LONG-TERM LAND USE DEVELOPMENT AND CHANGES IN STREAMS OF THE KYJOVKA, SVRATKA AND VELIČKA RIVER BASINS (CZECH REPUBLIC)

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Abstract

The analysis and assessment of land use changes and changes in streams in the upper river basins of the Kyjovka and the Svratka Rivers, and over the whole Velička river basin, is presented in this article. The changes were studied using sets of old topographic maps over five periods. A numerical analysis of the changes in the main stream length and the main stream sinuosity was carried out for all three rivers. The greatest changes were found in the Velička river basin.

Shrnutí

Dlouhodobý vývoj využití krajiny a změny na vodních tocích v povodích Kyjovky, Svratky a Veličky (Česká republika)

Autoři se v tomto článku zabývají analýzami a hodnocením změn využití krajiny a změn na vodních tocích v horních povodích Kyjovky a Svratky a v celém povodí Veličky. Změny byly studovány na základě sad starých topografických map z pěti časových období. U hlavních toků Kyjovky, Svratky a Veličky byly vyhodnoceny hydrografické změny a byla provedena numerická analýza změn délky hlavního toku a změn křivolakosti hlavního toku. Největší změny byly zjištěny v povodí Veličky.

Key words: *land use, river basin, river network, old maps, Kyjovka River, Svratka River, Velička River, hydrographic changes, Czech Republic*

1. Introduction

There are many different methods used to monitor long-term land use changes – such as the processing of statistical data sets, analysis of written historical documents and archival data, mapping of land use changes based on aerial and satellite photographs, or mapping based on topographic maps on a medium scale and on cadastral maps on a large scale. Medium-scale topographic maps enable the detection of the spatial distribution of land use changes from the second half of the 19th century. In the Czech Republic, a remarkable achievement represents the making public maps of the first, the second and the third Austrian Military Survey (Brůna et al., 2002). The advantage of these medium scale maps is their potential to study the changes of larger territories (Haase et al., 2007; Swetnam, 2007; Skaloš et al., 2010).

The changes in land use in the Czech Republic based on topographic maps were presented on territories delimited both from administrative and environmental views (Demek et al., 2008; Havlíček, 2008; Stránská and Havlíček, 2008; Demek et al., 2009; Havlíček et al., 2009; Mackovčin et al., 2009; Skokanová et al., 2009).

Individual land use processes, driving forces of the changes and an intensity of these changes are very often part of long-term land use development evaluation (Jeleček, 1995; Petek, 2002; Bender et al., 2005; Käyhkö and Skånes, 2006; Swetnam, 2007; Bičík et al., 2008; Bičík and Jeleček, 2009; Skokanová, 2009).

Land use changes are also often clearly detectable in the hydrography of river networks as well as in hydromorphology and/or hydrology of particular streams (e.g. Trimble, 2003; Allan, 2004; Gregory, 2006; Langhammer and Vilímek, 2008).

The study of the present state and changes on the streams or river patterns should therefore be, and in fact often is, an important counterpart to the analysis of land use changes (e.g. Hooke and Redmond, 1992;

Winterbottom, 2000; Jones et al., 2003; Demek et al., 2008). The changes on streams are analysed on different levels and in different time horizons (e.g. Downward et al., 1994; Hooke and Redmont, 1989; Kilianová, 2000; Skokanová, 2005; Žikulinas, 2008). The main information source for the study of processes on water streams are, similarly to the analysis of land use changes, sets of old maps (Hooke and Redmont, 1989; Kukla, 2007). Although hydrographic river pattern data gained from various sets of old maps are not quite comparable (because of the use of different scales, different visual display and/or approach of the authors of the maps providing a different planimetric accuracy), they can provide sufficient data for the analysis of hydrographic or hydromorphologic changes on streams (e.g. Downward et al., 1994; Matoušková, 2004; Langhammer and Vajskebr, 2007). Monitoring of land use development in selected basins of streams can be found, e.g. in studies made by foreign authors such as Trimbe (2003), Langhammer and Vilímek (2008), Benini et al. (2010) and Brázdil et al. (2011). These authors deal with correlations between land use changes and a rainfall-runoff, river pattern development, flood risks, etc. Long-term land use development in the basins of streams was studied in the Czech Republic by Havlíček et al. (2009), Brázdil et al. (2011).

2. Study area

Three medium sized basins of the Morava River were selected to monitor the development of land use and of a river pattern. To be precise, in the case of the Kyjovka River and the Svratka River the upper part of their basins to the first hydrologic station was monitored, and in the case of the Velička River it was the whole stream down to the town of Strážnice. The segment studied of the Svratka River ended by the village of Borovnice, and in the case of the Kyjovka River by the town of Kyjov.

Kyjovka River

The stream springs at an altitude of 512 m near the village of Staré Hutě on the southern slope of the Vlčák hill (561 m a.s.l.) in the Chřiby Higland, and flows into

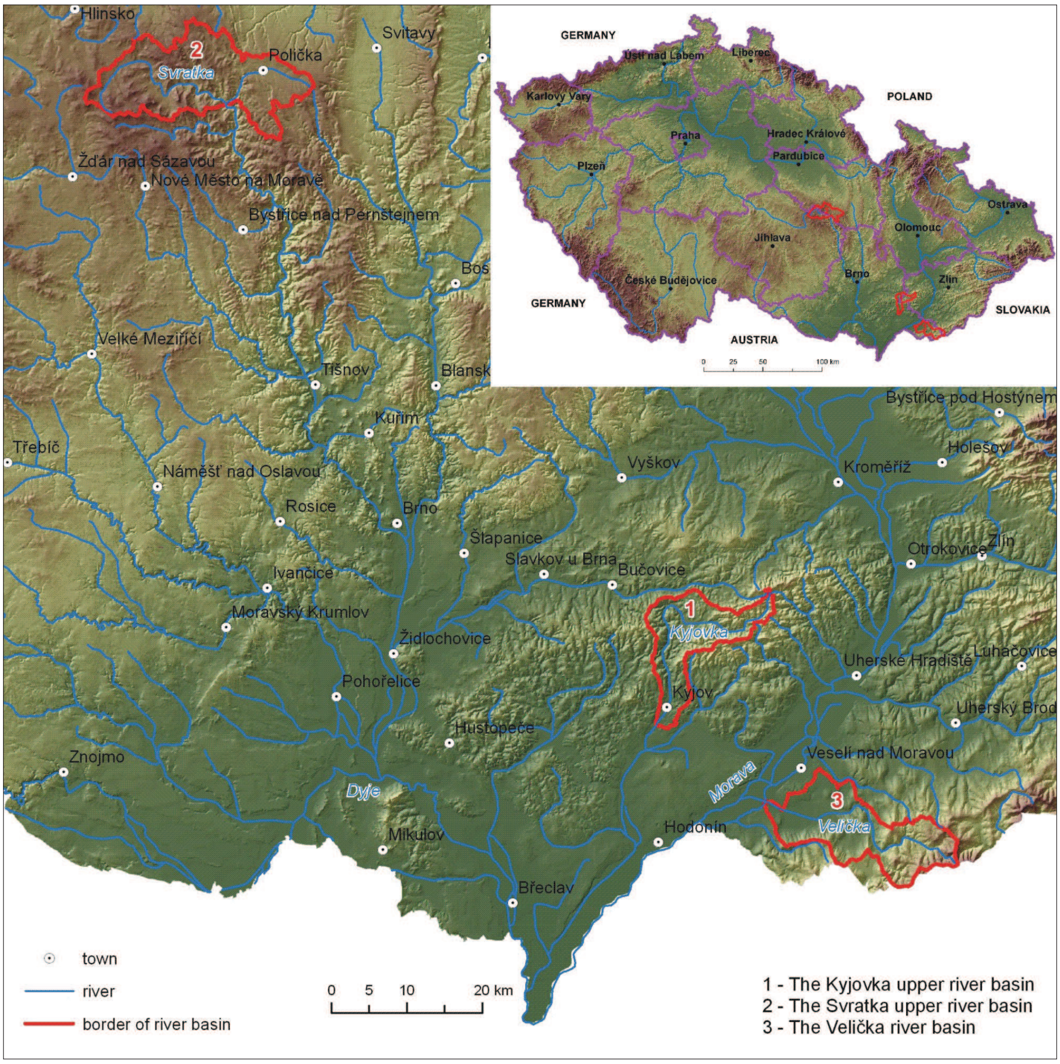

Fig. 1: Localisation of study area within the Czech Republic

the Dyje River near the town of Lanžhot at an altitude of 150 m. The total length of the stream is 86.7 km and its catchment has an area of about 665.8 km^2. The stream leaves the study area near a hydrometric profile in the town of Kyjov at an altitude of 181 m. The study area of the catchment is 124.8 km^2, the length of the segment of the stream studied is 40.7 km. The eastern part of the area belongs to the Chřiby Highland unit and the subunit Stupavská vrchovina Highland, and the northern and central parts to the unit Litenčická pahorkatina Hilly land and to the subunit Bučovická pahorkatina Hilly land. The western part lies in the unit Ždánický les Highland and the subunit Dambořická vrchovina Highland, and the southern part in the Kyjovská pahorkatina Hilly land and their subunits Mutěnická pahorkatina Hilly land and Věteřovská vrchovina Highland. A small part of southern hook belongs to the unit Dolnomoravský úval Graben and to the subunit Dyjsko-moravská pahorkatina Hilly land (Demek and Mackovčin, 2006).

Svratka River

The river rises in the Bohemian-Moravian Highland below the Žákova hora Hill (810 m a.s.l.) at an altitude of 771.9 m, and flows into the Dyje River in an area of the Nové Mlýny Dam at an altitude of 162.9 m. The total length of the stream is 168.5 km and the catchment area is 7,115.9 km^2. The river leaves the study area at the hydrometric profile at the village of Borovnice at an altitude of 515 m. The study area of the catchment is 239.3 km^2, and the length of the segment studied is 37.1 km. The largest area of the upper part of the basin belongs to the geomorphological unit of the Hornosvratecká vrchovina Highland and to its subunits of the Žďárské vrchy Highland and the Nedvědická vrchovina Highland. A very small part of the unit Železné hory Mountains and its subunit of the Sečská vrchovina Highland belongs to a study segment of the catchment to the west, and to the east is the unit Svitavská pahorkatina Hilly land and its subunits the Loučenská tabule Plateau and the Českotřebovská vrchovina Higland (Demek and Mackovčin, 2006).

Velička River

The river rises on the western slope of Velká Javořina Hill (970 m a.s.l.) at an altitude of 856 m, and flows into the Morava River near the town of Strážnice at an altitude of 169 m. The study area of the catchment is 176.9 km^2 and the study length of the Velička River is 36.0 km. The catchment belongs predominantly to the geomorphological unit of the White Carpathians and its subunits the Javořinská hornatina Mountains and the Žalostinská vrchovina Highland. Its northwestern part belongs to the unit Vizovická vrchovina Highland and its subunit of Hlucká pahorkatina Hilly land. Only a small part on the west falls into the unit Dolnomoravský úval Graben and its subunit of the Dyjsko-moravská niva Floodplain (Demek and Mackovčin, 2006).

3. Methods

3.1 Topographic maps

Land use changes have been evaluated on the basis of old and contemporary topographic maps using geographic information systems. The sources for the analysis are the following sets of maps:

- 2nd Austrian Military Survey on a scale of 1:28 800 (1836–1841) – source: Austrian State Archive / Military Archive, Vienna; Geoinformatics Laboratory, J. E. Purkyně University, Ústí nad Labem,
- 3rd Austrian Military Survey on a scale of 1:25 000 (1876) – source: Map Collection, Faculty of Science, Charles University in Prague; Silva Tarouca Research Institute for Landscape and Ornamental Gardening, Pub. Res. Inst.,
- Czechoslovak military topographic maps on a scale of 1:25 000 (1953–1955) – source: Department of Military Geography and Meteorology, University of Defence; Brno, Silva Tarouca Research Institute for Landscape and Ornamental Gardening, Pub. Res. Inst.,
- Czechoslovak military topographic maps on a scale of 1:25 000 (1991) – source: Military Geography and Hydrometeorology Office, Dobruška; Silva Tarouca Research Institute for Landscape and Ornamental Gardening, Pub. Res. Inst.,
- Czech topographic base maps on a scale of 1:10 000 (2002–2006) – source: Czech Office for Surveying, Mapping and Cadastre, Prague.

3.2 Data processing

A total of 9 basic land use categories was monitored: 1 – arable land, 2 – permanent grassland, 3 – garden and orchard, 4 – vineyard and hop-field, 5 – forest, 6 – water area, 7 – built-up area, 8 – recreational area and 0 – other area (Mackovčin, 2009; Skokanová, 2009).

Base maps of land use have been created in an ArcGIS 9.x software environment in the S-JTSK coordinate system. All the comparative maps were generated through overlaying (by use of a tool called Union) two maps of consequential periods. Other processes were used to create two synthetic base maps: (1) Number of changes in land use and (2) Stable plots. The number of changes in land use ranged from 0 to 4, due to use of five sets of maps.

As a further indicator completing the characteristics of land use changes the total intensity of changes in land use was chosen, in a similar way as used by Olah et al. (2006), Skokanová (2009) and Havlíček et al. (2009). Nine basic land use categories were grouped into five according to their intensity of landscape exploitation and were assigned coefficients: 5 – built-up area and other area (of an anthropogenic origin), 4 – arable land, 3 – orchard and vineyard, recreational area, 2 – water area and permanent grassland, 1 – forest.

By comparing land use changes between two adjacent time steps, five types of processes were distinguished: afforestation – changes of land use categories into forest; grassing over – changes of land use categories into permanent grassland; agricultural intensification – land use categories change into arable land, orchard or vineyard and hop-field; urbanization and other anthropogenic processes – changes of land use categories into built-up area, recreational area or other area and stable areas – there has been no change during the two time steps (Skokanová, 2009).

Land use development processes and their driving forces were in a similar way evaluated by other authors (Jeleček, 1995; Petek, 2002; Bender et al., 2005; Käyhkö and Skånes, 2006; Bičík et al., 2008; Bičík and Jeleček, 2009).

The total intensity of changes in land use was calculated as a grand total of the difference in intensity between adjacent mapped periods: $I = (I_{1876} - I_{1836}) + (I_{1953} - I_{1876}) + (I_{1991} = I_{1953}) + (I_{2006} - I_{1991})$. The outcome (integral numbers only) ranged from −4 to 4. Where the number 0 represents balanced landscape exploitation, i.e. plots exist in the area with stable use (plots without change in categories of use) and/or plots on which former intensification of land use is balanced by the opposite extensification. In this article, the total intensity of changes in land use are presented in maps and tables in the aggregated form as balanced land use plots ($I = 0$), plots with processes of intensification ($I > 0$) and plots with processes of extensification ($I < 0$).

The analysed streams (Figs 2 to 4) were vectorised over individual map sets with respect to their current course (i.e. with respect to the course of streams in layers A01 and/or A03 of the Digital Water Database from 2006), in order to ensure a link between the changes over the whole period, and in the case of older maps also to distinguish a particular stream from other linear elements in a floodplain. In the case of more recent map sets (from the 1990s), modified, already existing vector data were used such as DMU25 and ZABAGED. For each numerically analysed stream the total length of the stream was calculated as well as the direct distance between initial and end nodal points. There two values were used to calculate the stream sinuosity rate (Lehotský and Grešková, 2004). Changes in the length and the sinuosity of the main stream over the period from 1836 to the present are illustrated in Figs 1 to 3, and a survey of total changes for that period is presented in Tab. 7.

4. Results

4.1 Land use development

Kyjovka River. Over the period of 1836–1841 the largest share of the area in the Kyjovka upper river basin was covered by forests (43.54% of total area, see Tab. 1) and a slightly smaller share was represented by arable land (40.24% of total area). The forests were situated mainly at higher altitudes, whereas the arable land was predominantly at lower altitudes. Over the next two periods, the share of arable land increased and became larger than the share of forest. The greater share of forest returned again in the periods 1991 and 2002–2006. The biggest changes

Land use category	1836–1841	1876	1953–1955	1991	2002–2006
Arable land	40.24	46.19	49.11	39.15	35.79
Permanent grassland	11.53	6.71	0.95	3.51	6.29
Garden and orchard	0.09	0.03	0.23	1.43	1.40
Vineyard and hop-field	2.15	1.22	0.78	1.98	1.19
Forest	43.54	43.29	44.20	45.60	46.54
Water area	0.03	0.00	0.00	0.34	0.33
Built-up area	2.41	2.56	4.71	7.37	7.71
Recreational area	0.00	0.00	0.00	0.58	0.65
Other area	0.01	0.00	0.02	0.04	0.10
Total	*100.00*	*100.00*	*100.00*	*100.00*	*100.00*

Tab. 1: Land use development in the Kyjovka upper river basin 1836–2006 (proportion in %)

were connected with permanent grassland, its share reached a maximum (11.53% of total area) in the period 1836–1841 and a minimum (0.95% of total area) in 1953–1955. The process of partial permanent grassland regeneration is evident over two successive periods; the grassland re-establishment was primarily concentrated in the highlands. The share of built-up area grew by 3.2 times. The share of vineyards (there were never hop fields in study area) was the highest in the period 1836–1841 and reached its minimum in 1953–1955. The share of orchards increased in last two periods and reached a similar size as the share of vineyards. In the same period, there was a growth in share of recreational and water areas connected with the construction of the Koryčany water reservoir and a development of infrastructure required for the favourite Czech pastimes (keeping weekend houses, gardening, water sports, fishing, etc.).

Between 1836–1841 and 1876 agricultural intensification prevailed among the main processes of land use changes in the Kyjovka upper river basin, there were conversions of the area of permanent grassland, forest and vineyard into the area of arable land in this basin (4.37%, 2.08 and 1.19% of total area). The notable process was also afforestation – namely the conversions of arable land and permanent grassland into forest. Between 1876 and 1953–1955 agricultural intensification prevailed again, represented by the conversions of meadows and pastures into arable land (5.06% of total area), also afforestation occurred in some parts of the area and urbanization increased. The considerable changes in land use occurred between 1953–1955 and 1991. There can be observed an increasing relevance of grassing over and afforestation in this period. High relevance retained urbanization and other anthropogenic processes. As far as the latest period between 1991 and 2002–2006 concerns grassing over dominated, afforestation and urbanization were present only in a small extent compared to grassing over.

Svratka River. In all five periods, the biggest share of the area in the Svratka upper river basin was taken by forests (see Tab. 2). Vast expanses of the forests are concentrated mainly at higher altitudes. The second most frequent land use category, arable land, is situated mainly at lower altitudes close to built-up areas. The share of arable land reached its maximum in 1876 (40.91%), and the minimum was in 2002–2006 (25.72%). The third most frequent land use category, permanent grassland, is concentrated primarily in the surrounding areas of streams and forests, or in the hard to reach terrain at lower altitudes. The share of built-up areas increased over the whole study period by 1.9 times, mainly due to the spreading of small villages in proximity to streams. The share of other categories of land use was very low.

In the Svratka upper river basin between 1836–1841 and 1876 definitely prevailed agricultural intensification represented mainly by the conversions of permanent grassland and forest into arable land (7.14% and 2.44% of total area). At the same time the opposite processes of grassing over and afforestation occurred in some parts of the basin. Between 1876 and 1953–1955 grassing over (the conversion of arable land on 5.55% of total area) and afforestation prevailed, also urbanization increased. The process of grassing over grew stronger also among 1953–1955 and 1991 (by the conversion of arable land on 6.56% of total area) followed surprisingly by the opposite process of the conversion of permanent grassland into arable land (4.95%). There were also found significant shares of the processes of afforestation and urbanization in this

Land use category	1836–1841	1876	1953–1955	1991	2002–2006
Arable land	34.57	40.91	34.94	31.63	25.72
Permanent grassland	18.23	13.62	14.00	14.89	19.95
Garden and orchard	0.01	0.01	0.03	0.06	0.07
Vineyard and hop-field	0.00	0.00	0.00	0.01	0.00
Forest	44.24	42.95	46.61	47.69	48.56
Water area	0.18	0.08	0.09	0.16	0.24
Built-up area	2.76	2.43	4.26	5.18	5.27
Recreational area	0.00	0.00	0.05	0.33	0.15
Other area	0.00	0.00	0.02	0.05	0.04
Total	*100.00*	*100.00*	*100.00*	*100.00*	*100.00*

Tab. 2: Land use development in the Svratka upper river basin 1836–2006 (proportion in %)

period. Between 1991 and 2002–2006 definitely prevailed grassing over (by the conversion of arable land on 7.00% of total area). The processes of agricultural intensification and afforestation occurred in a substantially smaller part of the basin.

Velička River. In all five periods the biggest share of area in the Velička river basin was occupied by arable land, with the lowest rate in the period 1836–1841 and the highest one in 1953–1955 (see Tab. 3). Arable land was concentrated at lower altitudes. The second biggest rate over the period 1836–1841 belonged to permanent grassland. However, its rate gradually declined, so this category became the third most common. Areas of permanent grassland were situated mainly at higher altitudes (at the foot of the White Carpathians) and also partly at lower altitudes in the proximity of streams. The share of forests grew steadily over the whole study period, and from 1876 this land use category gained the second ranking. The largest expanse of forest was situated in the White Carpathians. Built-up area also grew steadily, the rate of which in study period increased by 2.5 times. The rate development of vineyards was mainly influenced by the decline of viniculture in southern Moravia at the beginning of the 20th century. The minimum rate was reached in 1953–1955, similarly to the land use category of orchard.

In the Velička River basin in the period between 1836–1841 and 1876 absolutely prevailed agricultural intensification, the conversion of permanent grassland into arable land occurred on 9.08% of total area. It was the most distinctive change in land use development in all three basins and across all study periods at the same time. The process of agricultural intensification also dominated between 1876 and 1953–1955, nevertheless the processes of afforestation, grassing over and urbanization were represented by significant shares at the same time. A change in the main processes occurred between 1953–1955 and 1991. The process of grassing over for the first time prevailed over agricultural intensification. The conversion of arable land into permanent grassland reached 4.05% of total area, the opposite process 2.68%. The processes of urbanization and afforestation were also significant in this period. The share of grassing over slightly increased between 1991 and 2002–2006 (up to 5.87%). followed by processes of afforestation and agricultural intensification.

4.2 Number of changes in land use and stable plots within the study area

Kyjovka River. There was at least one change in land use category for 31.71% of the total area in the Kyjovka upper river basin during the period 1836–2006. Only one change occurred in 17.88% of the total area, two changes over 10.33%, three changes over 3.02% and four changes over 0.48%. The majority of the changes were observed within built-up area (due to its gradual spread) but also in the proximity of streams (due to the disappearance of permanent grassland) and at borders of former fields (due to reconversion of permanent grassland to arable land and vice versa).

68.29% of the total area was stable plots of which vast expanses of forest represents 4,938 ha (i.e. 39.56% of the area) and arable land 3,338 ha (i.e. 26.75% of the area) situated mainly at lower altitudes. Stable plots of permanent grassland make up only 4 ha (i.e. 0.04% of the total area) which means a negligible extent in comparison to the Svratka R. and the Velička R. basins. Also, areas of vineyards went through dramatic changes, stable plots of vineyards make up only 2 ha (0.02% of the total area). Stable plots are also represented by historic districts of towns and villages (239 ha of built-up areas, i.e. 1.92% of the total area).

Land use category	1836–1841	1876	1953–1955	1991	2002–2006
Arable land	44.19	52.81	57.77	51.64	46.19
Permanent grassland	28.98	20.05	14.16	13.73	15.65
Garden and orchard	0.68	0.70	0.21	1.05	1.80
Vineyard and hop-field	2.38	1.92	0.79	2.27	2.28
Forest	21.56	22.16	23.45	25.65	28.03
Water area	0.00	0.00	0.00	0.01	0.01
Built-up area	2.19	2.34	3.57	5.53	5.58
Recreational area	0.00	0.00	0.02	0.10	0.11
Other area	0.02	0.02	0.03	0.02	0.07
Total	*100.00*	*100.00*	*100.00*	*100.00*	*100.00*

Tab. 3: Land use development in the Velička River basin 1836–2006 (proportion in %)

Svratka River. There was at least one change in land use category over 38.70 % of the total area in the Svratka upper river basin between the years 1836–2006. Only one change occurred in 18.56%, two changes over 13.72%, three changes over 5.13% and four changes over 1.30% of the total area. The majority of the changes occurred within a built-up area (due to its gradual sprawl), then to plots in the vicinity of forests and at borders of former fields (as a result of the conversion of balks, meadows, pastures and forests into arable land), but also in the category of arable land converted into permanent grassland or forest.

61.30% of the total area are stable plots, of which mainly vast expanses of forests cover 9,517 ha (i.e. 39.77% of the area) primarily at higher altitudes. Stable plots also represent 4,077 ha (i.e. 17.04%) of arable land at lower altitudes. In the category of permanent grassland, stable plots make up 783 ha (i.e. 3.27%). There is also 283 ha (i.e. 1.19%) of built-up area represented by historic districts of towns and villages among the stable plots. Without any change over the whole period 7 ha of water area also remained (i.e. 0.03%).

Velička River. In the period 1836–2006 there was at least one change in land use category on 42.60% of the total area in the Velička River basin. Only one change occurred on 26.13%, two changes on 1.42%, three changes on 4.32% and four changes on 0.70% of the total area. The majority of the changes occurred within built-up areas (due to their gradual sprawl) but also on the slopes of the White Carpathians (as a result of conversions of meadows and pastures into arable land and also due to timber felling or afforestation) and at the borders of former fields (at first due to the enlargement of arable land and afterwards due to its reconversion into permanent grassland).

57.40 % of the total area remained as stable plots during the whole period 1836–2006, which were mainly represented by vast areas of arable land (5,430 ha. i.e. 30.71% of the total area) situated primarily at lower altitudes. Stable use is also characteristic of the area covered by expanses of forest at the higher altitudes of the White Carpathians (3,391 ha. i.e. 19.18% of the total area). The area of permanent grassland made up 959 ha on all five sets of maps, which represents 5.42% of the total area and was primarily situated in the area of the White Carpathians. Historic districts of towns and villages included in the land use category of built-up area also represent stable plots (319 ha, i.e. 1.82% of the total area). The only area of vineyards present is located between the villages Louka and Blatnice pod Svatým Antonínkem (54 ha, i.e. 0.31% of the total area).

4.3 Total intensity of change in land use

Kyjovka River. In the Kyjovka upper river basin the balanced use of landscape also prevailed (75.61% of the total area, see Tab. 4 and Fig. 2). Over the whole period, intensification slightly prevailed over extensification (13.32% in contrast to 11.06% of the total area). Stable use predominated most of the geomorphological subunits, in some case interventions leading to intensification were compensated for by interventions leading to extensification. Distinctive predomination of processes of intensification occurred in the Bučovická pahorkatina Hilly land. In the Mutěnická pahorkatina Hilly land and the Věteřovská vrchovina Highland, in contrast to the Dambořická vrchovina Highland (situated at higher altitudes) intensification versus extensification was more balanced. On the other hand, prevailing extensification occurred in a spring area of the Kyjovka River in the Stupavská vrchovina Highland. The Dyjsko-moravská pahorkatina Hilly land forms only a very small part of the study area (0.78% of the total area), therefore an objective assessment of the total intensity of change in land use is not possible.

Svratka River. Unlike both the Velička R. and the Kyjovka R. basins there was a prevailing stable land use in the Svratka upper river basin (73.20%

Geomorphological subunit	Balanced	Intensification	Extensification
the Dambořická vrchovina Highland	84.75	9.18	6.07
the Bučovická pahorkatina Hilly land	75.14	16.87	7.99
the Stupavská vrchovina Highland	76.90	5.67	17.43
the Mutěnická pahorkatina Hilly land	65.61	25.02	9.37
the Věteřovská vrchovina Highland	76.99	18.66	4.35
the Dyjsko-moravská pahorkatina Hilly land	27.67	72.33	0.00
River basin total	*75.61*	*13.33*	*11.06*

Tab. 4: Total intensity rate of land use change in geomorphological subunits of the Kyjovka upper river basin 1836–2006 (proportion in %)

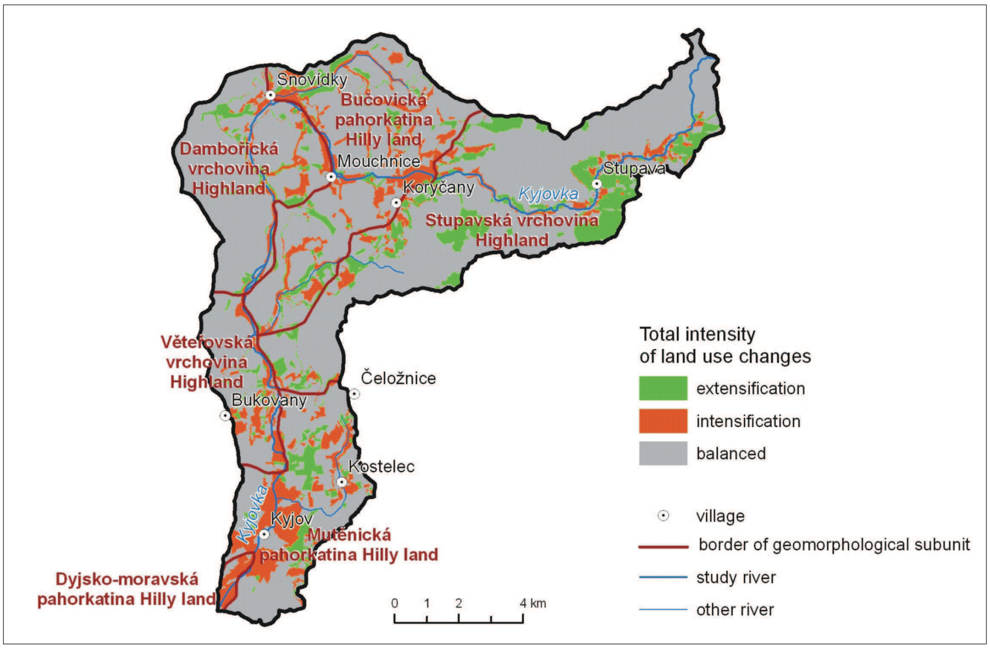

Fig. 2: Total intensity of land use change in the Kyjovka upper river basin (1836–2006)

of the total area, see Tab. 5 and Fig. 3). and over the whole period extensification prevailed over intensification (16.79% as opposed to 10.01% of the total area). Distinctive predomination of processes of extensification occurred in the Nedvědická vrchovina Highland and in the Žďárské vrchy Highland. There was obvious afforestation and part grassing over of landscape here, whereas in areas of the Loučenská tabule Plateau. the Českotřebovská vrchovina Higland and the Sečská vrchovina Highland intensification prevailed, presumably because of a higher rate of arable land in the area.

Velička River. The balanced use of landscape prevailed in the Velička River basin, founded on 65.55% of the total area (see Tab. 6 and Fig. 4). The area was characterised by stable and balanced use of land (i. e. interventions leading to intensification were compensated by opposing ones). Over the whole period, intensification slightly prevailed over extensification (18.33% as opposed to 16.13% of the total area). Intensification distinctively predominated in most of geomorphological subunits. namely in the Dyjsko-moravská niva Floodplain at the lowest altitude. Only in the case of the Javořinská hornatina Mountains did extensification prevail.

4.4 Changes on streams

Kyjovka River. The analysed stream (Fig. 2) begins at its spring and ends at the confluence with the Sobůlský potok Brook. The greater part of the Kyjovka River floodplain is narrow and only at sites of former water reservoirs and towards the end of the floodplain does it get broader. Considerable parts of the stream were mainly influenced by the construction of a number of relatively large water reservoirs before 1836 situated in broader segments of its floodplain (resulting in straightening and branching of the stream especially at sites of former water reservoirs). Subsequently the processes of straightening are not too distinctive and both a reduction of the stream length and changes in the main stream sinuosity are negligible (see Fig. 5 and Tab. 7).

Geomorphological subunit	Balanced	Intensification	Extensification
the Loučenská tabule Plateau	73.62	14.73	11.65
the Českotřebovská vrchovina Highland	90.44	7.24	2.32
the Nedvědická vrchovina Highland	57.87	14.57	27.56
the Žďárské vrchy Highland	76.18	7.88	15.94
the Sečská vrchovina Highland	66.93	20.54	12.53
River basin total	*73.20*	*10.01*	*16.79*

Tab. 5: Total intensity rate of land use change in geomorphological subunits of the Svratka upper river basin 1836–2006 (proportion in %)

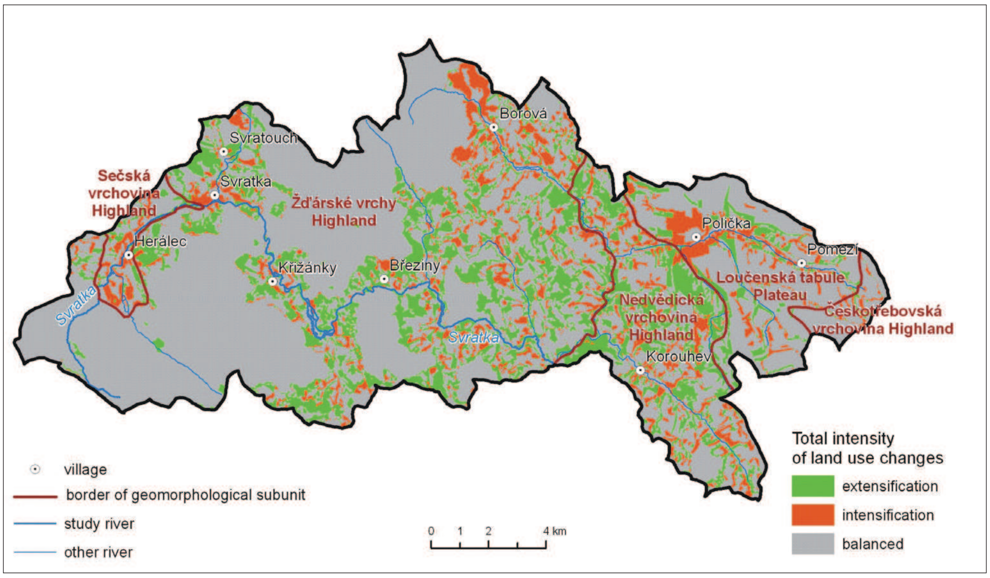

Fig. 3: Total intensity of land use change in the Svratka upper river basin (1836–2006)

Geomorphological subunit	Balanced	Intensification	Extensification
the Hlucká pahorkatina Hilly land	63.79	28.13	8.08
the Žalostinská vrchovina Highland	61.24	23.03	15.73
the Javořinská hornatina Mountains	70.07	3.97	25.96
the Dyjsko-moravská niva Floodplain	57.87	38.20	3.93
River basin total	*65.55*	*18.33*	*16.12*

Tab. 6: Total intensity rate of land use change in geomorphological subunits of the Velička River basin 1836–2006 (proportion in %)

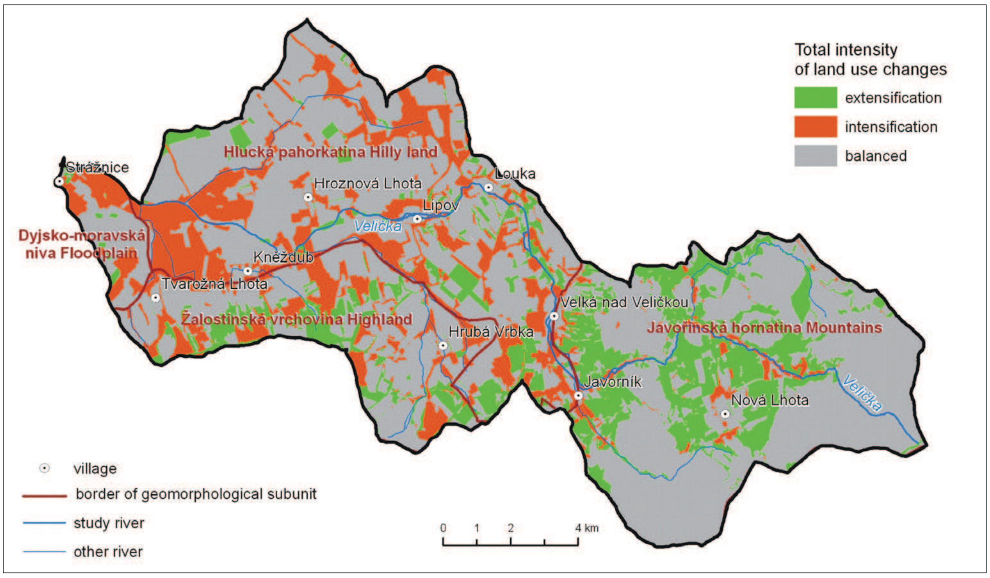

Fig. 4: Total intensity of land use change in the Velička River basin (1836–2006)

Svratka River. The analysed stream (Fig. 3) begins at its spring and ends at its confluence with the Bílý potok Brook (situated between the villages of Lačnov and Borovnice). The Svratka River floodplain is rather narrow but in some segments it becomes more or less broader. Changes on the stream due to regulation of its course and the construction of water reservoirs are negligible. Over the whole period meanders in most cases still run their course. There are slight differences in the courses of spring segments on individual sets of maps probably because of the different accuracy of each set (due to the different approach of the authors of the maps) which together with the larger scale of the latest set of maps (2002–2006) are obviously major causes of changes in main stream sinuosity (see Fig. 6 and Tab. 7).

Velička River. The analysed stream (Fig. 4) begins at its spring and ends at the confluence with the Morava River (or more precisely by its mouth with the current Baťa kanál navigation channel. i.e. former lateral branch of the Morava River). The first half of the Velička River floodplain is mostly narrow, the second half becomes slightly broader. The stream was regulated (mainly by straightening, sporadically by a change of course – replacing to an other stream bed) in broader segments of its floodplain. No water reservoirs have been constructed on the stream, and no obvious remains of older ones have been found. Stream regulations were most probably connected with the agricultural use of the landscape, flood control, eventually with road construction (at narrow parts of its floodplain). The main stream length and the main stream sinuosity were only slightly reduced (see Fig. 7 and Tab. 7).

5. Discussion

5.1 Land use development

In the study area of the basins of the Svratka River and the Kyjovka River the biggest share of the area was covered by forests during most of the period assessed, and the proportion gradually increased and varied from 43 to 48%. In the Velička River basin the biggest share of the area was represented by arable land, which varied between 44 and 58%. The third biggest rate belonged to permanent grassland, however there were different development trends in individual basins. In all three basins the area of permanent grassland gradually declined between 1876 and 1953–1955. In the case of the Svratka River the decrease was relatively moderate, and the rate gradually returned to its original value of the period 1836–1841. In the case of the Velička River, the rate of permanent grassland dropped to the middle of the 1950s to about a half of its value from the period 1836–1841. The most visible fall of the area of permanent grassland was noted in the Kyjovka upper river basin, from about 11% (1836–1841) to less than 1% (1953–1955). However, subsequent return to more extensive agriculture helped re-establish some of the meadows and pastures.

For all three study areas there was a characteristic increase in the share of built-up area. The rate of vineyards was the biggest in both the Velička and the Kyjovka river basin during 1836–1841, the decline

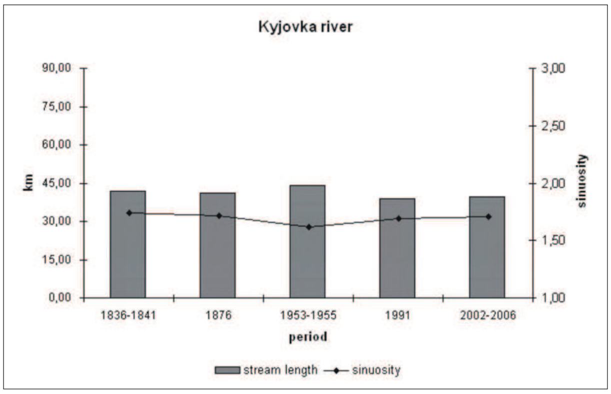

Fig. 5: Kyjovka River – changes in the length of the main stream; changes in the main stream sinuosity

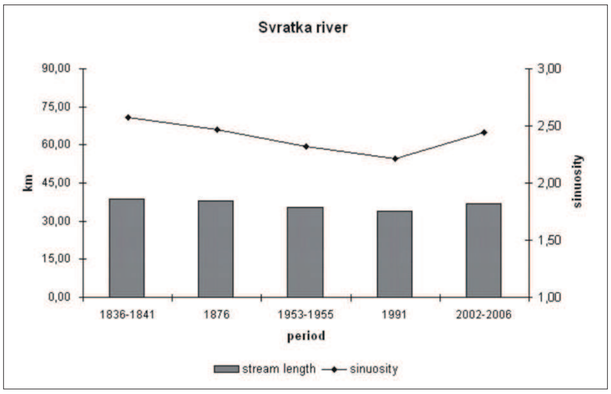

Fig. 6: Svratka River – changes in the length of the main stream; changes in the main stream sinuosity

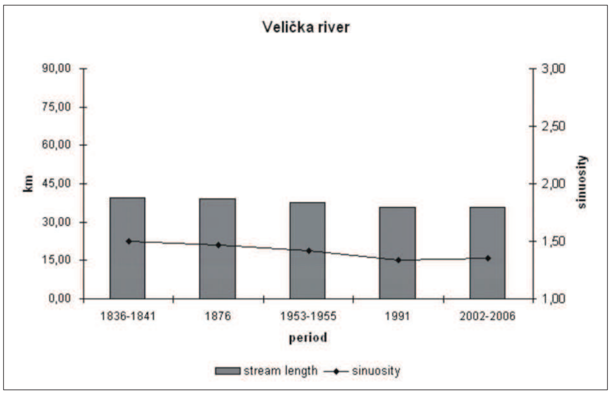

Fig. 7: Velička River – changes in the length of the main stream; changes in the main stream sinuosity

River	Main stream length change		Sinusoity change
	km	%	
Velička	−3.70	−9.33	−0.15
Kyjovka	−2.23	−5.32	−0.03
Svratka	−1.91	−4.91	−0.13

Tab. 7: Total change of the main stream length and the main stream sinuosity in analysed segments of the Velička River, the Kyjovka River and the Svratka River (1836–2006)

of viniculture in southern Moravia at the start of the 20th century was manifested by a reduction of the area of vineyards during 1953–1955. In the Velička River basin, the area of vineyards in 2002–2006 approximated original values from the mid 19th century, in comparison to the Kyjovka upper river basin, where the value remained slightly lower. The rate of orchards gradually grew in all three basins. The share of water area gradually fell at first, but later there was greater or smaller growth caused by the redevelopment or construction of new water reservoirs. The processes and changes described above correspond to findings of similar studies within the south Moravia region, e.g. of the Dolnomoravský úval Graben and the Dyjskosvratecký úval Graben (Demek et al., 2009, where the authors refer to a clear decline of the areas of permanent grassland, similarly to the lowest altitudes of the Velička River basin), in the Litava River basin (Havlíček et al., 2009) or in the district of Hodonín (Havlíček, 2008).

The basic findings about land use development in all three study basins correspond with the long-term land use development as described by the LUCC UK Prague database processed for the whole territory of the Czech Republic (Bičík et al., 2008). The consensus was found primarily in the gradual growth of the share of forest, in the significant decrease of the share of permanent grassland in the second half of the 20th century and its partial reestablishment in the present. For the whole territory of the Czech Republic and/or for smaller regional studies within its territory is characteristic the highest share of arable land at the end of the 19th century or in the middle of the 20th century and its gradual decrease till the present (Bičík et al., 2008; Demek et al., 2009; Skokanová, 2009). The consensus was also found in the gradual growth of built-up area which has been proved in all three studied basins. There was a significant decrease of the area of permanent grassland together with a continuous increase of the area of arable land till the recent period in the study area of the characteristic agricultural landscape of the Nové Dvory – Kačina (Skaloš et al., 2010). The similar pattern of land use development was observed only in the lowlands and the hilly lands of the Velička River basin.

All three basins showed some identical processes of land use development. During the comparative periods 1836 × 1876 and 1876 × 1953 the process of agricultural intensification prevailed, in contrast to the periods 1953 × 1991 and 1991 × 2006 when grassing over prevailed mainly. Agricultural intensification in the second half of the 19th century can be explained by these driving forces: the abolition of serfdom, the climax of the agricultural revolution and in case of the Velička River also by the differential rent I (Jeleček, 1995; Bičík and Jeleček, 2009). Agricultural intensification in the second half of the 20th century related to the driving forces: collectivization and transformation of private plots into vast cooperative fields (Jeleček, 1995; Bičík and Jeleček, 2009). The grassing over, which was in progress till the first half of the 20th century, was driven by the impact of the differential rent II, from the beginning of the second half of the 20th century the subsidies for the cooperative and state farms placed in the substandard production conditions became significant in this process. After the year 1990 main driving forces of grassing over became the subsidies for LFA (less favoured areas) and the support of various environmental programmes (Jeleček, 1995; Bičík and Jeleček, 2009).

The process of urbanization gradually became more significant especially in lowlands and floodplains. The same findings were presented in other papers from the Czech Republic (Bičík et al., 2008; Demek et al., 2009; Havlíček et al., 2009; Skokanová, 2009). The intensity of the process of afforestation was the same across all study periods. From an aspect of the spatial distribution was afforestation concentrated mainly within the spring areas of the study basins. Similar results were presented in the paper Bičík et al. (2008). Land use development was rather different on the upper stream of the Svratka River basin where the processes of grassing over and afforestation prevailed in most of the periods. This can be explained by predominance of highlands in this basin. The processes of grassing over and afforestation were highly significant also in other mountains and highlands of Central Europe (Petek, 2002; Bender et al., 2005; Olah et al., 2006). In the lowlands and the hilly lands of Central Europe the processes of agricultural intensification and urbanization prevailed (Haase, 2007).

5.2 Number of changes and total intensity of change in land use and stable plots within studied areas

The greatest number of land use changes occurred in the Velička River basin (42.6%). This can be explained mainly by the higher rate of the area having agricultural use at lower altitudes of its basin, and also by land use change in hilly lands and in the highlands in the area of the White Carpathians and their foothills. Changes in the Svratka upper river basin embodied 38.7% of its area, the changes were represented mainly by a growing rate of forests, the disappearance and re-establishment of permanent grassland, and a gradual spread of built-up area. The lowest number of land use changes was found in the Kyjovka upper river basin (31.7%), caused by disappearance and re-establishment of permanent grassland and gradual sprawl of built-up area. Similar values over comparably long periods are described by Demek et al. (2009) in the Dyjskosvratecký úval Graben (39.0% of the changed area) and in the Dolnomoravský úval Graben (52.0% of the changed area), the area of Dolnomoravský úval Graben is described as very changed with unstable use. Havlíček et al. (2009) refer to the Litava River basin with 28.3% of area changed, which is an even lower value than the one found in the Kyjovka upper river basin.

By comparing the stable use areas in all three study basins it was found that the highest rate of forest occurs in the upper basins of the Svratka River and the Kyjovka River (about 40% of its area). The highest rate of stable use area in the arable land category is found in the Velička River basin. Similar findings (regarding the rate of stable use area and total intensity of change in land use) are also published for the mainly agricultural area of the Dolnomoravský úval Graben (Demek et al., 2009), the Litava River basin (Havlíček et al., 2009) and the Hodonín district (Havlíček, 2008). The stable area of permanent grassland at least partly remained in the Svratka upper river basin (3.3% of the area) and in the Velička River basin (5.4% of the area), its rate in the Kyjovka upper river basin is negligible (less than 0.1% of the area). Considerable reduction in the area of permanent grassland and minimum preserved area in the Kyjov region is described by Havlíček (2008).

5.3 Changes on streams

Anthropogenically conditioned hydrographic changes are present on the absolute majority of Czech streams (Matoušková, 2004; Just et al., 2005; Kukla, 2007; Demek et al., 2008; Langhammer and Vilímek, 2008; Chrudina, 2009; Chrudina, 2010a, b; and others), mainly on their central and lower parts.

Hydrographic changes on streams made by man from the beginning of the industrial revolution in the second half of the 18th century until now were studied in detail, e.g. in the Litava R. (Chrudina, 2009) and the Jevišovka River basins (Chrudina, 2010a). On the basis of the study of 5 elementary types by man conditioned processes which can exist in streams, the following was defined (Chrudina, 2010b): (1) foundation and cancellation of water reservoirs, (2) extinction of side channels (branches), (3) straightening of stream, (4) change in position of the stream mouth and (5) changes of headwaters. The above mentioned processes are also present in different proportions in the assessed segments of the Kyjovka, Svratka and Velička Rivers. The upper part of the Kyjovka River was mainly influenced by the foundation and cancellation of water reservoirs constructed at the broader parts of its floodplain. In the case of the Svratka River (on the first part of its upper segment) the same processes occurred, however in a much smaller extent. Similarly, in a small extent this also resulted in the straightening of the stream. In contrast, in case of the Velička River (where nearly the whole stream was analysed) there were no foundations or cancellations of water reservoirs, and the straightening of stream prevailed.

Langhammer and Vajskebr (2007) studied in connection with floods spatial (hydrographic) changes in the Otava River basin from the second half of the 19th century till the end of the 20th century. The biggest shortenings of the stream the authors found on the midstream and mainly downstream areas and on smaller streams in a mainly agricultural landscape. These findings correspond with the relatively small extent of shortening of all three studied streams. In the Kyjovka R. and namely in the Svratka R., their upstream areas were studied where the shortening during the whole study period was insignificant (although the small shortening of the Kyjovka River can be explained by the fact, that the stream was previously influenced by the construction of its water reservoirs). In contrast to more significant shortening of the Velička River where the whole stream was analysed including its downstream running through wide and rather intensively used floodplain.

All three analysed streams (their study length was approx. the same) vary significantly from an aspect of anthropogenically conditioned hydrographic changes. This can be explained primarily by differences in their floodplains (from other causes we can also pinpoint a connection with altitude, especially in the case of the Svratka River which is placed at the highest altitude of the streams studied and its range of anthropogenic changes was the lowest). The consequent impact of man made changes on the main stream length and sinuosity was the greatest in the case of the Velička River (see Tab. 7 and Figs. 5 to 7); the results of the analysis of the Svratka River have probably been distorted by a different range of cartographic generalisations of individual sets of maps.

The relation between the changes on streams and the land use development is complex and multi-level. It covers many aspects from spatial (hydrographic) changes of a river network through morphologic changes of stream beds, the processes of erosion and sedimentation to an impact of these changes on the biota of streams and water reservoirs, (e.g. Trimble, 2003; Allan, 2004; Gregory, 2006). Old maps provide primarily spatial (hydrographic) information about changes on river patterns and/or river streams (Downward et al., 1994; Matoušková, 2008 and others). These changes, as mentioned by Trimble (2003), Just et al. (2005) or Langhammer and Vilímek (2008), are mainly related to flood control (especially in the vicinity of built-up areas) and to changes in the agricultural use of the landscape (drainage or irrigation requirements).

With respect to the limited extent of this paper (which focuses primarily on the changes in land use) it is possible at least to mention that the hydrographic changes found on the studied streams are in most cases related to the changes in the agricultural use of their floodplains (the area of the canceled water reservoirs, mainly in the Kyjovka River basin, was usually converted into the area of arable land or permanent grassland) or to urbanization (sprawling of the built-up area connected with its flood control reflected in a local straightening of the stream). The straightening of the Velička River downstream could also relate to the drainage requirements. The impact of a development of transportation infrastructure which can also be one of the significant anthropogenic factors of the changes on river network and individual streams (Žikulinas, 2008; Blanton and Marcus, 2009), was in relation to stream hydrography observed only sporadically (the Velička River).

6. Conclusions

Land use development in all three study basins was to a relatively high degree determined by natural conditions, although the intensity of farming also had a considerable impact. In terms of the proportional representation of individual land use categories in space and time, the most important categories were forest and arable land. Forests prevailed in the Svratka River basin and in the Kyjovka River basin (in the second example except for the period of 1876 till the mid-1950s). Arable land predominated in the Velička River basin.

All three basins showed some identical processes of land use development. During the comparative periods 1836 × 1876 and 1876 × 1953 the process of agricultural intensification prevailed, in contrast to the periods 1953 × 1991 and 1991 × 2006 when grassing over mainly prevailed. The most considerable change in land use occurred in the Velička river basin (where 43% of the area was changed), slightly fewer changes occurred in the Svratka river basin (39% of the area) and similar changes in the Kyjovka river basin (32% of the area). The different physical geographic conditions of these three areas were manifested by rates of areas being exploited intensively and extensively: in the Velička and the Kyjovka river basins intensive exploitation prevailed and in the case of the Svratka river basin it was predominately extensively exploited.

Anthropogenically conditioned hydrographic changes were found on all three streams, mainly on the Kyjovka River (foundations and cancellations of more water reservoirs) and the Velička River (straightening of the stream). In the case of the Svratka River, the range of anthropogenic changes was the lowest (small changes in the course of the stream and foundations of water reservoirs). The consequent impact of these changes on the main stream length and sinuosity was the most significant in the case of the Velička River. This can be explained by the fact that the whole stream was analysed, including its downstream part through wide and rather intensively used floodplain (in contrast to the Kyjovka and the Svratka Rivers that were only upstream analysed).

Hydrographic changes on all studied streams can be in most cases related to changes of the agricultural use in their floodplains or to urbanization, sporadically also to the development of the transportation infrastructure in their floodplains.

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