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Landscape pattern changes in the Šumava region – a GIS approach

Změny krajinného rázu v Pošumaví – hodnocení pomocí GIS

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Abstract

Changes of the landscape pattern in the course of last two centuries has been assessed using two land-use categories on the territory of the current Klatovy, Prachatice, and Český Krumlov districts. The shape index and proximity represented the landscape parameters in this GIS study. A 17% reforestation and a 3% deforestation highly influenced pattern, and significant differences appeared in the woodland shape indices, average grassland proximity, and the 60 m proximity between 1840's and 1990's.

Key words: landscape pattern, proximity, patch shape, GIS

Introduction

Landscape pattern refers to the number, size, and juxtaposition of landscape elements or patches which are important contributors to overall landscape structure and to the interpretation of landscape processes (GARTNER & al. 1987). Both patch size and shape influence floral and faunal composition and richness and have important implication for transitions of biotic and abiotic features of the landscape to the adjacent patch (FORMAN & MILNE 1986). The proximate consequences of changes in landscape pattern relate to changes in dispersal capabilities of organisms, among other factors. Many formulas have been tested to quantify landscape spatial patterns and their affects on ecological processes (FORMAN & GODRON 1986). A state-of-art review is given in (TURNER & GARDNER 1990).

This paper focuses on evaluation of temporal changes of landscape pattern in the area experienced significant reforestation in the last two centuries (e.g. MRÁČEK & KREČMEK 1975, ZENKER 1891, BENEŠ 1996). Landscape pattern is expressed as a combination of woodland and grassland areas (PLOWMAN 1995).

The study aims to quantify the extent of long term reforestation and deforestation changes through GIS and image analysis techniques and to test the significance of landscape pattern changes.

Study area

The study was carried out in the territory of three districts, namely Klatovy, Prachatice, and Český Krumlov (Fig. 1). The estimations of pattern changes were also calculated for the Šumava Mts. and the Šumava piedmont, for the Šumava National Park and its Wilderness Areas, and for trapeziums of Central European grid mapping system (BUCHAR 1982) within the districts.

Data and methods

a) Land-use change

Two terms of military maps of the study area were used to estimate land-use changes and landscape patterns. The first map set originates from the military mapping of the Austria-Hungarian Empire 1842–1853, scale 1:28 800 (Roubík 1951), the second one from recent military maps (1990), Gauss-Krüger projection, scale 1:25 000. Both map sets were vector digitised and rasterized and the historical one was registered into 1990's. The map overlay showed the places of land-use changes. Only two land-use categories were investigated: woodlands and grasslands. Within this study woodlands refer to all forest soils and woodlots outside the settlements, grasslands are a complement to the woodlands.

Recent forest types (coniferous, broad-leaved and mixed forests) in reforested areas were derived from supervised classification of satellite Landsat 5 TM data, 1995.

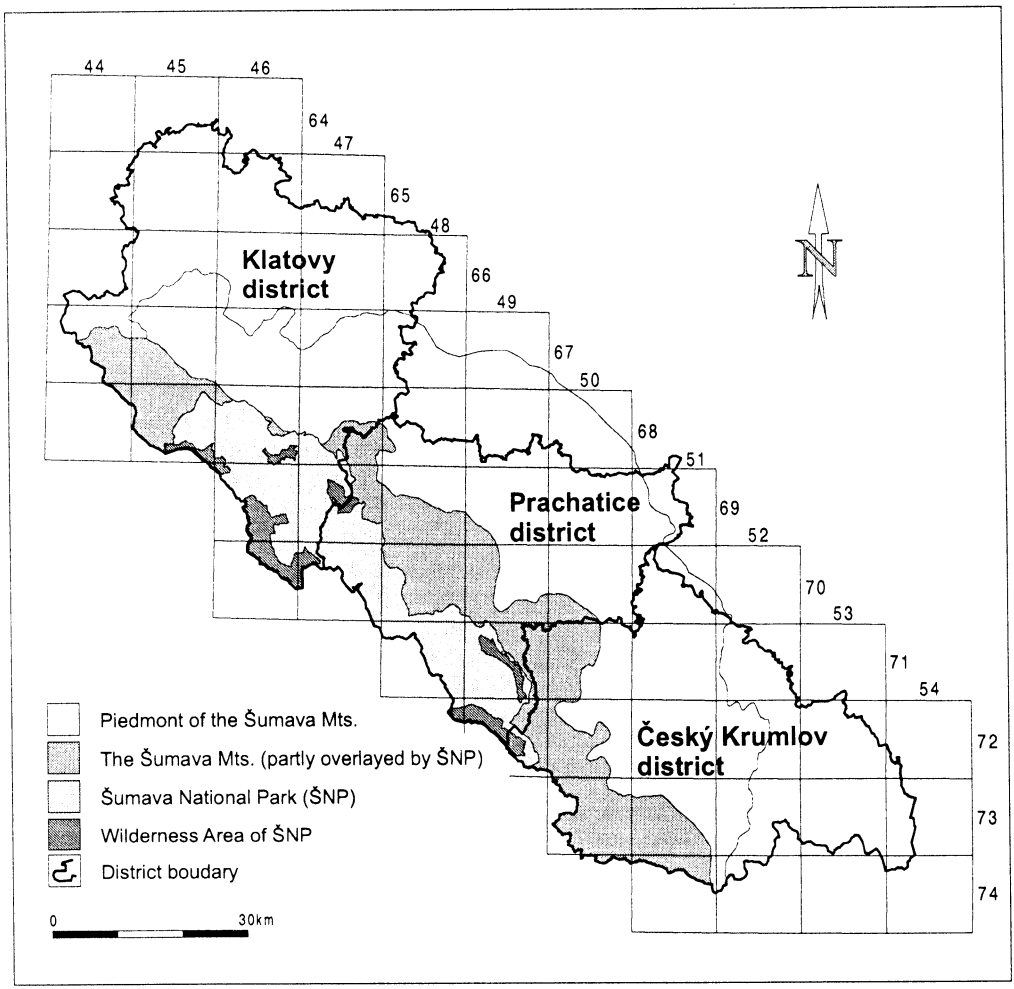

Fig. 1. – Study area with the Central European grid.
Obr. 1. – Studované území se středoevropskou kvadrátovou sítí.

b) Landscape pattern change

From the wide range of parameters proposed in assessment of landscape pattern by different authors we applied two: proximity (PCI manual 1995) and index of the shape of a patch (FORMAN & GORDON 1986).

Proximity is the shortest distance of a spatial element of one class to the boundary of other class. A pixel of 30 x 30 m was used as a spatial element (resolution of TM data) and we calculated the distance of each woodland pixel to the nearest grassland pixel and vice versa. Overall evaluation of proximity is expressed by two parameters:

1. mean proximity of each study unit, i.e. average distance of all pixels in the unit from closest boundary of other class
2. a 60 m proximity zone, i.e. area lying within the distance of 60 m from other class, here in [%] of total area of the unit

The shape index S_i of a patch i (e.g. woodland area) is measured using the formula:

$$S_i = \frac{2\sqrt{\pi A}}{P} \cdot 100$$

where P is the perimeter and A is the area of the patch. It reflects the relationships between the perimeter of a polygon and the perimeter of a circle, whose area is equal to the area of the polygon. The shape index ranges from 0 to 100 and is equal to 100 for a circle. This index was calculated only for the cells of the Central European grid to meet assumption of comparable units.

The hypotheses of differences between pattern parameters of two time horizons were tested using T-test (SHAW & WHILLER 1996).

Results and discussion

a) Land-use change

The results (Table 1.) show a 17% average increase of woodlands (calculated from total area) in three districts between 1840's and 1990's. The distribution of reforestation among the districts is quite uneven (21% Český Krumlov, 17% Prachatice, 14% Klatovy), while the deforestation is less than a 3% in each of the districts.

The Šumava Mts. undergone similar reforestation to the Šumava piedmont (18%) and we found a 14% reforestation within the Šumava National Park.The extent of the area reforested

Table 1. – Woodland area changes in [%] of total area between 1840's and 1990's.
Tabulka 1. – Změny lesnatosti (%) vůči celkové rozloze území v letech 1840 a 1990.

Area	Total area [km²]	Woodland 1840 [%]	Woodland 1990 [%]	Deforestation [%]	Reforestation [%]	
					Coniferous	Broadleaved
Klatovy dist.	1898	33.2	44.9	2.5	11.0	3.2
Prachatice dist.	1375	39.6	53.7	2.9	11.4	5.6
Č. Krumlov dist.	1569	33.5	51.8	2.8	13.8	7.2
Šumava Mts.	1579	57.2	73.9	3.1	14.8	5.0
Šumava piedmont	1849	25.8	41.6	2.9	12.2	6.6
Šumava NP	683	70.2	80.4	3.6	11.0	2.9
Wilderness Area	111	79.0	87.5	4.4	9.9	3.1

Table 2. – Woodland area changes (1840's and 1990's) of total area of the Central European grid cell.
Tabulka 2. – Změny lesnatosti (léta 1840 a 1990) zkoumaného území v jednotlivých polích středoevropské kvadrátové sítě

Central Europen Grid	Woodland 1840 [%]	Woodland 1990 [%]	Deforestation [%]	Reforestation [%]	
				Coniferous	Broadleaved
6545	26.3	30.8	3.0	4.7	2.8
6546	18.9	27.5	1.3	6.7	3.2
6645	13.2	17.6	1.9	4.2	2.1
6646	25.3	33.5	2.2	7.4	3.0
6647	12.2	21.0	2.0	10.6	0.2
6744	38.7	58.5	1.7	13.6	7.9
6745	29.7	53.8	1.8	20.3	5.6
6746	27.9	38.4	2.5	10.1	2.9
6747	17.7	26.1	2.3	8.0	2.7
6845	71.0	85.2	2.4	14.2	2.4
6846	41.8	65.1	3.1	22.0	4.4
6847	35.6	55.5	5.3	18.5	6.7
6848	26.3	36.3	4.1	11.4	2.7
6946	73.8	85.6	3.7	13.1	2.4
6947	71.4	79.0	2.6	8.4	1.8
6948	33.3	55.9	3.3	19.1	6.8
6949	23.4	38.8	2.9	13.1	5.2
6950	27.8	34.4	2.8	6.0	3.4
6951	10.3	16.5	1.7	5.0	2.9
7047	77.8	81.5	3.7	5.3	2.1
7048	55.8	72.3	2.1	13.4	5.2
7049	40.0	61.3	2.2	15.2	8.3
7050	26.6	55.4	1.3	15.9	14.2
7051	25.7	44.3	2.1	11.0	9.7
7148	58.0	63.5	6.0	8.2	3.3
7149	63.4	72.3	3.1	7.7	4.3
7150	43.8	65.0	2.9	13.4	10.7
7151	37.6	54.8	1.6	10.5	8.3
7152	17.4	28.3	2.6	8.8	4.7
7249	58.2	72.7	2.5	11.4	5.6
7250	24.7	39.6	4.4	13.9	5.4
7251	21.6	41.6	2.2	13.2	9.0
7252	26.6	42.4	2.7	12.9	5.6
7253	29.0	46.9	2.0	11.9	8.0
7350	32.3	63.9	3.2	27.6	7.2
7351	42.1	58.9	3.9	15.2	5.5
7352	26.5	44.0	3.4	13.6	7.3
7353	35.4	58.2	2.2	16.5	8.5
7354	86.5	89.3	2.1	4.3	0.6

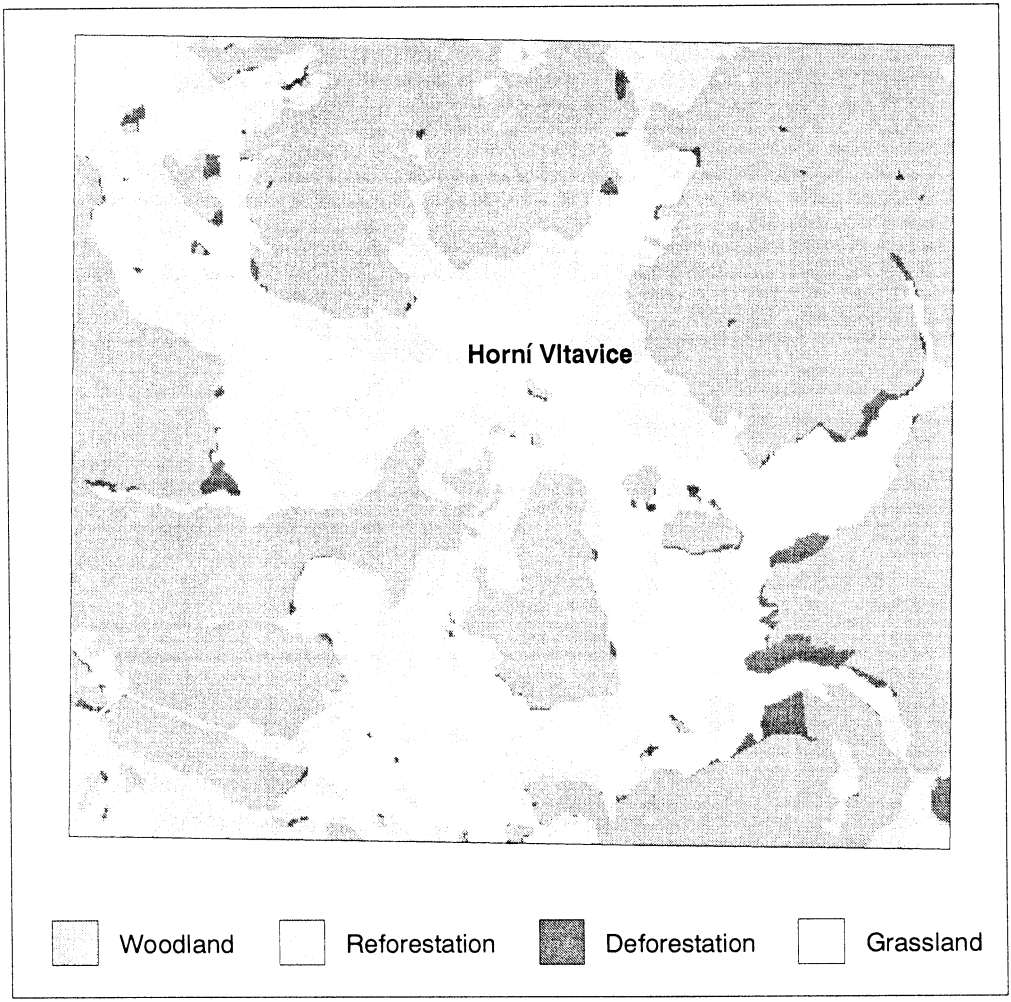

Fig. 2. – Example of land-use changes (1840's and 1990's) in cell 7048 of Central European grid.
Obr. 2. – Příklad změn využití území (léta 1840 a 1990) v poli 7048 středoevropské kvadrátové sítě.

by broad-leaved and mixed forest does not exceed a third of total reforested territory in any above used units.

The reforestation under the trapeziums of the Central European grid (Table 2) ranges from 0.2% to 14.2% of broad-leaved and mixed forests and from 4.2% to 27.6% of coniferous forests, respectively. The highest reforestation (34.8%) displays the cell 7350, the lowest (4.9%) the cell 7354. An example of spatial distribution of land-use changes in cell 7048 shows Fig. 2.

The deforestation in the trapeziums lies in the interval from 1.3% to 6%.

We evaluated only cells overlapping more than 50% of their area in any of three districts because of data unavailability outside the districts (Fig. 1).

a) Pattern change

Tests of differences between two data terms of average woodland proximity, average grassland proximity and 60 m proximity (Tables 3, 4) show statistically significant differences ($P<0.01$) in latter two categories. Average grassland proximity decreased and 60m proximity

Table 3. – Average proximity [m] is calculated as an average distance of pixels of one land-use class to the border of another class. A 60 m proximity is an area [%], which lies within 60 m zone from each side of border between two classes.

Tabulka 3. – Průměrná blízkost [m] je počítána jako průměr vzdáleností pixlů jedné třídy využití území k hranici jiné třídy. Blízkost 60 m je plocha [%], která leží v oblasti do 60 m od každé strany hranice dvou tříd.

Area	Average woodland proximity [m]		Average grassland proximity [m]		60 m proximity [%]	
	1840	1990	1840	1990	1840	1990
Klatovy dist.	242	278	419	226	20	28
Prachatice dist.	353	344	332	184	21	30
Č. Krumlov dist.	172	234	253	151	29	36
Šumava Mts.	357	401	240	125	23	26
Šumava piedmont	127	167	299	172	26	37
Šumava NP	440	484	245	108	18	21
Wilderness Area	383	426	278	76	17	21

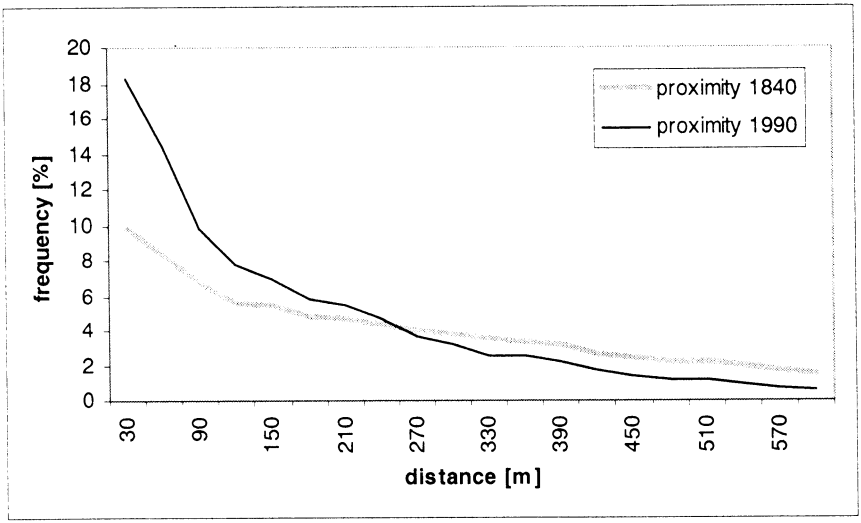

Fig. 3. – Frequency histograms of grassland proximity to woodland.
Obr. 3. – Frekvenční histogramy blízkosti bezlesí vůči lesu.

The results indicate:

I. Some open areas in woodlands from 1840's were filled up with forests, which caused extensive and more homogenous complexes of forest blocks and the lost of some secondary grasslands (slightly higher average woodland proximity)

II. An arise of new, small and isolated patches of forests in former grasslands (significantly lower average grassland proximity and higher 60 m proximity)

Table 4. – Average proximity [m] is calculated as an average distance of pixels of one land-use class to the border of another class. A 60 m proximity is an area [%] lying within 60 m zone from each side of border between two classes. Shape index reflects the relationships between the perimeter of a polygon and the perimeter of a circle, whose area is equal to the area of the polygon.

Tabulka 4. – Průměrná blízkost [m] je počítána jako průměr vzdáleností pixelů jedné třídy využití území k hranici jiné třídy. Blízkost 60 m je plocha [%] ležící v oblasti do 60 m od každé strany hranice dvou tříd. Tvarový index vyjadřuje vztahy mezi obvodem polygonu a obvodem kruhu, jejichž plochy jsou shodné.

Central European Grid	Average Woodland proximity [m]		Average Grassland proximity [m]		60 m proximity [%]		Woodland shape index	
	1840	1990	1840	1990	1840	1990	1840	1990
6545	158	168	418	274	20	26	10	8
6546	118	133	507	258	17	26	12	8
6645	132	110	831	377	11	20	14	8
6646	154	170	392	180	22	33	9	6
6647	89	89	445	206	16	32	8	5
6744	178	317	392	329	27	26	12	14
6745	152	258	301	183	25	32	9	8
6746	139	146	296	152	26	38	8	6
6747	120	111	434	222	18	32	9	6
6845	393	449	200	98	20	20	20	21
6846	161	250	200	121	31	34	8	9
6847	245	188	284	133	22	38	11	7
6848	219	168	303	176	23	38	12	8
6946	360	404	206	81	19	23	23	19
6947	396	431	233	148	17	19	20	17
6948	197	258	286	146	24	34	9	8
6949	129	140	313	165	23	41	8	5
6950	139	149	373	232	22	30	10	7
6951	109	107	620	311	11	22	15	9
7047	420	620	202	128	17	17	34	29
7048	426	410	294	128	16	23	18	14
7049	258	370	258	173	29	31	8	9
7050	128	203	259	140	27	40	7	7
7051	102	254	302	205	26	29	10	11
7148	471	376	263	121	17	29	28	15
7149	523	550	338	149	18	23	18	13
7150	249	333	197	142	29	30	9	10
7151	183	302	286	168	26	29	9	9
7152	100	95	409	231	21	36	9	6
7249	575	529	299	140	17	23	26	19
7250	98	115	275	143	24	37	7	6
7251	78	118	230	129	30	45	6	5
7252	101	149	236	143	29	40	7	6
7253	132	197	295	157	28	38	8	7
7350	99	298	226	108	32	34	7	9

Central European Grid	Average Woodland proximity [m]		Average Grassland proximity [m]		60 m proximity [%]		Woodland shape index	
	1840	1990	1840	1990	1840	1990	1840	1990
7351	143	189	172	116	36	38	7	7
7352	95	150	235	158	33	39	6	6
7353	170	222	237	131	31	37	8	8
7354	413	463	131	114	17	15	50	53

increased. Also difference in woodland shape indexes (Table 4) is statistically significant ($P<0.05$). Fig. 3 demonstrates the frequency histogram of change in grassland proximity between 1840's and 1990's, that was calculated with 30 m step (pixel size).

Conclusion

Relatively high reforestation of the Šumava region in last two centuries resulted into new patterns of ecosystem and landscape structure and influenced ecosystem processes. This regional case study aimed to demonstrate some of the facilities and tools which can help landscape researchers and manages to identify and quantify landscape and ecosystem changes on different information level.

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