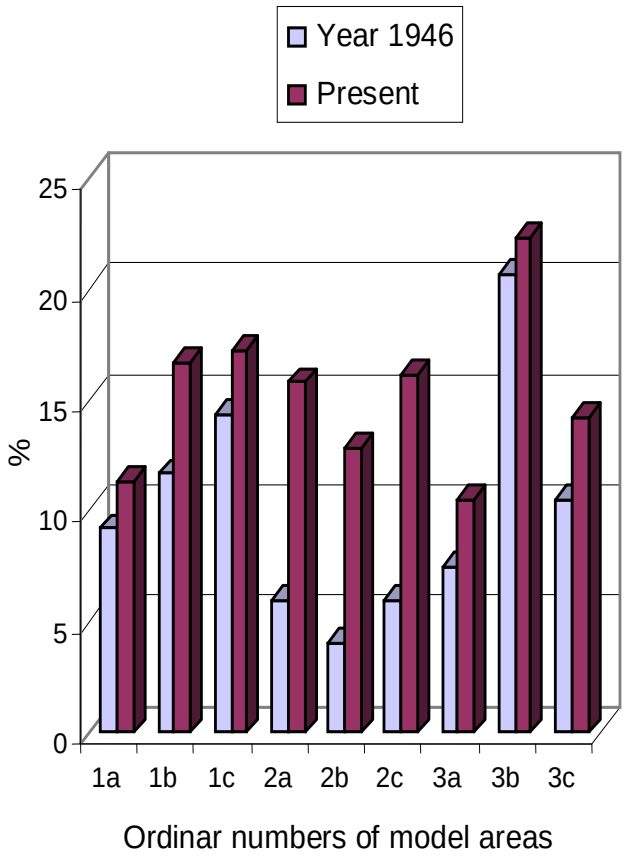

Figure 12. Chart of area changes in percentage representations of the forest landscape element in the individual model territories.

The surface area of the forests landscape element has predominantly grown at the expense of the element of fields and meadows (gradual forestation) as well as at the expense of anthropogenic shapes landscape element (forestry reclamation).

ANTHROPOGENIC SHAPES

The landscape element of anthropogenic shapes has reached the second largest percentage increase in the surface area among all the six monitored landscape elements.

Back in 1946, anthropogenic shapes took up 1.85 km^2, which represented 0.97% of the monitored area. In 2001, it was 4.81 km^2, which equals 2.53% of the total area. The surface area of anthropogenic shapes thus expanded by 2.96 km^2, which showed an increase of 159.74%. It is necessary to point out that the mentioned areas are not the only anthropogenic shapes in the monitored areas as built-up or afforested areas have been included into their relevant landscape element categories. Changes in the surface area of the landscape element of anthropogenic shapes in the individual partial territories (1a to 3c) are provided in Table 6 and charted in Figures 13 and 14.

Among anthropogenic shapes there are dumps, sedimentation basins, flood banks, heaps, mud sumps and waste dumps. In the course of analyses of landscape element changes so far there have been only two cases of surface area decrease in all the model territories (fields and meadows) or surface area increase (forests and built-up area). In the case of the landscape element of anthropogenic shapes, the situation is more complicated in terms of trends. Only in the model territory 3c there was a drop in surface area of anthropogenic shapes (e.g. the dumps of Alexander Mine, Na haldě). This was due to gradual forestry reclamation.

An increase was registered in the model territories 1a, 1b (along the already existing dump of Vrbická halda there were further dumps of Hrušov, near the Koblov Plant and near Heřmanice Mine), 1c (a set of mud sumps in the premises of Třebovice Power Plant, heaps), 2a (the dumps of Petr Bezruč Mine, Svoboda Coking Plant or of Oskar Mine), 2b (the dumps of Trojice Mine, Jan Maria Mine, the lagoons of Ostramo and flood

Table 6. Changes in the surface areas and percentage representations of the anthropogenic shapes landscape element in the individual model territories.

Type of area	Anthropogenic shapes (km^2)		Anthropogenic shapes (%)	
	Year 1946	Present	Year 1946	Present
1a	0.37	0.56	3.1	4.7
1b	0.02	0.43	0.13	3.34
1c	0	0.25	0	2
2a	0.23	0.44	1.08	2.09
2b	0.01	0.97	0.05	4.85
2c	0.44	0.93	1.49	3.13
3a	0	0.57	0	2
3b	0	0	0	0
3c	0.78	0.66	2.93	2.48

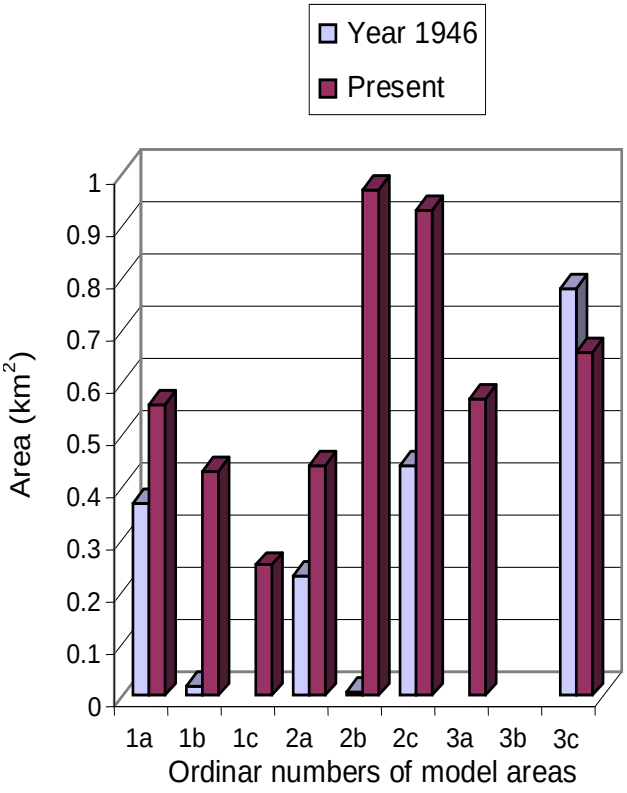

Figure 13. Chart of area changes (in km^2) representations of the anthropogenic shapes landscape element in the individual model territories.

banks of the Ostravice and Lučina Rivers), 2c (the settling ponds of Rudná, Bartovice, dumps) and 3a. In the majority of heaps gradual reclamation is under work and it can be expected that even in those model territories there will be a decrease in surface area of anthropogenic shapes to the benefit of forest landscape element.

WATER AREAS

In the monitored area, water areas represent a fractional but very important element in the landscape. With regard to this, there is a growing tendency to increase the surface area of water bodies.

In 1946, water areas took up only 0.77 km^2, which

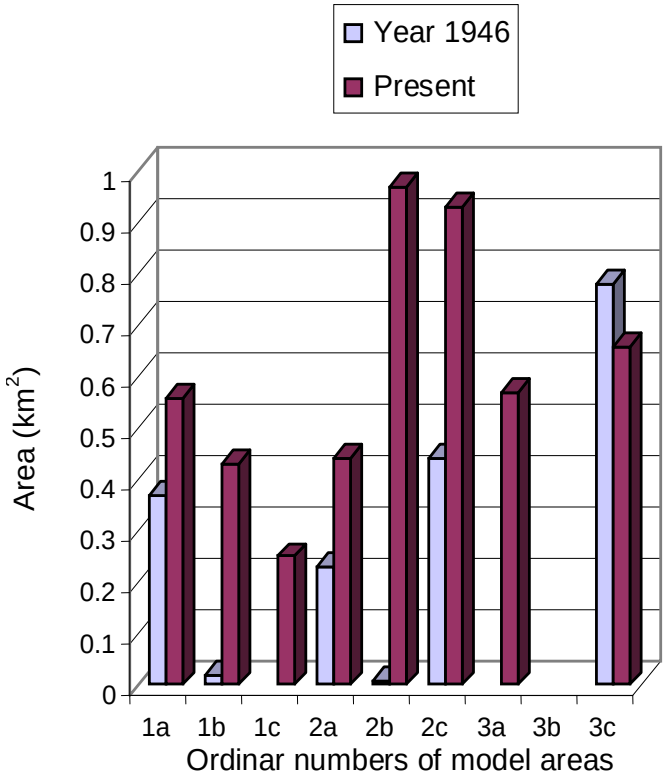

Figure 14. Chart of area changes in percentage representations of the anthropogenic shapes landscape element in the individual model territories.

Table 7. Changes in the surface areas and percentage representations of the water areas landscape element in the individual model territories.

Type of area	Water areas (km^2)		Water areas (%)	
	Year 1946	Present	Year 1946	Present
1a	0.02	0.08	0.1	0.7
1b	0	1.5	0	11.6
1c	0	0.1	0	0.8
2a	0.01	0.07	0.06	0.36
2b	0.02	0.04	0.1	0.2
2c	0.1	0.153	0.33	0.51
3a	0.3	0.39	1.06	1.38
3b	0.24	0.29	0.89	1.08
3c	0.08	0.12	0.29	0.47

represented 0.4% of the monitored area. Currently, it is 2.74 km^2, that is, 1.44%, which means a rise of 256.7%. Changes in the surface area of the water areas landscape element in the individual partial territories (1a to 3c) are displayed in Table 7 and charted in Figures 15 and 16.

The landscape element of water areas registered the largest rise in surface area among all the analyzed elements. Among the most significant reasons there is gravel extraction (e.g. in Vrbice). Next, water areas were widened thanks to the Odra River, having created crescentic lakes that provided bases for ponds (model territory 1a and 1c). In the model territory 2a water area surface grew due to the construction of new ponds in the ZOO in Hladnov. Due to their ecological balance, certain water areas have deserved better protection, such as the

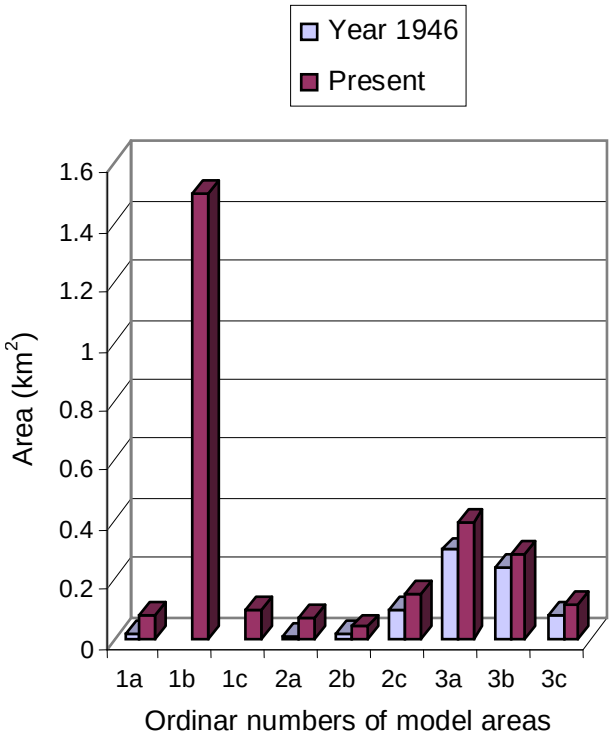

Figure 15. Chart of area changes (in km^2) representations of the water areas landscape element in the individual model territories.

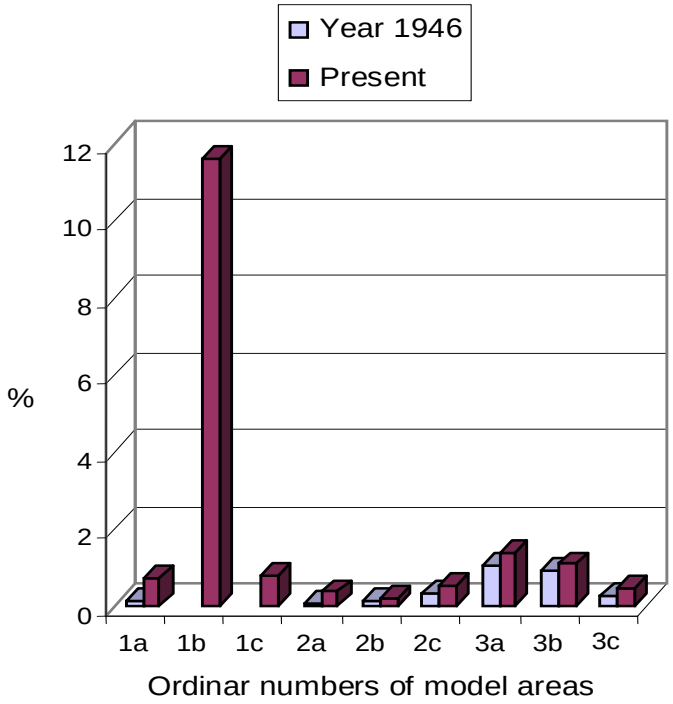

Figure 16. Charts of area changes in percentage representations of the water areas landscape element in the individual model territories.

Table 8. Changes in the surface areas and percentage representations of the water courses landscape element in the individual model territories.

Type of area	Watercourses (km^2)		Watercourses (%)	
	Year 1946	Present	Year 1946	Present
1a	0.37	0.37	3.1	3
1b	0.39	0.33	3	2.55
1c	0.12	0.05	0.97	0.4
2a	0.21	0.25	0.99	1.19
2b	0.21	0.12	1.05	0.6
2c	0.18	0.18	0.61	0.6
3a	0.16	0.26	0.56	0.93
3b	0.21	0.16	0.79	0.61
3c	0.18	0.13	0.69	0.5

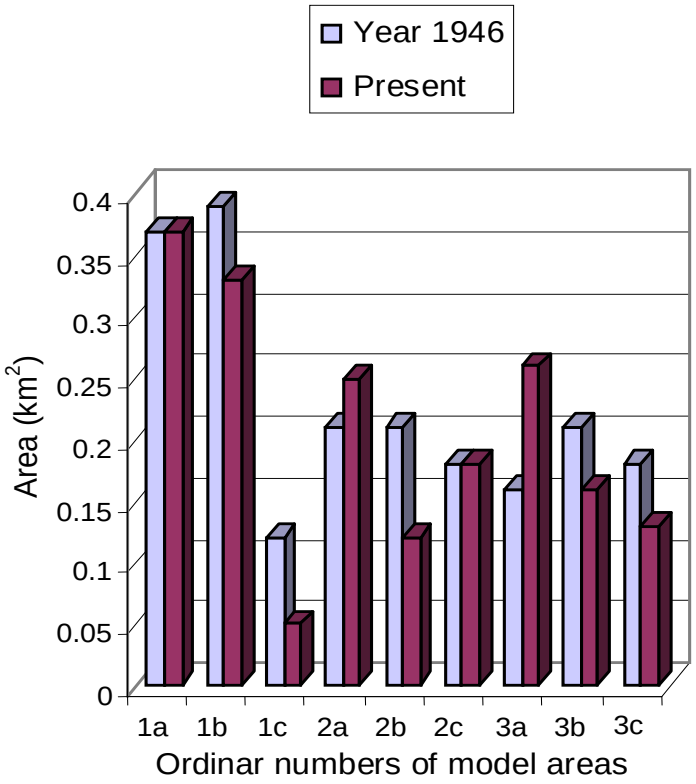

Figure 17. Chart of area changes (in km^2) representations of the water courses landscape element in the individual model territories.

Štěpán Pond (reserve situated in the model territory 3b), which belongs among the most valuable protected areas in Ostrava – its significance is comparable to the prime reserves in CHKO Poodří Reserve.

WATER COURSES

The landscape element of water courses has slightly lost on its percentage in time. In 1946, rivers took up 2.03 km^2, which represented 1.07% of the area. At present, it is 1.85 km^2, that is, 0.97% out of the total monitored area. This equals to a decrease of 9.06%. Changes in the surface area of the water course landscape element in the individual partial territories (1a to 3c) are given in Table 8 and charted in Figures 17 and 18.

Among rivers that have been studied, there are the Odra, Opava, Ostravice, Porubka, Černý potok a Lučina.

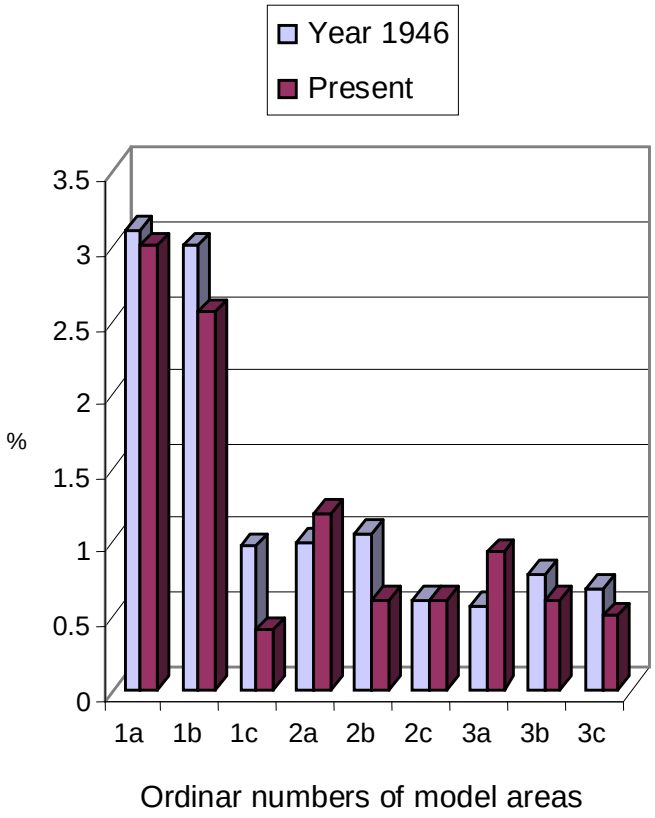

Figure 18. Chart of area changes in percentage representations of the water courses landscape element in the individual model territories.

A small decline has been caused by a gradual improvement of water areas, and construction of flood banks.

RESULTS AND DISCUSSION

In the monitored area, there have been significant changes in the landscape character. Four landscape elements increased (built-up area, forests, anthropogenic shapes and water areas) and two elements lost on their percentage (fields and meadows, water courses).

The surface area of built-up area grew by 43.57 km^2, which represents a rise of 99.68%. The main reason was industrial development, which resulted in increased building activities in the region of Ostrava (construction of industrial premises and housing estates). The built-up area mainly increased at the expense of the fields and meadows.

One of the most important discoveries was the fact that the surface area of forests in the studied fraction of Ostrava grew by 54.95% (10.3 km^2), despite the intense industrial development. Forest percentage predominantly grew due to forestry reclamation of anthropogenic shapes and the gradual process of forestation of fields and meadows.

Anthropogenic shapes enlarged by 159.76%. This trend could have been more prominent but the reclaimed or built-up anthropogenic shapes were classified in their relevant landscape elements. Waste heaps represent an important part of this landscape element being a serious ecological issue. This can be solved by forestry reclamation, which contributes to a positive trend in decreasing the surface area of this landscape element in the selected model territories. It can be expected that a similar trend in the future will reduce the surface area of waste heaps as well as of all anthropogenic shapes.

The water areas gained in most of the surface areas (256.7%) are due to gravel extraction in Vrbice, and the formation of new ponds from Crescentic Lakes of the Odra River.

Both the largest surface area and the most significant percentage drop were registered with the landscape element of fields and meadows (decrease of 58.98 km^2, that is, of 47.88%). The main cause was expansion of the built-up area.

Similarly, the percentage lost (by 9.06%) observed in water courses was due to the improvement in water

courses. In the monitored area, there were significant changes that were documented, and which will be used as an important background for subsequent research. However, they are available for the needs of town planning and environmental protection in areas affected by mining activities.

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