Original Research

Sinuosity and Edge Effect – Important Factors of Landscape Pattern and Diversity

Dagmar Stejskalová[1], Petr Karásek[1]*, Lenka Tlapáková[2], Jana Podhrázská[1]

[1]Research Institute for Soil and Water Conservation, v.v.i., Lidická 25/27, Brno, 602 00, Czech Republic
[2]Research Institute for Soil and Water Conservation, v.v.i., Boženy Němcové 231, Pardubice 530 02, Czech Republic

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Abstract

The paper is focused on two crucial landscape-forming aspects: linear elements (watercourses, linear tree plantings, road network) and neighbouring edges of landscape segments, or ecotones. Linear elements accentuate the character of landscape, its division, pattern, and contribute significantly to landscape passability and its diversity. The edges of neighbouring landscape segments not only create the spatial arrangement of landscape, but they also are important habitats for plants and animals. So they are irreplaceable for the maintenance of ecological stability of landscape and they are an important element of its biodiversity.

The analysis of trends of changes in the length of linear elements and ecotone edges was performed in three time horizons: in the first half of the 19th century, in the 1960s, and at the present time. The evaluation was done in four model territories. Ous paper evaluates the sinuosity of linear elements (roads and railways, watercourses, dirt roads, linear tree plantings) and the lengths of common borders of segments of arable land – permanent grasslands and arable land – forests.

Keywords: linear elements, ecotones, sinuosity, watercourses, GIS

Introduction

Landscape ecology includes the study of landscape patterns, functions, and changes. Thorne and Huang [1] defined the landscape as a set of repeated groups of interactive ecosystems that have a clear visual identity. The quantity, quality, and spatial arrangement of stable ecosystems influence the ecological stability of a landscape [2]. Peterson, Allen, and Holling [3] stated that there exist boundary limits of land use when negative interventions may significantly restrict the living conditions of organisms and reduce biodiversity.

Fjellstad and Dramstad [4] studied the intensities of the use of different landscapes and drew the conclusion that the higher the intensity of land use, the greater its homogenization while there is a significant reduction in ecotone edges. The studies of Reger, Sheridan, and Simmering [5] demonstrated that the pronounced homogenization of European landscape has occurred in recent years as a result of European agricultural policy (production-coupled payments).

Koellner and Scholz [6] analyzed the species diversity of thousands of parcels for 53 types of different intensity of land use. Their results confirmed that highly intensive farming has led to the lowest richness of plant species, while under an extensive farming system almost threefold species diversity of plants was maintained at the evaluated site.

In their article "Ecotones in Landscape," Sklenička and Pitnerová [7] stated that these relatively stable parts of landscape mediate positive effects on the surrounding labile matrix; they also mentioned positive functions of ecotone edges and demonstrated that ecotone edges fulfil an important production function. The edge effect is of crucial importance in landscape from the aspect of biodiversity,

*e-mail: karasek.petr@vumop.cz

conservation of agricultural land resources, and landscape ecology. Its analysis describes to some extent the patchiness of landscape, its arrangement, heterogeneity, and diversity. The CR landscape underwent the most profound changes during intensification of agricultural production in the 1960s to the 1980s. The typical landscape patchiness of the 19th century gave in to the pressure of production collectivization and intensification in the form of land consolidation and to the formation of large blocks of arable land. As a result of ploughing up balks, dirt roads, liquidation of grasslands, and groves, a pronounced decrease in the edge effect occurred.

High homogenization and geometrization of the landscape pattern as a result of intensive land use introduced into landscape often hardly surmountable barriers that create not only impassable areas but also in general reduce the landscape ability to balance negative phenomena, mainly the phenomena connected with the hydrological function of landscape.

Namiesnik and Rabajczyk [8] indicate that aquatic ecosystems are exposed to permanent anthropogenic pressure. Several authors have evaluated ecological quality and the development of watercourses according to chemical or biological indicators [9, 10]. The effect of watercourses and wetlands is more complex. These landscape features have a decisive influence on the formation of morphological and hydraulic properties of the landscape. From this point of view Hawkins, Dobrowolski and McDonnell [11] highlight that the most important task of education is to prepare professionals with a comprehensive ecological education.

The contribution of a natural watercourse to landscape is evident as it has high biodiversity, capacity to retain water in landscape, and to slow down discharges of torrential rains. E.g. Maasop and Gasst [12] have stated that the natural environment around a meandering stream acts as a sponge when water is retained in depressions and wetlands, and so the stream reduces peak discharges. Langhammer [13] studied the anthropogenic training of streams, floodplains, and consequences of floods in the Opava watershed. Although it is a concrete territory with specific conditions, limiting conditions of retention potential use are not only natural geomorphological conditions (narrow valleys of the upstream segments of watercourses), but also intensive housing development because of which the majority of streams is capacitated for the fast drainage of water. Gordon and Finlayson [14] have described the longitudinal profile of a watercourse and its curvature as sinuosity, expressed by the value of the sinuosity index. They determined the value of the index as 1-1.5 for straight watercourses and 1.5-4 for meandering streams.

The development of traffic systems and homogenization of the landscape pattern introduced into the landscape hardly surmountable linear and area barriers that create not only impassable areas but also generally reduce the landscape ability to balance negative phenomena.

In the framework of the solution to stage 1042 of Research Plan of the Ministry of Agriculture of the Czech Republic No. MZE0002704902, “Integrated Systems of the Conservation and Use of Soil, Water and Landscape in Agriculture and Rural Development”, four model territories were chosen: Hustopeče (7 cadastres, 9,238 ha) – intensive agricultural area (South Moravian Region); Maršovský potok watershed Hubenov (17 cadastres, 8,313 ha) – infiltration territory of the Hubenov Water Reservoir (Vysočina Region); Žejbro watershed (23 cadastres, 11,534 ha) – intensive agriculture in a hilly area (Pardubický Region); and a part of the territory of Železné hory Mts. Protected Landscape Area – PLA (7 cadastres, 3,612 ha) – protected territory (Pardubický Region). In these territories analyses of trends of changes in the length of linear elements and ecotone edges were conducted in three time horizons – in the first half of the 19th century, in the 1960s, and at the present time.

Experimental Procedures

Input data have been taken from historical and contemporary materials. Among historical materials, imperial obligatory prints of the Stable Cadastre maps were processed for the purposes of this solution. These maps, covering the entire territory of the Czech Republic, are deposited in the Central Archive of Geodesy and Cadastre in Prague (Czech Republic) in paper form and provide detailed and accurate information about land use in the first half of the 19th century. Their contents correspond to the basic topographical map. These are the oldest maps that can be used to solve the given problem. Stable Cadastre maps were created in the first half of the 19th century (1825-39) at scale 1:2,880. As further documentation we used historic black-and-white aerial photos from 1950-68 provided by the Military Geographical and Hydrometeorological Office of Dobruška (Czech Republic). The scale of these photos ranges between 1:13,000 and 1:18,000, according to the photographed locations and the quality of employed aerial camera. It is a period when substantial interventions were realized in landscapes to influence the arrangement of landscape patterns, and used as a further source of information on the historical situation of landscape. The evaluation of the present situation on the basis of coloured orthophotomaps (at a scale 1:5,000) covers the last analyzed period. This choice of materials represents land use under feudalism, socialism, and at the present time. Input data (maps, aerial photos, and orthophotomaps) were georeferenced into the coordinate system (S-JTSK) for subsequent use in GIS environment (ArcGIS – ArcInfo) and vectorized (manually) according to the proposed legend common to all territories and time series at a scale of 1:2,000. Vector map layers of LandUse/LandCover were created. These above background materials had to be processed so as to obtain a multitemporal geodatabasis.

In the environment of geographic information systems (GIS) these materials were processed for subsequent analyses of:

- the length of common borders of blocks of arable land and permanent grasslands
- the length of common borders of blocks of arable land and forests
- the length of landscape linear segments

Table 1. Changes in the real length of linear elements (from the first half of the 19th century and from the 1960s to the present time (increase, decrease in %).

	Hustopeče		Hubenov		Žejbro		Železné hory	
	1825-2006	1968-2006	1838-2006	1961-2006	1839-2006	1966-2006	1839-2006	1950-2006
Roads and railways	1459.1	62.7	617.3	116.8	206.7	20.0	759.5	-9.5
Dirt roads	-48.3	0.8	-76.8	4.4	-88.0	-54.0	-76.6	-36.9
Linear tree plantings	*	-30.4	*	738.5	*	176.3	*	69.0
Watercourses	-1.6	*	-62.4	*	-21.1	*	72.4	48.0

* data are not available

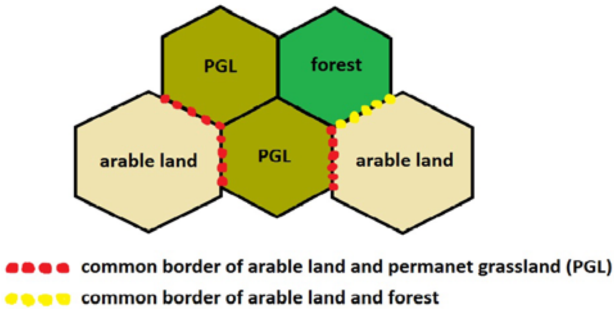

Fig. 1. An example of graphical representation of the edge effect evaluation.

Changes in Common Borders (Ecotone Edges)

Our evaluation is based on a comparison of the lengths of common borders of land use (LU) categories and on an assessment of trends of their development within the studied time horizons (Fig. 1). Undoubtedly, in spite of quite intensive use (e.g. the area of arable land was higher in all territories in the first half of the 19th century than at present), the landscape was considerably heterogeneous in the first half of the 19th century. Landscape diversity (heterogeneity) improves with the increasing length of common borders of two different LU categories. Changes in the neighbourhood were evaluated for three main landscape categories: arable land and permanent grasslands, arable land, and forests.

Changes in Sinuosity of Linear Elements (Sinuosity Index)

The analysis of changes in sinuosity of linear elements also was performed in the GIS environment. The method is based on evaluation of the real length of linear elements and its change in time and on evaluation of sinuosity (and/or the rate of straightening) in time by comparing the total length of linear elements with the total length of their straight lengths – connecting lines. Sinuosity expresses a difference between the real length and straight (straight line) length of the initial and terminal points of the same line (Fig. 2).

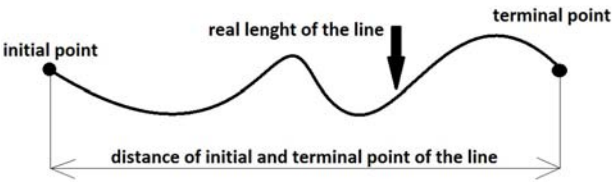

Fig. 2. The method for determining the sinuosity of linear elements in landscape.

In general, the sinuosity of linear elements is expressed by this relation:

$$l_s = l_r / l_p$$

...where l_s expresses a difference in lengths, l_r is the real length of linear elements, and l_p is the straight line length of linear elements.

Results

Evaluation of Development of the Real Length of Linear Elements over the Studied Period

Linear elements have undergone a pronounced shortening of the real length in the period from the 1st half of the 19th century to the present time (with the exception of railways and roads) (Table 1).

In the evaluation presented below a comparison of the initial period (1st half of the 19th century) and the present time was made if not indicated otherwise.

In Hustopeče territory an increase in the length of railways and roads by more than 1,000 percent is obvious. In the other territories the increase was by hundreds of percent. There has been a constant decrease in the length of dirt roads until now. The largest shortening of the length of dirt roads occurred in Žejbro territory – up to 88% of the initial length, in Železné hory PLA it was by 77%, in Hubenov territory by 77%, and the smallest shortening was observed in Hustopeče territory, by 48.3%.

Since the 1960s linear tree plantings have shown a decrease only in Hustopeče territory (by 30.4%). In the other territories there has been a substantial increase by hundreds of percent (it was probably connected with the development of railway and road traffic – companion tree plantings). The trend of watercourse development was negative because they have undergone great changes. In Železné hory model territory the length of watercourses has increased by 72% compared to the first half of the 19th century.

Table 2. Changes in the sinuosity of linear elements in model territories over the studied periods.

Linear elements	Hustopeče			Hubenov			Žejbro			Železné hory PLA		
	1825	1968	2006	1838	1961	2006	1839	1966	2006	1839	1950	2006
Roads	3.0	7.6	3.9	8.8	6.8	5.9	6.6	11.6	7.2	7.9	22.6	12.9
Railways	*	6.7	1.4	9.6	10.2	12.6	*	7.2	7.8	0.0	0.0	0.0
Dirt roads	9.8	10.1	12.3	*	11.4	18.8	7.5	13.8	8.2	14.3	8.1	12.2
Linear tree plantings	*	5.4	5.2	*	3.8	13.2	*	2.3	6.0	*	4.3	5.6
Watercourses	65.0	*	5.1	38.3	*	9.3	21.5	*	13.1	46.3	43.7	12.2

*data are not available
Note: the higher the value, the greater the sinuosity, while the lower value indicates a trend of worsening (line straightening)

The trend has been opposite in the other territories. The most pronounced decrease in the length of watercourses occurred in Hubenov territory (a decrease in total length by 62%). The situation in Hustopeče territory has been quite constant and balanced (a decrease by 1.6%), while there has been a decrease by 21% in Žejbro territory.

Evaluation of Development of Linear Element Sinuosity over the studied Period

The evaluation of sinuosity of linear elements shows changes in their spatial pattern in time. The values in Table 2, below, document an increase in the real length of a line in landscape (real length) compared to the straight line connecting the initial and terminal points of a given line (expressed in %).

In Hustopeče territory the trend of an increase in the sinuosity of dirt roads has been slightly positive (by 2.2% since the ‘60s). On the contrary, the downward trend of linear tree plantings has been observed. The greatest difference among the studied categories occurred in watercourses. The sinuosity of watercourses decreased from 65% to 5% in comparison with the first half of the 19th century. It implies a significant straightening of watercourses compared to their real initial length. If changes in the sinuosity of watercourses are expressed by a sinuosity index, sinuosity has changed from 1.65 (meandering streams) to 1.05 (straight streams) at the present time. Decreasing sinuosity of linear tree plantings was connected with the straightening of watercourses when a moderate decrease in sinuosity from 5.4% to 5.2% has occurred since the ‘60s (Table 3).

In Hubenov territory a slightly upward trend of dirt road sinuosity has been recorded from the ‘60s to the present time (by 7.4%). Sinuosity of linear tree plantings has slightly increased since the ‘60s. An opposite trend was observed in watercourses because there was a substantial decrease in sinuosity (from 38% to 9%) from the period of Stable Cadastre to the present time. Expressed by sinuosity index, the decrease was from 1.38 to 1.09, hence from the category of meandering streams to that of straight streams.

In Žejbro watershed dirt roads showed a trend of an increase in sinuosity until the sixties. Since the sixties there has been a decrease from 13.8% to 8.2%. An upward trend was observed in linear tree plantings. On the other hand, the sinuosity of watercourses has decreased from the 1st half of the 19th century to the present time (from the initial 21.5% to 13.1%). Expressed by sinuosity index, it was a decrease from 1.21 to 1.13. This means that also in the initial period of 1938 watercourses were quite straight, very slightly meandering with gradual straightening until the present time.

In cadastres belonging to the Železné hory Mts. dirt roads were found to show variable trends of sinuosity. From the period of the Stable Cadastre to the 1950s there was a decrease from 14.3% to 8.1%. Since then, the trend has been upward and at the present time the rate of dirt road sinuosity is 12.2%. A slightly positive trend also has been obvious in elements of linear tree plantings from the ‘50s to the present time. There has been an apparent trend of watercourse straightening also in the Železné hory Mts. (from initial 46% sinuosity to the present 12%), expressed by sinuosity index, from 1.46 (meandering streams) to 1.12 (straight streams).

Evaluation of the Edge Effect of Arable Land – PGL over the Studied Periods

Input data are data on land use-arable land and permanent grasslands (PGL) in all model territories over the studied periods (Table 4). The analysis also contains an overview of the total area of a given category, number of parcels, and average size of parcels.

In all territories a radical decrease in the lengths of ecotone edges occurred in the categories of arable land and PGL (Fig. 3).

Table 3. Development of watercourses in model territories (expressed by sinuosity index).

	First half of 19th century	Present situation
Hustopeče	1.65	1.05
Hubenov	1.38	1.09
Žejbro	1.21	1.13
Železné hory	1.46	1.12

In Hustopeče territory a decrease at the present time against the Stable Cadastre was 76.4%, compared to the ‘60s when it was 10.1%.

In Hubenov territory a decrease in the ‘60s against the Stable Cadastre was 67.5%, while it was 33.8% at the present time compared to the ‘60s.

In Žejbro territory a decrease in ecotone edges in the ‘60s against the Stable Cadastre was 41.9%, at the present time against the ‘60s it was 63.4%.

In the Železné hory cadastres a decrease in the common edges of PGL and arable land in the ‘60s against the Stable Cadastre was 28.3%, while it was 92.6% against the present time. In this case there was a relatively steep decrease in the total area of arable land and extensive establishment of grasslands was realized.

Evaluation of the Edge Effect of Arable Land – Forests over the Studied Periods

Input data are data on land use (arable land and forests) in all model territories over the studied period (Table 5). The analysis contains an overview of the total area of a given category, the number of parcels and the average size of parcels.

Three model territories – Hubenov, Žejbro and Železné hory – saw a decrease in the lengths of common borders of the areas of arable land-forests (Fig. 4). In Hustopeče territory in the studied periods there was a radical decrease in the total area of forests (liquidation of floodplain forests as a result of the construction of the Novomlýnské nádrže reservoirs) and a reduction in the total area of arable land. Contrary to the other territories, in spite of this situation the length of common edges increased by 92.8% in the 1960s compared to the Stable Cadastre period. At present, the length of common borders of arable land and forests has increased by 178% compared to the ‘60s. This can be explained by the shape of forest stand areas in Hustopeče territory, which often are windbreaks (and/or ecological corridors). In terms of the area, these are not forests of large areas but in spatial terms these are areas of linear character whose length is hundreds of meters. These windbreaks mostly divide large soil blocks of arable land, which increases the length of common borders of arable land-forest. At the same time it implies the crucial importance of windbreaks due to their polyfunctionality while they are a significant element with eco-stabilizing function, increasing the biodiversity of a territory.

In Hubenov territory in the 1960s there was an almost 50% increase in the lengths of common edges of arable land and forests compared to the Stable Cadastre, but a decrease at the present time compared to the 1960s was 47.2%. This decrease is a result of grassland establishment on arable land in the watershed of the Hubenov Water Reservoir (in former water protection zones – WPZ, currently in protection zones – PZ).

In Žejbro territory the lengths of ecotone edges increased by 55% in the 1960s compared to the Stable Cadastre, while at present there has been a decrease by ca. 7% in comparison with the ‘60s. This situation can be explained by a reduction in the total area of arable land and by subsequent afforestation.

In the cadastres of the Železné hory PLA common borders of arable land and forest were shortened by 31.4% in the sixties compared to the Stable Cadastre and at the present time by 43.9% in comparison with the sixties. In this territory there was a significant reduction in the areas of arable land, an increase in PGL, and a gradual increase in the area of forests in the studied periods.

Table 4. Input data for evaluation of the edge effect of PGL – arable land.

Hustopeče	Land Use	Number of parcels	Total area (ha)	Average size (ha)
1825	arable land	11746	3727.6	0.3
	PGL	3625	1457.2	0.4
1968	arable land	345	3990.7	11.6
	PGL	297	610.4	2.1
2006	arable land	561	3267.1	5.8
	PGL	387	301.4	0.8
Hubenov	Land Use	Number of parcels	Total area (ha)	Average size (ha)
1838	arable land	1415	1583.0	1.1
	PGL	2579	796.2	0.3
1961	arable land	772	1901.8	2.5
	PGL	455	522.4	1.1
2006	arable land	294	1309.7	4.5
	PGL	613	921.3	1.5
Žejbro	Land Use	Number of parcels	Total area (ha)	Average size (ha)
1839	arable land	6967	3870.8	0.6
	PGL	8043	1521.1	0.2
1966	arable land	2507	3887.2	1.6
	PGL	1441	1080.9	0.8
2006	arable land	727	3274.8	4.5
	PGL	1013	1318.7	1.3
Železné hory	Land Use	Number of parcels	Total area (ha)	Average size (ha)
1839	arable land	1294	920.5	0.7
	PGL	2539	873.1	0.3
1950	arable land	1140	535.9	0.5
	PGL	1086	1204.4	1.1
2006	arable land	50	367.3	7.3
	PGL	271	905.9	3.3

Table 5. Input data for evaluation of the edge effect of arable land-forests.

Hustopeče	Land Use	Number of parcels	Total area (ha)	Average area (ha)
1825	Arable land	11,746	3,727.6	0.3
	Forests	216	1,067.1	4.9
1968	Arable land	345	3,990.7	11.6
	Forests	57	1,181.0	20.7
2006	Arable land	561	3,267.1	5.8
	Forests	69	449.7	6.5
Hubenov	Land Use	Number of parcels	Total area (ha)	Average area (ha)
1838	Arable land	1415	1,583.0	1.1
	Forests	508	1,066.7	2.1
1961	Arable land	772	1,901.8	2.5
	Forests	166	1,077.3	6.5
2006	Arable land	294	1,309.7	4.5
	Forests	208	1,185.6	5.7
Žejbro	Land Use	Number of parcels	Total area (ha)	Average area (ha)
1839	Arable land	6,967	3,870.8	0.6
	Forests	867	621.7	0.7
1966	Arable land	2,507	3,887.2	1.6
	Forests	342	913.4	2.7
2006	Arable land	727	3,274.8	4.5
	Forests	318	1,275.8	4.0
Železné hory	Land Use	Number of parcels	Total area (ha)	Average area (ha)
1839	Arable land	1,294	920.5	0.7
	Forests	380	1,672.3	4.4
1950	Arable land	1,140	535.9	0.5
	Forests	96	1,704.5	17.8
2006	Arable land	50	367.3	7.3
	Forests	117	1,881.1	16.1

Conclusions

While the lengths of ecotone edges of arable land-PGL in model territories measured hundreds of kilometres in the first half of the 19th century, they reach only tens of kilometres at the present time. Mutual interaction has been reduced by 76-95%. This situation indicates a substantial decrease (on the same level) in the number of ecotone sites inhabited by small animals, insects, and plants, and reduces biodiversity of the territory and significant influence of these communities on agricultural production. Changes in the lengths of common edges of arable land-forests in time do not show such an unambiguous downward trend as changes in arable land-PGL. There has been a diminishing area of arable land in time and an increasing share of the category of forests and PGL (except the Hustopeče territory). Changes in the lengths of common edges of arable land and forests have exceptionally occurred in hundreds of percent in Hustopeče territory (a fivefold increase in the lengths of common borders over the studied periods). In the other model territories, common borders increased by 44% in Žejbro territory between the first half of the 19th century and the present time (a considerable increase in the area of forests, decrease in the area of arable land) while they decreased by 21% in Hubenov territory (constant reduction in the area of arable land, moderate increase in the area of forests), and by 61% in the Železné hory Mts. (constant pronounced decrease in the area of arable land and increase in the area of forests). A reduction in the area of arable land in time and an increase in the area of forests are typical for all territories (except Hustopeče territory). With regard to biota diversity changes in the common edges of arable land-forests have a more pronounced influence on biodiversity and ecological stability of the territories than the common edges of arable land-PGL.

The results of the analyses of edge effect in model territories document substantial changes in development and length of common borders of different land use categories. It has also been verified that the used method based on multitemporal analysis of input data and subsequent GIS analyses is applicable on any scale in any territory. The analysis of development of changes in ecotone communities provides valuable material for the determination of biodiversity development in any territory over time.

The line elements represent important elements in the landscape. They segment the landscape matrix, increase landscape diversity, often have an anti-erosive function, and augment the aesthetic value of the area. They may also increase the overall biodiversity of the area. Well executed and established line elements in the landscape (e.g. shelterbelts) of several meters may form an ecological network and represent a shelter for many animals. In some types of intensively agriculturally employed and deforested landscapes (e.g. Hustopeče region), the line elements play a significant role in increasing landscape diversity along with

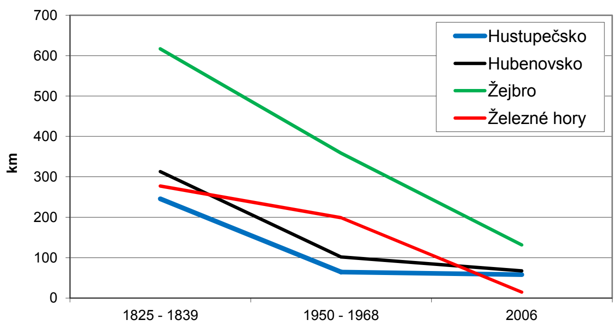

Fig. 3. Comparison of the lengths of common edges of arable land-PGL in model territories over time.

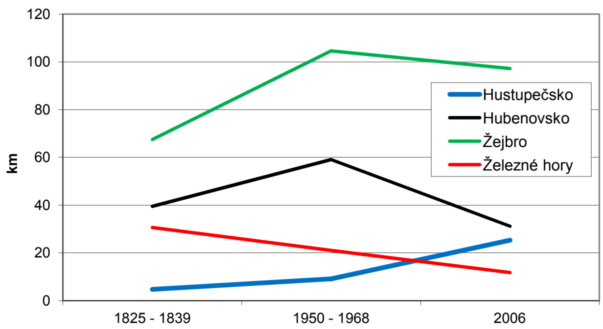

Fig. 4. Comparison of the lengths of common edges of arable land-forests in model territories over time.

augmenting ecological biodiversity. Considering the real length and sinuosity of linear elements in landscape, the least favourable development was observed in watercourses. Their real length decreased in time by 62, 21, and 1.6% in Hubenov, Žejbro, and Hustopeče territories, respectively. The benefits of a natural watercourse for landscape are evident: it has high biodiversity and water-retaining capacity in landscape. E.g. Maasop, Gasst [12] stated that the natural environment around a meandering stream acts as a sponge when water is retained in depressions and wetlands and the stream reduces peak discharges in this way. Shortening of the real lengths of watercourses and reduction in their sinuosity must necessarily have opposite effects – water draining from the territory and acceleration of peak discharges. The Železné hory Mts. are an exception: the real length of watercourses as well as the length of straight connecting lines have increased. Hence the number and total length of watercourses increased while sinuosity was reduced and watercourses are currently straight. Causes of this trend may lie in the historical period. In the Stable Cadastre period this territory comprised a great amount of waterlogged meadows and wetlands. In the period of agricultural production intensification of overall drainage was performed using systematic tile drainage systems or open ditches in the form of drainage channels (in total about 15% of the Železné hory model territory has been drained). An increase in the category of watercourses may be caused by the realization of straight drainage channels. In all territories the trend of stream straightening is quite evident (considerable decrease in sinuosity by tens of percent).

The situation of dirt roads is similar. If their initial real length was reduced by a half or three quarters, such a situation clearly documents homogenization of the landscape pattern, creation of huge entities, and radical reduction in landscape passability. Not even a moderate increase in their sinuosity at present (e.g. in Hustopeče and Hubenov territories and in the Železné hory PLA) can have a positive influence when their total real length was diminished to such an extent over the studied periods. Landscape has gradually become a means of production with maximum use of mechanization. In earlier history the overall diversity of agricultural land was much higher (many different small agricultural land plots of various utilization – arable land, pastures, permanent grasslands). In the course of intensification of agricultural production these small land plots divided by ridges and field roads were substituted with large blocks of arable land. The presence of field roads (with accompanying greenery) increases the overall diversity of the landscape and alternation of cultures. In this way, it may contribute to augmenting the edge effect of arable land vs. permanent grasslands. The field roads may represent one of the elements enhancing segmentation of the agricultural land. In such cases one may expect changes in the distribution of land use, and thus also potentially increased edge effect of select categories.

The analysis of the real length and sinuosity of road and railway network demonstrates a high increase in real length with very low sinuosity. Development of the road and railway network substantially contributes to an increase in the number of migration barriers. There arise barriers not only to migrating biota but also to humans for whom the landscape (and/or agricultural landscape) becomes a hardly accessible territory.

In the future it will be possible to use the analysis of these and other results for proposals of the optimization of landscape pattern and functional use of the territory.

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