CHANGES IN FARMING IN THE LANDSCAPE OF EASTERN SUDETES AS A FACTOR INFLUENCING THE DYNAMIC OF FLUVIAL PROCESSES

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Abstract

The paper deals with relationship between the landscape patterns establishing after medieval colonization in Hrubý Jeseník foothills and fluvial dynamics in catchments of small-scales. The dissected landscape of Zlatohorská vrchovina Uplands has retained features of landscape structure, created by stripes of fields diverging to both sides of valleys. The way of farming and cultivating individual fields within the band structure appears – from present point of view – as very thrifty, stabilizing itself after beginning unsteady period of deforestation. Remarkable channel erosion (depth and mainly lateral), cut banks in meander belt with marks of downstream meander progression, widening of active channel and gravel bars accumulation were found in the Kobylí potok Brook near village Jelení in Zlatohorská vrchovina Upland. These features confirm activity of flood and high water flow. On the top of it, implication of cattle grazing and tramping of banks were discovered. In paper are discussed following questions: Are these features accordant with natural development? Can be these changes linked with dynamic equilibrium disruption between sediment transport and velocity of flow as a result of changes in farming, grassing of land and natural erosion reduction?

Key words: Zlatohorská vrchovina Upland, human impacts, landscape structure, grassing, sediment deficient water, lateral erosion

INTRODUCTION

The aim of this paper is to contribute to understanding of variability in channel dynamics and lateral erosion in small catchments in piedmont landscape of the Eastern Sudetes in relation to human activity and land-use since the beginning of settlement, especially after the Second World War. This study is based on the analysis of colonization history and the landscape structure of Eastern Sudetes (on the example of extinct village Jelení/Hirschberg in the Kobylí potok Brook valley), using aerial photographs interpretation and field surveys.

STUDY AREA

The study area is situated in Zlatohorská vrchovina Upland, at the watershed among the Opavice River in the north and the Opava River in the south, in the upper reach of the Kobylí potok Brook. The Zlatohorská vrchovina Upland lies in the area with relatively cold, humid summer and long winter. The snow cover lies on the average 102 days in year. Mean annual total amount of precipitation reaches up to 900-1,200 mm. The most amount of precipitation, in a long-term mean of years 1901 to 1950, in spring and summer months had the peak in July (135 mm, weather-station Heřmanovice). The area consists mainly of flyschoidal layers of "Andělská Hora formation" of Upper Devonian up to Lower Carboniferous age with prevalence of greywackes or slates. The region with mean altitude 680 m a. s. l. can be characterized as Hrubý Jeseník Foothills (Fig. 1).

The Kobylí potok Brook with the catchment area of 23.2 km^2 is 7.7 km long, the mean discharge at the mouth to Opava is 0.22 m^3/s. In respect of

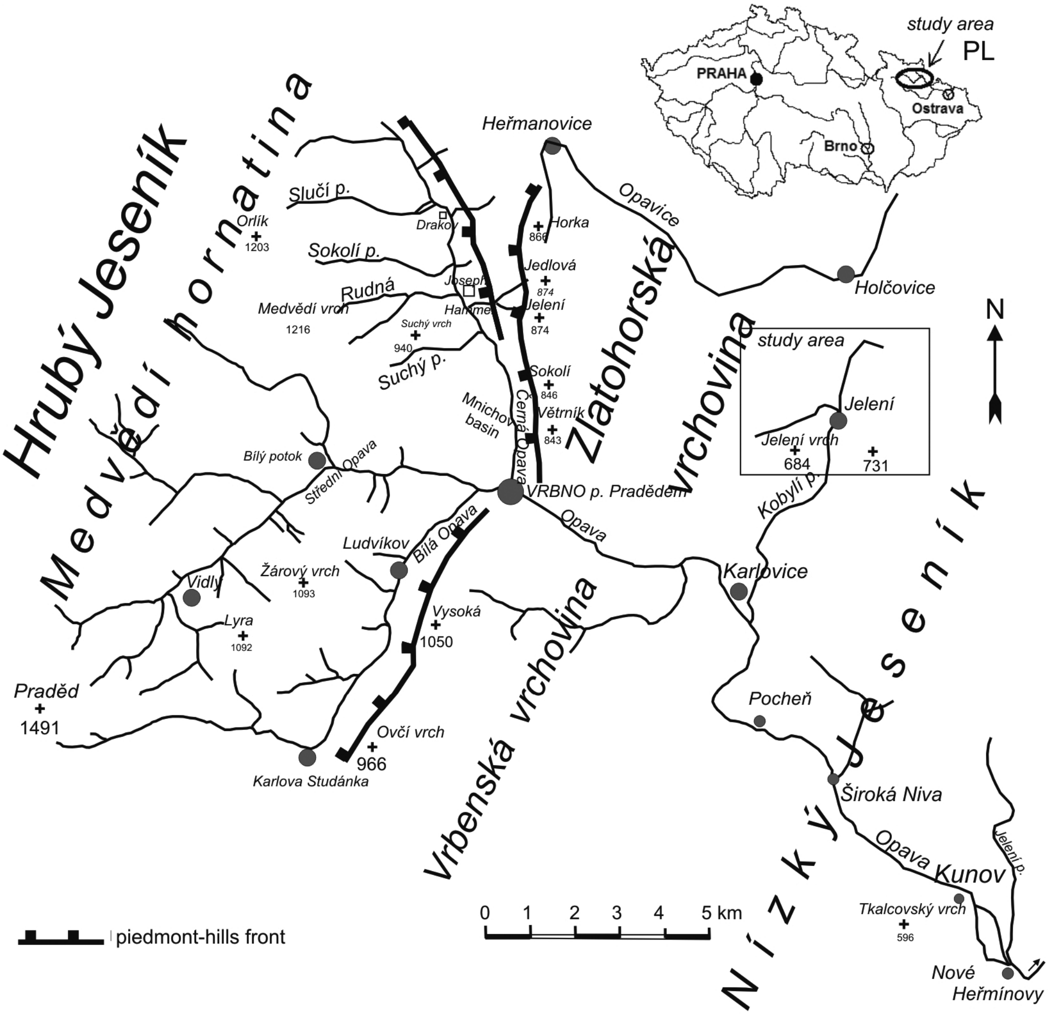


Figure 1 The study area.
Source: www.mapy.cz.

snowmelt, the highest water-level stage occurs during spring months, whereas the autumn months are typical with the low-flow stages. There are mainly two reasons why the valley of mentioned brook is greatly suitable for evaluation of impact of variations in farming and land-use on geomorphological processes: firstly, phases of expansion of the land register from establishment to present state are precisely known here, secondly, the erosion processes and dynamic equilibrium disruption are still in progress in the stream channel.

The Zlatohorská vrchovina Upland was repeatedly affected by number of disastrous floods in former times, catastrophically affected were villages lying along the Opavice and Opava River. In 1605 the catastrophic flood caused property damages (houses, mills, meadow, fields, corn, cattle). The flood on August 26, 1813 destroyed 13 houses and all the bridges in near village Holčovice, in village Hejnov 16 houses were destroyed and 30 houses were damaged. In accordance to historical records, the water in evangelistic church gained upon height 30 cm in 1829 on June the 10 after several-

-day rainfalls. The other floods took place in years 1847, 1880, 1883, 1920 and 1940. One of the most devastating flood occured in 1903 in July the 10, when Opavice River flowed catastrophically over the banks after five-day heavy rainfalls. The total day amount of precipitation of 184.7 mm was recorded on weather-station in Heřmanovice. This natural disaster washed down or destroyed number of buildings, bridges, reads, a new school building, brew-house and several factories. Other extreme flood took place in July 1997.

RESEARCH METHODS

Field research, measurement of basic parameters of river channel (bend radius, meander belt width, wavelength, sinuosity) and analysis of aerial photographs acquired in years 1937, 1955, 1979 and 2006 (obtained from Office of Military Geography and Hydrometeorology in Dobruška) were the main methods used to investigate changes in farming and subsequent impacts on fluvial dynamics. The approximate type of land-use was determined, as well as the particular field product. Patterns of grey-coloured tones (from light to dark) in aerial photography in 1937 indicates larger scale of crops growing in the fields in various maturity – winter and spring corn, potatoes, grass herbage etc. After 1945, the uniform gray shade dominates indicating the prevalence of permanent grass vegetation (light colour with symbol in Fig. 2). Moreover, the eastern part of the Kobylí potok valley was covered with this grey colour already in 1937, which implies the use of colder slope for pasture as so-called "winterhalde". Furthermore, the sinuosity of the channel bed in individual aerial photographs was compared.

HISTORICAL DEVELOPMENT OF LANDSCAPE LAND-USE

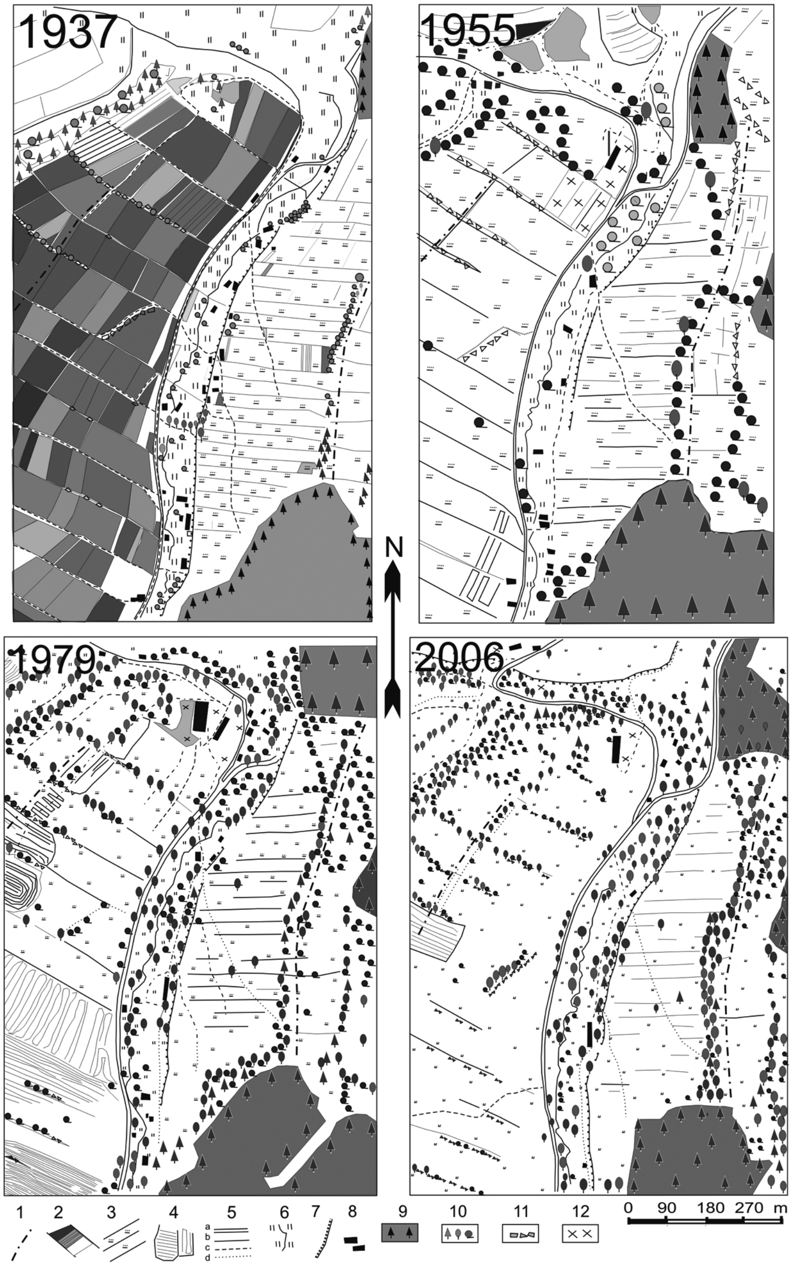
The acquaintances of landscape historical development from first settlement and land-use methods were used in land-use changes evaluation. The area of Zlatohorská vrchovina Upland was colonized in the course of several periods, which are perceptible in its structure. The mining colonization relating to gold-mining was the oldest one. Gold-washing took place from early middle ages (Večeřa, Večeřová 2001). Main valleys of Opava River and Opavice Rivers were settled by so-called large colonization in 13th and 14th century. During this period the first colonies were established. The exact establishment time of the villages during the large colonization is not known, the first mentions are dated considerably later – e.g. the villages Heřmanovice (Hermannstadt) in 1339 or Holčovice (Hillersdorf) in Opavice Valley first mentioned even in 1478. These villages originated as long forest lane villages, so-called *"Waldhufenflur"* (in German) with typical field arrangement in long strips getting from each farmstead in valley up to the hills, approximately perpendicular to the valley axis. *"Flur"* means entire farmland cultivated in three-field crop rotation including pastures with a third of land kept waste every year. English language has no nomenclature for this type of fields setting (in Czech *"plužina"*) on account of different historical development. Therefore it is logical to use German terminology, where the type of organization is possible to describe as *"flur mit langstreifen besitzparzellen"*. In English as a system of open fields which does not describe the subject matter. This belt system created the main feature of landscape structure in colonized valleys and is evident nowadays mainly due to long dry stone walls and balks.

In the same time as a large colonization the river alluvium were scoured and washed which led to belts of placer hill formation, which were later either removed (e.g. on Opavice River – *"Gold Oppa"*) or were preserved, e.g. in valley of Opava River where its massive distribution caused considerable local constriction of floodplain area (Hrádek 2008). In 18th century and after the Thirty Years War, the second period of colonization took place. During this colonization the less opportune places were populated, the highest locations were colonized at the very latest e.g. Rejvíz (Reihwiesen) 770 m a.s.l. in the second half of 18th century). The hamlet Jelení originated on August 29, 1666 south of Holčovice village in place called *"im oberen Hirschgrundt"*. This small village had 20 colonists. Each of them received a piece of land, 108 rods long and 15 rods wide (one rod = 3.79 m). Rye, oat, barley, flix, pulses, potatoes and fodder crops were grown in stony fields. New created village during second colonization had also features of *"waldhufenflur"* as that arisen in the course of the first period; however the build-up area was opener.

Most part of upland landscape was cultivated. The long-term using of a three-field crop rotation was very environmentally friendly to the landscape. In 1900, 44% of Holčovice's land register was covered by forests. Land-use data for Jelení village have been known since 1905. At that time 459 citizens lived in Hirschberg (Jelení) in 80 houses, situated in the Kobylí potok Brook valley. Generally, 288 ha of ground were used as arable land (204 ha), meadows (29 ha), gardens (2.09 ha), grasslands (5.46 ha) and forests (35 ha). The arable land was dominated. Another development of land-use is well noticeable in aerial photograph taken in 1937 (Fig. 2). Strips of *"flur"* divided in individual rectangular or square plots and situated up hill are noticeable in the photograph. The varied mosaic of fields is evident, individual plots were ploughed across a slope (contour plowing). Meadows were situated mainly in valleys along water courses but the little fields were also situated in floodplain of the Kobylí potok Brook. The well developed road network is apparent, following the stripes of *"flur"* and boundaries of fields. After the displacement of German inhabitants in 1945, the population decreased dramatically and has never reached even third of its pre-war state. Many houses and fields stayed abandoned. In 1945, a mountain pasture cooperative was established in Jelení. Deserted buildings were demolished and the village Jelení practically died away. More about land-use in Jelení is apparent from aerial photographs taken in 1955 and in 1979. In the photograph from 1955 (Fig. 2) is evident that the major part of land register of former Jelení was not cultivated at all. Only marginal parts adjacent to neighbouring villages (mainly to Holčovice) were cultivated. The old mosaic structure of *"flur"* stripes dividing in individual plots was already not kept. The amount of old roads was reduced, new ones originated. In the aerial photograph from 1979 (Fig. 2) about one third of parcels were cultivated in the entire length, the rest of land lied waste, the amount or roads kept on decreasing, the forested area started to increase. Since 1993, private company has been farming round village Jelení. Pastures take up major part of landscape according to the aerial photography from 2006 (Fig. 2). The structure of landscape, marked out by belts of land strips, stayed well-established, even though not functional. The area of overgrowing former grazing lands and fields by trees and shrubs also increases. The main difference in land-use is the extension of grasslands at the expense of arable land. The amount and length of used roads decreased with changes in farming.

HUMAN IMPACTS ON FLUVIAL SYSTEM

Fluvial systems in small catchments are well responded to impacts of changes in land-use and farming. The small catchments reply more immediately and with greater intensity to processes linked with precipitation run-off and they also more reflect changes in surrounding landscape than large basins (Hrádek 1989). The agriculture system kept by human appears, under the special terms, may be quite steady. The belt system of fields in steep land gradually gained these properties. Whereas in beginning period in medieval times, the processes of erosion were considerable after forest clearing (Hrádek 1980, 1989, Klimek et al. 2002), especially when coincide with the beginning of LIA (Hrádek 2007), after establishing the three-field crop rotation and contour plowing the situation steadied and field system came to equilibrium state even though intensive land-use activity. The post-war period in 20th century brought changes in land-use. Investigation in Eastern Sudetes brought new evidence on erosion processes in small catchments. Klimek and Malik (2005) studied effects of deforestation and processes of erosion in small tributary of Černá Opava River near Drakov in land register Heřmanovice in western part of Zlatohorská vrchovina Upland. As dendro-chronological methods suggest, the origin of erosion is associated with lateral channel migration mainly during large floods. The start of erosion processes is dated to the last 30 years. According to the authors, the main reasons are the excess of energy and a lack of transported material. Latocha (2005, 2006) closely analyzed the Luty potok Brook in Polish side of Rychlebské hory Mts. and confirmed the recent age of fluvial sediments in floodplain in consonance with former knowledge Teisseyre (1985). The beginning of the channel erosion is referred to changes in population



1 – rounded ridge; 2 – band structure of fields and plots; 3 – band structure of perennial grassland which primarily arisen under the thumb of exposition on cold valley side; 4 – marks of land cultivation after the year 1946; 5a – local roads, 5b – main path, 5c – other path, 5d – inactive path; 6 – meadows in Jelení potok Brook; 7 – edge between valley side slope and floodplain; 8 – farmsteads and other buildings; 9 – forest; 10 – coniferous and broad-leaf trees and bushes out of forest; 11 – dry stone walls; 12 – degraded ground.

Figure 2 Variations in farming in southern part of village Jelení's land register.
Source: own research.

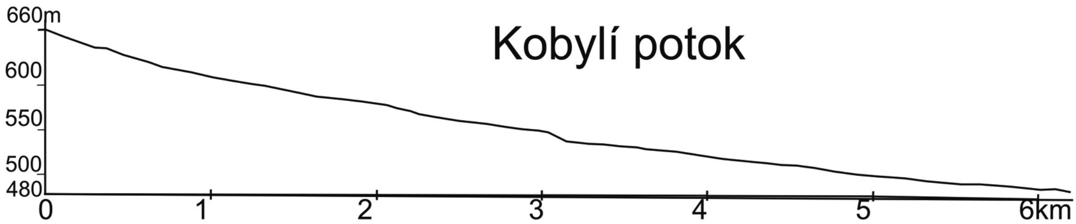


Figure 3 Longitudinal profile of the Kobylí potok Brook with the maximal slope (and meander sequence) in the middle section.
Source: topographic data from the map.

density and overgrowing of former fields with herbal, shrubby and forest vegetation in years 1930-1950. The author also refers to other forms of erosion associated with e.g. cattle grazing.

Changes in the Kobylí potok Brook valley

The Kobylí potok Brook can be considered as an example of small-scale catchment. Field survey in 2005 found marks of lateral erosion, meander progression and shallow channel incision into the floodplain (from 0.7 to 1.5 m). The analysis of aerial photographs taken in 1937 up to 2005 revealed distinct meandering patterns of the Kobylí potok Brook namely in 2005. Especially the meander situated in the lower part of former village became greatly remarkable in the photography taken in 2005. During field investigations the following problems were discussed: is the lateral and deep erosion a part of a natural development of channel or should be considered as a feature of instability as a result of variations in land-use? Data describing characteristic dimensions of meanders sequence is listed in table 1.

Table 1 Parameters documenting the meander sequence in mentioned reach on the Kobylí potok Brook.

Bend radius	10 – 12 m
Meander belt width	20 m
Wavelength	24 m
Sinuosity	1,35

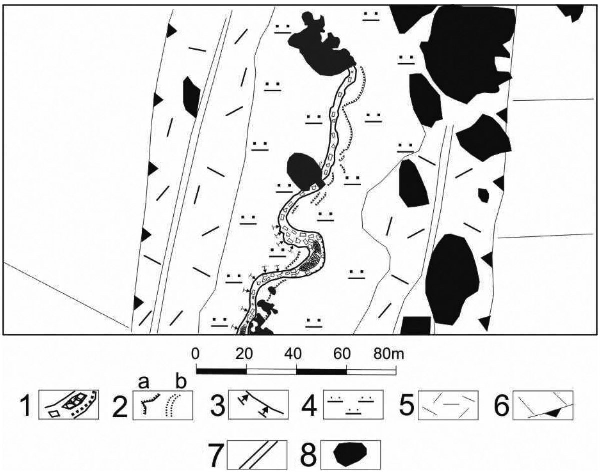
Investigated meander sequence is situated in the middle section of stream in lower part of former village, towards the mouth to the Opava River, where the channel slope is changing from 20 m/km to 27 m/km (Fig. 3).

On the left side of channel in upper part of meander belt the scars of left banks as low steep slopes (up to 0.5 m high) were kept, with typical feature of shifting – so called cusp, indicating meander progression (Fig. 4 and 5). The channel width varies; it is relatively narrow above the meander belt, (generally approximately 1 m width) and it extends in meander belt up to 5 m. The concave meander bank is affected by lateral erosion and the structure of floodplain is striped on the wall of cut banks. Poorly sorted clastic silty sand deposits of small thickness (0.25-0.4 m) form the upper part of cross profile lying above coarse tabular and angular gravel and cobble with prevalence of greywackes. Investigated structure of floodplain and lateral erosion point to immature of floodplain associated with redeposition of weathered Pleistocene greywackes deposited at the base of steep slopes (15-20°). The small thickness of fine-grained overbank flow deposits proves the low transportation rate of fine-grained material with lower content of suspended load and thereby lower erosion in the catchment. The right side of channel bed is affected by several types of geotechnical failures – partly cantilever failures attacking turf layer, partly caused by cattle grazing and tramping, as a negative implication of predominant grazing. Sandy gravel horizon part of banks lying below the turf is affected by freeze/thaw processes and dry granular flow. As a result of lateral erosion and banks instability, the

Figure 4 View on the floodplain of the Kobylí potok Brook with meander belt. Photo: Mojmír Hrádek, 2006.

water course is supplied with abundant material, namely with coarse gravel; the channel has typical features of gravel bed channel. Thorne (1998) defines present status of channel whether or not the channel width is adjusted to the present flow and the sediment regime. The adjusted channels have *"stable widths over time, although they may still be laterally active if they erode one bank and deposit sediment at the other to migrate in 'dynamic equilibrium' "*. The present state of the Kobylí potok Brook indicates that the width of channel bed is not adjusted to present flow with low water content and even not to the sequence of one eroded bank and deposit sediment at the other. In the course of the year, the stream channel is more watery in spring and low-flow in autumn. During low water stages, the gravel bars are covered with vegetation. A big width of channel bed in the first outstanding meander with mid-channel bar and imbricated tabular gravel corresponds to high-energy processes such as flood in July 1997, flood in August 2002 and strong snowmelt in 2006. Erosion of cut banks, the channel widening and creating of mid-channel bars are concerned with effects of meandering thalweg during the overbank flow (Levin 1976, Schumm et al. 1987) which were also found on other rivers (Hrádek 2005, 2006). According to Baker (1987), in a meandering alluvial stream with a floodplain, the rising stages of flood flow yield sequences of adjustments within the channel. At the beginning width does not markedly increase as depth increases rapidly up to bankfull stage. The stream erodes sediments from its bed to keep pace with an increasing equilibrium rate. If the sediment concentration increases faster than the equilibrium rate, the overbank flow deposits the excess sediment as natural leveé, thereby restoring equilibrium (Maddock 1976). If sediment transport does not keep pace the equilibrium rate, the flow will attack the banks, widening the channel. Equilibrium is thereby restored since sediment is added to the flow, and the enlarged channel reduces velocity for given discharge thereby producing a lower transport rate. The absence of leveé indicates no greater excess of sediment material on the Kobylí potok Brook. On the contrary, the processes of meander formation, channel deepening and channel widening are apparent.

The destructive effects of flood in 1997 became evident also on channelized lower reach of the Kobylí potok Brook, where the stone revetment was destroyed during channel widening. A lack of erosion and transported sediment material on middle and upper reach of the Kobylí potok Brook is probably associated with increasing of areas with meadows and pastures as indicates analyzing of aerial photographs from years 1955 and 1979. The overgrowing of inactive roads increases, causing



1 – widened reach of channel with mid channel bar and left cut bank; 2a – scars of left bends as a testimony of meander progression, 2b – abandoned channel; 3 – right channel bank affected by gravity cantilever failures and dry granular flow; 4 – floodplain; 5 – accumulations of colluvial deposits at foot of steep valley sides; 6 – lower slope egde; 7 – road; 8 – woody vegetation.

Figure 5 Channel of the Kobylí potok Brook with meander sequence in lower part of Jelení. Source: own research.

decrease in road erosion, as pointed out by Latocha (2005). According to field measurements of Rychnovská (1985), the perennial herbage stand is able to reduce erosion about hundred times. The decreasing amount of bed load and suspended load in river channel of grassing upland landscape is highly actual, leading to sediment deficient water stage. To keep the dynamic equilibrium, the stream creates meanders and erodes its own channel to supply the bed load. Even very little depth of fine-grained overbank flow deposits in floodplain points to reduced rate of natural erosion. Erosion consequences of changes in land-use were discovered also at other places in Sudetes. Remarkable meanders were found for instance in case of small tributary of Černá Opava River near Drakov in upper part of the stream at the point of channel slope increasing (Klimek, Malik 2005) as well as on larger water courses such as Luty potok Brook near Lutynia in Kłodzko basin (Latocha 2005, 2006). The above mentioned streams differ in a sum of kinetic energy of longitudinal profiles, stream order, local lithology and features of landscape structure. The main reason for channel erosion is probably similar in all cases – the dynamic equilibrium disruption between sediment transport and kinetic energy in consequence of the long-term grassing of farmland.

CONCLUSION

The band structure of of Zlatohorská vrchovina Upland landscape was established on the beginning of stable settlement in the Middle Ages. In response to landscape deforestation and field system setting the erosion reaction and soil loss occured. It is apparent, that after stabilizing, the new system managed to keep in equilibrium the processes of run-off and material transport in channels of small catchments in the course of intensive farming activity. After the Second World War, the steady state was disturbed by one-way grazing technique of farming. The channel erosion can express as deep or lateral erosion and on the Kobylí potok Stream proceeds during high-energy stages of floods through meandering thalweg, meander progression and channel widening with channel bars formation. Also cattle grazing and tramping contributes to river bank erosion. The landscape near extinct village Jelení, which is situated at water divide between Opava River and Opavice River, was colonized relatively late. The landscape structure formation was influenced by organization of belt open field system. The prevalence of greywackes of "Andělská Hora formation", the three-field crop rotation and the contour plowing created relatively steady system, which was locally only disturbed by occasional floods. The deep and lateral erosion (pursuant to the meander belt), increasing in sinuosity, meander progression, channel widening and gravel bars formation were investigated ten years after flood in July 1997 in middle reach of the Kobylí potok Brook. All these processes were identified as a result of meandering thalweg channel operation during flood in 1997, and slowly progressing in the next years. This type of widening of unstable channels has been known in the Czech Republic on the larger altered streams as the Bečva River. The instability on the Kobylí potok Brook is related to disproportion between sediment transport and flood flow velocity induced by long-term changes in farming near water divide between Opava River and Opavice River, mainly by grassing and grazing land-use. The effects of permanent herbage cover which prevents from erosion were experimentally demonstrated and they were also confirmed from other parts of Eastern Sudetes.

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Résumé

Změny v hospodaření v krajině Východních Sudet jako faktor ovlivňující dynamiku fluviálních procesů

Fluviální systémy v povodích malých měřítek velmi dobře odrážejí vliv změn v hospodaření a využívání krajiny. Tato povodí s větší intenzitou reagují na procesy spojené se srážko-odtokovým procesem a také více reflektují změny v okolní krajině na rozdíl od povodí větších měřítek.

Cílem studie je objasnit příčiny ve změnách fluviální dynamiky vodních toků v povodích malých měřítek podhorské krajiny Východních Sudet. Zjištěné skutečnosti jsou analyzovány v souvislosti se změnami v hospodaření v krajině od počátků osídlení, zejména pak se změnami vyvolanými hospodařením v období po druhé světové válce. Modelovým územím je horní část povodí vodního toku Kobylí potok situovaná v oblasti Zlatohorské vrchoviny poblíž zaniklé obce Jelení (Hirschberg). Tato oblast představuje území vhodné k hodnocení dopadu změn v hospodaření a využití krajiny na dynamiku fluviálních procesů zejména ze dvou důvodů: i) záznamy o vývoji hospodaření v katastru obce se vyskytují souvisle od dob jejího založení až po současnost a ii) v korytě místního vodního toku dochází k porušování dynamické rovnováhy. Studie srovnává vliv několika posledních etap vývoje hospodaření na fluviální dynamiku systému na základě hodnocení série leteckých snímků, terénních výzkumů, historické analýzy kolonizace v oblasti a rozboru vzniklé krajinné struktury.

Krajina Zlatohorské vrchoviny byla osidlována v několika kolonizačních vlnách. Nejstarší byla kolonizace hornická, spojená s vyhledáváním ložisek zlata, která probíhala od raného středověku. Hlavní údolí v oblasti byla osidlována v průběhu tzv. velké kolonizace ve 13. a 14. století, během níž byly zakládány jednotlivé osady. Tyto obce vznikaly jako dlouhé lesní údolní vsi (něm. tzv. *waldhufenflur*), jejichž typickým rysem bylo uspořádání polí v dlouhých pásech probíhající od každé usedlosti či dvora zhruba kolmo na osu údolí v pásech vzhůru do svahů. Pásová struktura krajiny založená již v počátcích trvalého osídlení krajiny Zlatohorské vrchoviny dokázala při intenzivním hospodářském využívání krajiny udržovat v rovnováze procesy odtoku a transportu materiálu v korytech toků v malých povodích. Zjištěné skutečnosti ukazují se, že zemědělský systém založený člověkem může dosahovat poměrně stabilního stavu. Ustálenou podobu získal ve svažitém terénu postupně i pásový systém polí. Zatímco v počátečním období po vymýcení lesa v období středověku obvykle docházelo k intenzivní erozi (Hrádek 1981, 1989, Klimek et al. 2005), zejména pokud se tato doba shodovala s nástupem malé doby ledové (Hrádek 2007), později po zavedení trojpolního systému a obdělávání podél vrstevnic se situace ustálila a polní systém se dostal do poměrně rovnovážného stavu i přes intenzivní využívání půdy. Změny v charakteru hospodaření přineslo poválečné období v minulém století. Při jednostranném pastevním způsobu využívání krajiny v období druhé poloviny dvacátého století začalo postupně docházet k diskrepancím v rovnovážném stavu fluviálně-dynamického systému.

Korytová eroze, nabývající podoby hloubkové i boční eroze, se v současné době na Kobylím potoce vyskytuje během vysokoenergetických stavů (povodní) a projevuje se zejména meandrováním proudnice, posunem zákrut, rozšiřováním řečiště a vytvářením štěrkových lavic. Menší měrou k erozi přispívá k erozním procesům i pastva dobytka a sešlapování břehů. Příčinou korytové eroze je v tomto případě porušení dynamické rovnováhy mezi transportem a kinetickou energií toků způsobené dlouhodobým zatravněním pozemků. Zjištěné závěry odpovídají výsledkům výzkumů prováděných dalšími autory v oblasti Východních Sudet.