RETENTION IN THE FLOODPLAIN FOREST IN LITOVELSKÉ POMORAVÍ

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Abstract
The paper deals with the retention of floods in a specific landscape with well-preserved anastomosis river pattern of the Morava River. Water regime of the Morava River in the Protected Landscape Area Litovelské Pomoraví connected with regular floods led to the formation of unique floodplain forest ecosystem. Research activities were conducted with a typical floodplain forest with preserved naturally meandering watercourse and system of permanent and periodic river arms and linear depressions. Due to the unique system of floodplain forest, which is in the relatively well-preserved section to investigate the importance of floodplain forest, specific river system in conjunction with the retention of water during floods or extreme precipitation events. This article aims to reveal the possibility of retention in a specific type of river landscape with a few proven methods. The classic method is to use double-ring infiltrometer to measure infiltration in the environment of floodplain forest and meadows, which are dominant land-use types in the research area. To detect the capacity of water retention in the system of river branches and depressions have been used traditional total station survey combined with DGPS (differential GPS technique) to obtain accurate extent of depressions, channels and surface. The calculations were carried out in ArcGIS software with extensions. The research activities were performed within 3 years from September-April (2007-2009). The measurement in the floodplain forest can be realized only during the dormancy period after the winter, when the surface was free of herb layer (summer aspect) before spring floods occured.

Key words: floodplain forest, retention, infiltration.

INTRODUCTION

Factors affecting the flood are particularly weather, interception (capturing rainfall by vegetation cover – see the comparison of different vegetation types in Table 1), infiltration and surface runoff. The fact that the water soaks into the soil is temporarily excluded from the drain and only affects a small portion of the flood wave. Two factors are very important for infiltration: infiltration rate, and the retention capacity of soil. We should consider two scenarios for the infiltration rate: 1) infiltration rate is higher than rainfall intensity or both variables are the same (all the water seep to soil and remain away from surface runoff); 2) infiltration rate is lower than rainfall intensity. Water that is not captured by vegetation cover or does not seep into soil after filling the depressions in the ground flows out as surface runoff. The speed of surface runoff is then dependent on the terrain slope and roughness of terrain. The roughness of the terrain increases mainly with microforms of relief and vegetation. For floodplain forest is a significant root system of trees and dead woody material. In terms of flood protection should be viewed separately to whole floodplain, not as a phenomenon closely tied to water flow. Measures taken in the floodplain are among the most effective, often significantly exceeding the effects of massive water management structures. According to the calculations of Hnutí

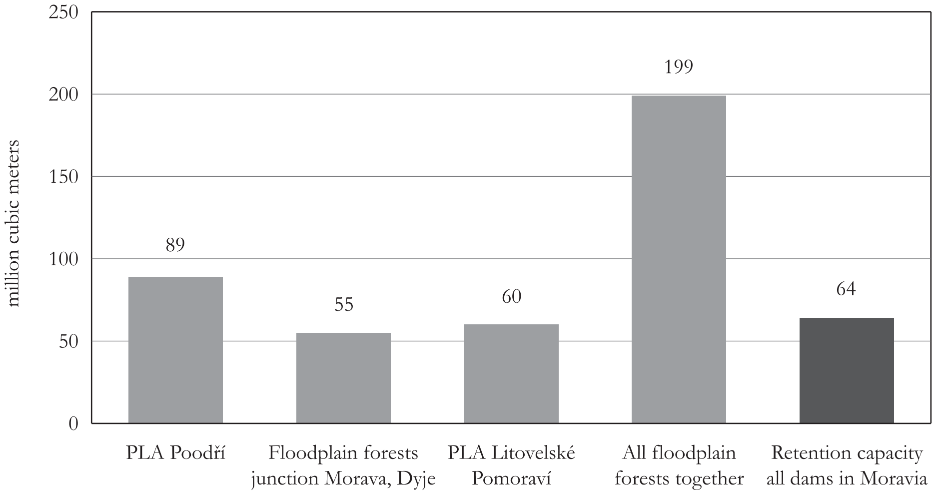

Figure 1 The amount of flood water retained in 1997. Source: calculation of Hnutí Duha.

Table 1 Interception of various types of vegetation. Source: Krešl 1999.

Vegetation types	Interception value (captured rainfall in mm)
Spruce stand (60 years old)	5.1
Beech stand (60 years old)	3.5
Pine stand (60 years old)	3.0
Luzula luzuloides	2.9
Blackberry stand	2.6
Blueberry stand	1.2

Duha (Friends of the Earth Czech Republic, non-profit organization) captured the last three complexes of floodplain forests, meadows and wetlands in the flood in 1997 more water than all the dams in the basins of the Morava River and Odra River together (Fig. 1). Spring flood overflows are a natural phenomenon of alluvial land. During the 20th century the vast majority of our natural ability to flow as a result of overflowing water management measures (flood embankments and drainage flow) gradually lost nature form. Natural overflows have exceptional retardation capacity. The water here does not hold permanently, but is delayed for several days or weeks. A good example of the arrangement of the landscape, which is consistent with natural processes and also does not interfere with the rights of society to use the flat grassy or wooded floodplain with a strongly meandering river or stream. Such stream is usually very shallow. Even with a small regular flood water flows into the floodplain and slowly flows parallely with the brook or river. Height of flood is low because the water spreads abroad (in width). What evolved is a floodplain, the greater may be overflow with flood waters. Koutný (2003) considers the fundamental way to solve the July floods range (meaning a flood in July 1997), with the accumulation of flood waves in reservoirs, polders and inundation areas (grasscovered or better covered by floodplain forests).

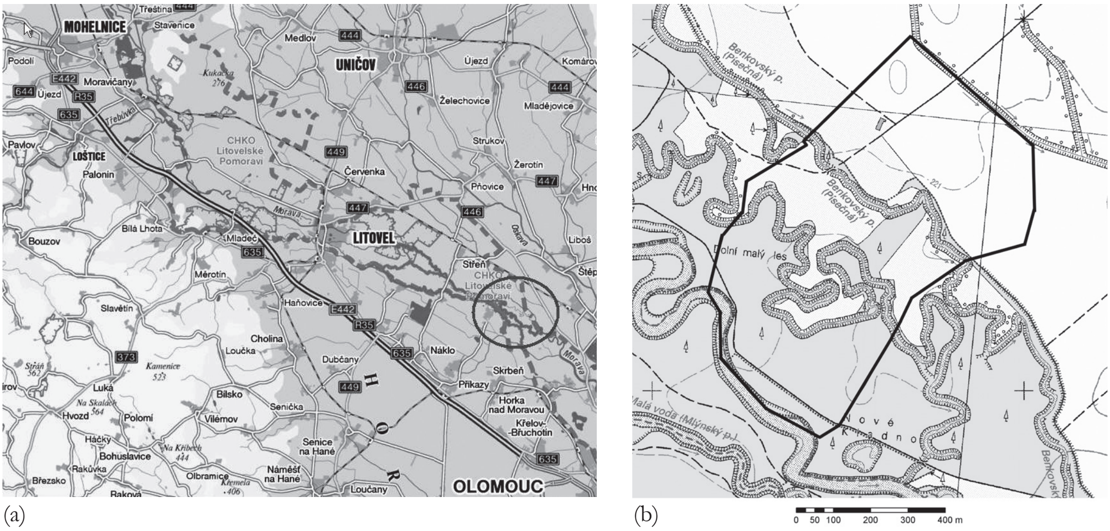

Figure 2 Research area and its location in central Moravia (a), study area (b).

RESEARCH AREA, METHODOLOGY

Research area lies in the part of the Morava River floodplain with protected fragment of soft flodplain forests. There exists special type of river pattern (anastomosis). In past, anastomosis was included in one category of braided streams. The anastomosis is like braided streams characterized by frequent bifurcation of the channel. But for braided streams are characterized rivers transporting gravel and sand sediments in unstable, rapidly displaced laterally channels. In contrast, the anastomosis were developed in loamy alluvial sediments and are characterized by high stability. Anastomosis preserved example in the Czech Republic is currently in the Morava River in Protected Landscape Area (PLA) Litovelské Pomoraví (Králová 2001). The river pattern in PLA is complicated (river channels, depresions) and the research activities were not possible to capture the whole territory. Therefore, the selected landscape fragment was chosen with a specific mosaic of meadows and floodplain forest (Fig. 2a). In terms of longer-term development of the area there were identified certain facts pointing to changes in the system, and it is also desirable to observe and record the current stage. Changes in the system of river pattern in roughly the last 200 years were reconstructed through the study of archival (historical) maps. The older historical maps of Moravia from the latter half of the 16th century and the early 18th century were used (the maps of Fabricius, Comenius, Cornelli and Müler map of Moravia). These maps show only the framework of the channells course, its tributaries and branches. Most important data brought analysis of Müller map so called "Estates map of Moravia" from 1716 and its derivatives. The beginning of branching is in Třesínský práh riverbed drop, then the flow can be seen three arms of the Morava River. The most significant is the northernmost arm, identified as Zámecká Morava (now called Štěpánovská smuha), which is now inactive. All three arms were being equivalent or the main water flow was provided by Zámecká Morava arm (Kirchner, Ivan 1999). For research activities was chosen arm called Štěpánovská smuha (Zámecká Morava). During spring floods have been regularly fulfilled from the Morava river watershed and acts as a temporary flow. The system of periodicaly flooded arms and channels have been changed during the last years. Due to deepening of main channel the functionality of flooding arms was disturbed and typical processes occure only during the highest flood water level. However the system of larger and smaller arms remained unchanged until the present. This situation is caused due weirs on the main course – Morava River (Kirchner, Ivan 1999). For research activity was chosen area flowed by Štěpánovská smuha and Benkovský potok with other small arms and depression close to Morava

River. Štěpánovská smuha is left-side arm branch out from the Morava River in the area close to Kenický meander. The new branch was restored in occasion to reactivate Štěpánovská smuha function as a periodically flowed arm (Máčka 2001). The shape of the channel in the various sections resemble to main channel forms (typical meanders). The floods increased the overall capacity with activation of channels for the transfer of flood water. Studied area are typical fragment (combination) of floodplain forest with arms system (Fig. 2b), floodplain meadows with arm Štěpánovská smuha and Benkovský potok system. Region was for a long time used by human but with attention to preserve nature system (mowing meadows). To reveal the importance of a specific type of land for water retention, two methods were chosen to help show the characteristics of the system and its importance to capture flood waters. The research was focused on the involvement of two different methods, which were used for:

- measurement infiltration capacity of the environment of floodplain forest and floodplain meadows (capture soil infiltration),
- modelling river landscape and calculate the volume of stored flood water and simulate arms actvivity and retention capability in different water levels (model of river landscape).

For the aims was used standard tools (double-ring infiltrometer) and GIS software for modeling and surface analysis. Input data for description and modeling were obtained by mapping with the total station Trimble 5300. Real position of mapping base (total station base points) gave DGPS Ashtech Promark 2.

Hard conditions of research has been given by relatively short period suitable for direct field measurements. Ideal conditions for measurements are in the spring months before the flood regimes (arms to fill the system with water) and in autumn in the floodplain meadows. During summer and autumn time in flodplain forest is not possible to make any measurements because of the abundant vegetation (summer aspect) and calamitous occurrence of mosquito (May-October). Mapping the parameters of arms and depressions have been solved by surface measurement or extrapolation of transect values for the inaccessible parts of the mapped area.

SOIL INFILTRATION

Infiltration intensity (speed) depends on several factors that significantly affect the properties of the soil or directly involved to infiltration process. A layer of topsoil humus, in itself, has the ability to bind about 20 mm of rainfall. Humus with the overlying vegetation cover absorbs the impact force of raindrops and prevents the disruption of soil structure and the formation of surface crusts with low water permeability. Humus improves soil structure, rough soil surface and prevents soil erosion. In cases where the removal of the forest floor was realised, the water permeability significantly got worse (Binder 1970). One of the factors that help water permeability into the deeper soil layers are the pores and pathways of various origin. There could be roots affection or soil fauna corridors. Both affects make retention subsurface area and the pathways for water seepage to the deep soil horizonts. If water being supplied to the soil surface at a rate at which is infiltrate, we can measure the maximum value of infiltration rate, also known as infiltration capability (Kutílek 1978). The actual infiltration for given time shows the intensity of infiltration. The total amount of infiltrated water is referred as cumulative infiltration. The course of the potential intensity of infiltration at a time is characterized by infiltration curve (Štibinger et al. 1998). Curve parameters are determined experimentally, using the method of double-ring infiltrometers or by tension infiltrometer. For the determination of soil infiltration was chosen double-ring infiltrometer with all recommendation (Štibinger et al. 1998). Measurements were carried out in April 2008. Simultaneously three measurements were carried out in a floodplain meadow near Štěpánovská smuha. Three other measurements were carried out in a floodplain forest near the Morava river bed.

Infiltration in floodplain meadow

Significantly better infiltration properties than the arable land have permanent grassland. In contrast to the influence of rainfall on bare soil absorbs contiguous grassland kinetic energy of raindrops and the rough surface slows runoff effect and

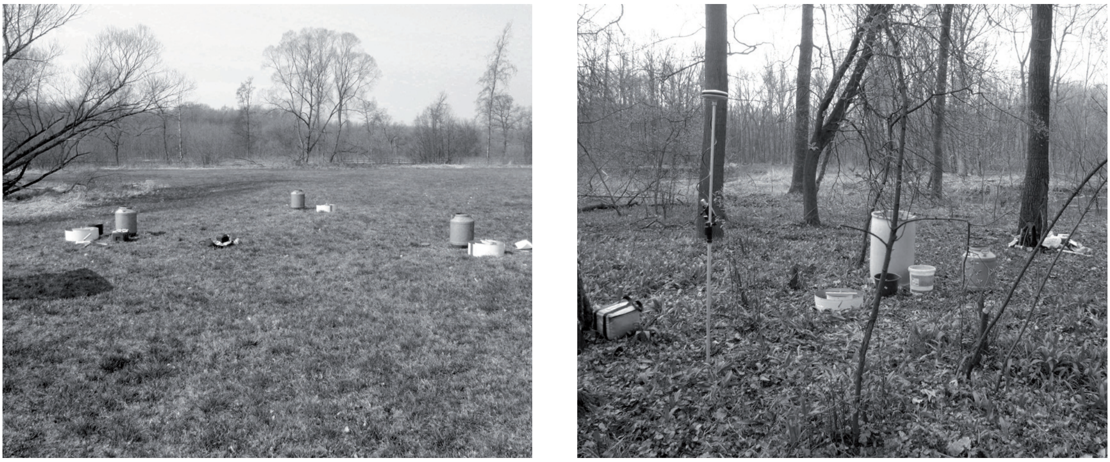

Figure 3 *In situ* infiltration measurement (meadow, forest).

improving infiltration. Permanent grasslands are mostly used as a pasture or mowing meadow. Here as like as arable land due to use of mechanization creates compaction layer less permeable for water. The lack of trees inhibits to drain the water into the deeper layers along the roots. Grassland have therefore generally better absorption characteristics than the arable land but usually worse than the forest. Important role in this comparison, however, plays a type of grassland (from the degraded grassland to mowing meadow with permeable soil).

The first measurements on an floodplain meadow (meadow 1) has increased the intensity of infiltration and the total amount of infiltrated water than the other two measurements of marked meadow 2, 3 (see Fig. 4). Increased infiltration was probably caused by a greater number of preferential water pathways (rodents). The final value of cumulative infiltration (Fig. 5) was 1,237 mm (meadow 1), 578 mm (meadow 2), and 370 mm (meadow 3). Reduced intensity (speed) infiltration and reduced cumulative infiltration in the measurements meadow 2, 3 could be explain by soil compaction.

The volume of infiltrated water reached 35.59 liters for a period of 3 h 19 min 20 sec. The intensity of infiltration calculated from these values for an one hour interval about 10.7 litres per hour.

Infiltration in the floodplain forest

About the effect of forest to runoff conditions are in a question now. The small experimental watersheds showed, that forests have a unique capability to retain rains. Retention capacity of forests depends on land morphology, vegetation structure, management practices and particular soil characteristics.

All these factors influence quantitatively. Water retention in a forest is based on interception of tree, herb layer, topsoil humus and by the soil infiltration. Soil infiltration could be the main aspect during enourmous rain epizodes. Interception have not effect in a long term rains. According to Válek (1977) is the root system the most essential factor for the soil interception throw different tree species. Its shape, rooting depth and other parameters significantly affect the soil retention capacity and infiltration parameters. Comparison of rooting depth of different species is shown in Table 2.

Generally we can say that the deep-rooting trees such as beech have a significantly better effect to the water soil infiltration. The most important factor should be the quality of the root system and its impact on soil porosity.

Soil fauna (edafon) are for soil texture and its water adsorption properties also very important. In forests with balanced species composition, and thus with

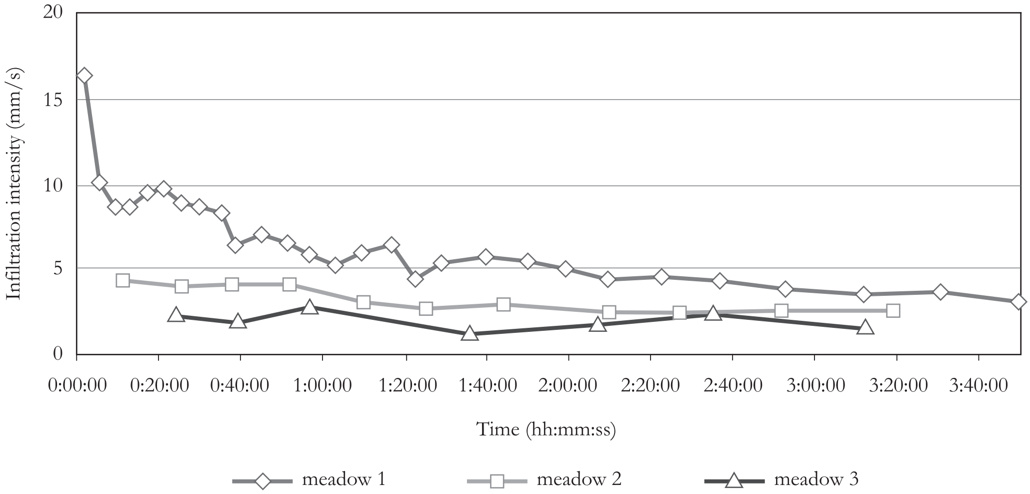

Figure 4 Infiltration intensity in meadow (simultaneous measurement April 1, 2008).

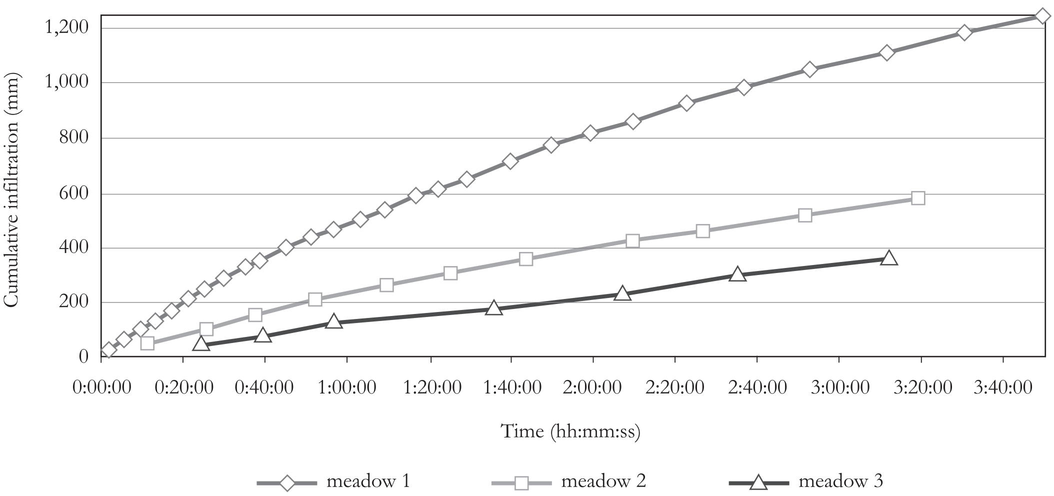

Figure 5 Cumulative infiltration in meadow (simultaneous measurement April 1, 2008).

Table 2 Rooting depth of different tree species. Source: Válek 1977.

Rooting depth	Tree species
< 30 cm	aspen, spruce
< 100 cm	common maple, birch, hornbeam, Norway maple, rowan tree, alder, European bird cherry, poplar, willow
> 100 cm	beech, oak, ash, elmtree, horse chestnut, sycamore, lime tree, pine, fir, larche

the appropriate composition of soil and humus, a large number of macropores have been formed by soil fauna especially by earthworms. Earthworms leave in a soil vertical pores called by Czech "pedohydatody". Through these structures created by one earthworm with the diameter of 5.5 mm can pass from 1.55 to 2.33 cubic meters of water. Considering the number of earthworms per hectare in a good condition forest, it is clear that their share in the water infiltration into the soil and eliminating surface runoff is substantial.

The use of forest machinery is damaging the soil and its water retention capacity primarily due to: the pressure of heavy machinery (compaction, reducing soil porosity) and churn up soil surface (causing erosion rills). The disturbance of the soil structure also affects the exposure of the field during the winter season. Forest land and grassland floodplain soils are covered with vegetation or detritus.

In the field experiment, infiltration into the soil in the floodplain forest was again carried out by three measurements (in figures referred to as forest 1, 2, 3). As shown in Fig. 6 and 7, there are the results of measurements Forest 2 significantly different from the measurement of other forest measurements. This difference – the total value of cumulative infiltration was 919 mm (forest 1), 248 mm (forest 2) and 945 mm (forest 3) could be caused by soil compaction with forest harvesters. Soil analyses did not show any differences of the three measurements.

The volume of infiltrated water reached 56.59 litres for a period of 2h 38 min 36 s. The intensity of infiltration calculated from these values for one hour interval is about 21.3 litres per hour.

MODEL OF THE RIVER LANDSCAPE

Model of the river landscape, or a digital terrain model (DTM) in the area of the floodplain forest was generated in ArcGIS 9.x. From the measured field data, map analysis were obtained altitudinal field. Other hypsometry data were put for better DTM calculation for the most authentic terrain. For DTM calculation there was chosen spline with pension interpolation model by Mitáš and Mitášová (1993). Final DTM was used for retence calculation and for scenarios modelling. To model the capacity of store flood waters were calculated with two options for comparing the differences and specifics of the landscape in the floodplain forest. The first option was calculated from the measured values, which were concentrated and added with regard to the morphology of the terrain and the faithful captured the real condition. The second model was generated as an area affected by human activity, which corresponds to the type of meadow land, field without any depressions. Both models were applied to the analysis of the same amount of flooding water. Scenarios evaluate the level of flooding at an altitude of 220.0, 220.5, 221.0, 221.5, 222.0 m. The results document the visual and numerical differences in different environments and scenarios (Fig. 8).

Flood water level 220.0 m above sea level

Scenario 1 is calculated by taking the altitude level of 220.0 m level floods. For this scenario has not developed a comparative model without the inclusion of depression, because the relief of the area does not reach (up to a system of depressions) values of less than 220.0 m. At the height level of flooding occurs only in the deepest parts of periodically flooded arms (Fig. 8). In the area of interest there are two main arms (Štěpánovská smuha and Benkovský potok). Benkovský potok in this scenario is normally flowed, while Štěpánovská smuha has the charakter of the pool in the top and bottom part and has the periodic depression character in the modeled part.

Flood water level 220.5 m above sea level

For this water level was not created a comparative model without channels and depresions, because the relief of the area lies below values of less than 220.5 meters above sea level. The projected increase in water level by 0.5 m was the flooding of smaller channels and depresions. It is obvious that Štěpánovská smuha became flowed for overall length in the study area. There was also an increase of water level in Benkovský potok brook, but still without spilling due the deeper bed.

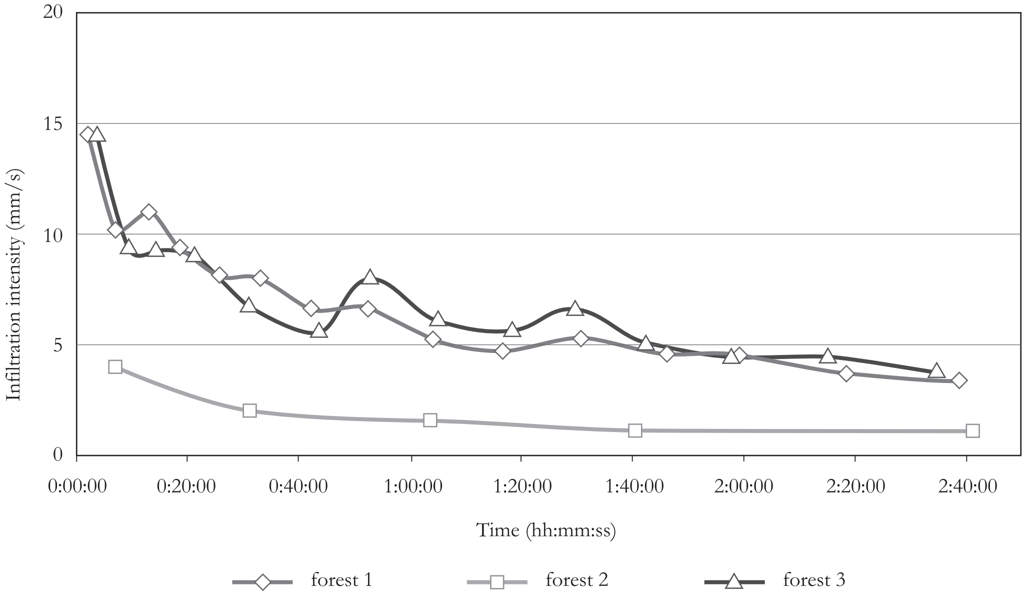

Figure 6 Infiltration intensity in the floodplain forest
(simultaneous measurement April 1, 2008).

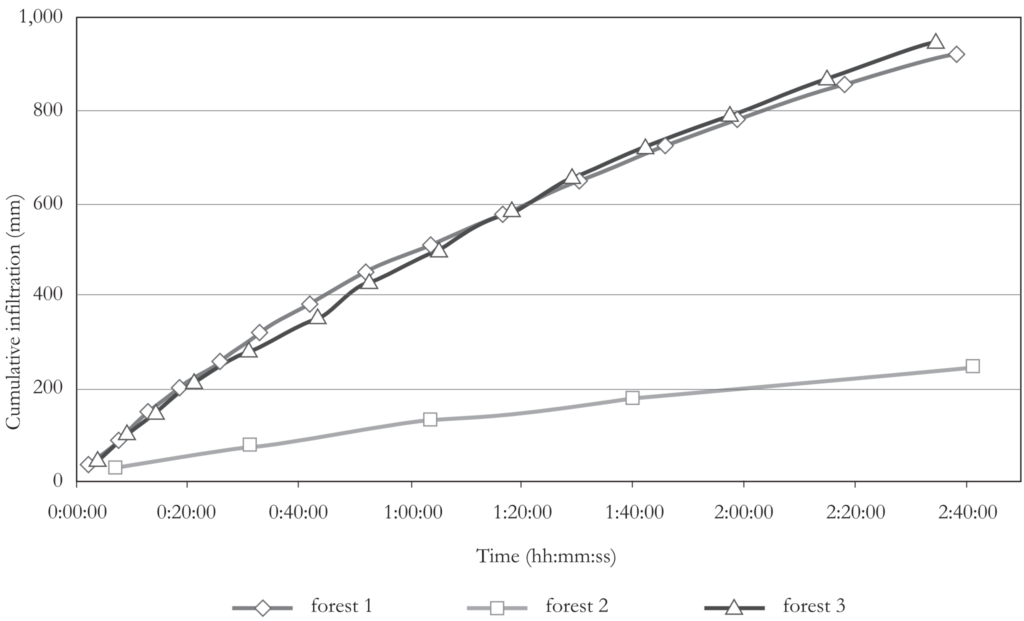

Figure 7 Cumulative infiltration in the floodplain forest
(simultaneous measurement April 1, 2008).

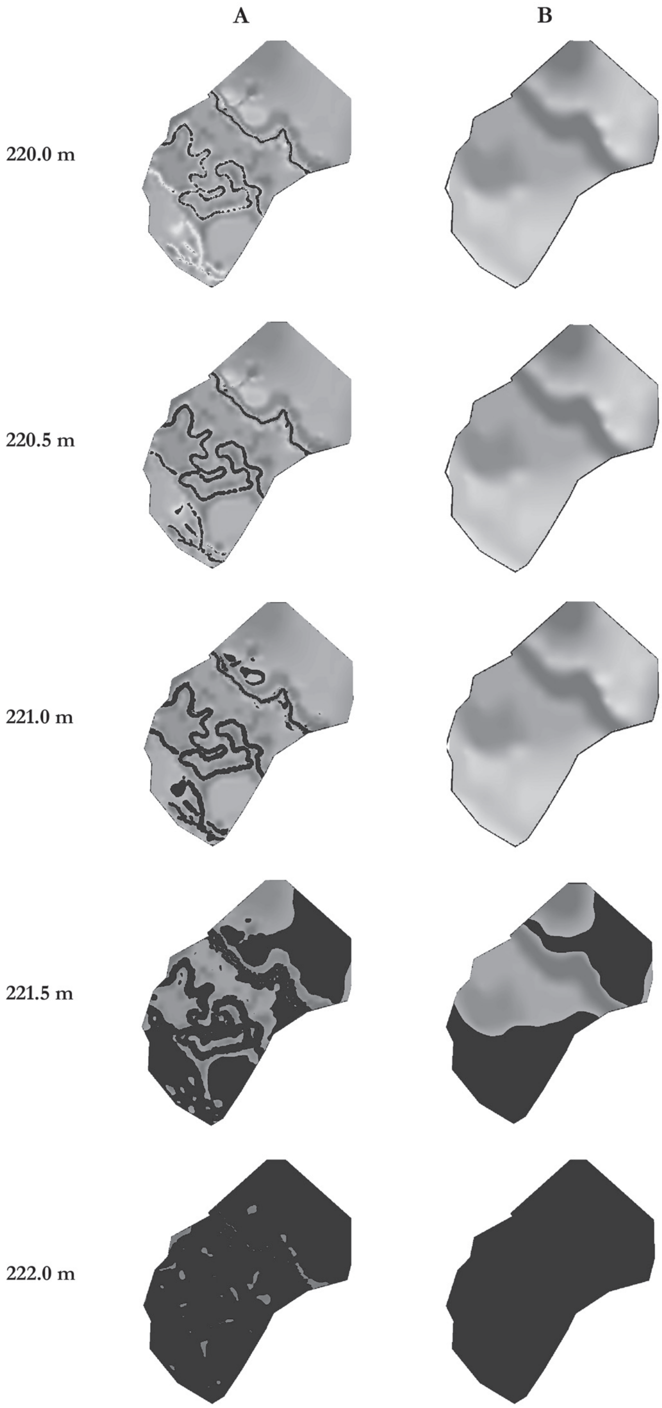

Figure 8 Model of flooding research area in all water level scenarios (A – real conditions, B – no depressions).

Table 3 Comparison of calculated values for water retention in the two model options.

Model flood water level		Option A (real conditions)	Option B (no depressions)
220.0 m a.s.l.	area in 2D model	10,407.06 (m^2)	–
	area in 3D model	10,557.29 (m^2)	–
	volume	1,962.89 (m^3)	–
220.5 m a.s.l.	area in 2D model	27,398.04 (m^2)	–
	area in 3D model	27,907.88 (m^2)	–
	volume	10,992.36 (m^3)	–
221.0 m a.s.l.	area in 2D model	57,262.78 (m^2)	–
	area in 3D model	58,183.79 (m^2)	–
	volume	31,192.79 (m^3)	–
221.5 m a.s.l.	area in 2D model	285,624.13 (m^2)	239,590.04 (m^2)
	area in 3D model	286,817.84 (m^2)	239,591.14 (m^2)
	volume	99,169.14 (m^3)	31,343.51 (m^3)
222.0 m a.s.l.	area in 2D model	484,951.66 (m^2)	499,538.04 (m^2)
	area in 3D model	486,267.25 (m^2)	499,542.85 (m^2)
	volume	296,961.33 (m^3)	227,257.81 (m^3)

Flood water level 221.0 m above sea level

The flood water level 221.0 m almost completely fills periodically flooded channels. There is a something like connection of small depressions, which were separated from the previous scenarios. From the Benkovský potok brook intrude water into contiguous depressions.

Flood water level 221.5 m above sea level

Flood water level 221.5 m activates the 2 option (land with no depressions). Flood comes from arms (Benkovský potok, Štěpánovská smuha). These channels gradually spread flood water into the surrounding depression and then to places in a floodplain forest with a lower altitude. There is flooding of fields neighbouring with the Benovský potok brook. The total volume of flood water retained in the area is 99,169.14 cubic meters. Compared with the model without depression system (ie the use of land as meadows or fields) there is three times more.

Flood water level 222.0 m above sea level

In both options we find only a few places in the area that are not flooded. This is essentially a mound of Benkovský potok brook that was in some places overflooded in the previous scenarios. In flodplain forest there are not flooded only highest points (local elevations).

CONCLUSION

The result of GIS analysis shows that the conservation of floodplain landscape contributes to the water distribution in the country, serves as a reservoir of water in the lower water level and increasing the amount of water that infiltrating into the soil. Retention of water in the landscape is undoubtedly important for the rainfall runoff and water budget and positively affects the local climatic conditions. From a certain level, the effect of water retention in depressions is not effective (the big flood), but is still visible above the value of stored water. Comparing the two scenarios help to clarify the impact of land terrain changes, which were made in the reduction of flooded forest and transformation to meadows, pastures and fields. As well as the volume of periodically flooded river arms and depresion for water retention in the landscape is importance of water infiltration into the soil. As confirmed the values of the total volume of water infiltrating into the soil resulting from documented charts and graphs show that floodplain forest soil is more intense (a speed of water infiltration into the soil). But also the cumulative infiltration value (the total amount of water seepage) is higher than of floodplain meadows.

Its role in water retention in the landscape has undoubtedly interception, thus capturing rainfall by vegetation. Highest values of interception achieve spruces, but retention of water in forests is not connected only with current process. From a comprehensive viewpoint are better species such as oak, poplar, linden, willow, hornbeam, alder and others, whose root system is more extensive and make easier infiltration of water into the soil. Spruce root system reaches a maximum depth of 30 cm. Based on the above factors, play a floodplain forest landscape with system of periodically flooded depressions and permanent grassland irreplaceable role in the retention of flood waters. Loss of fluvial forms in the landscape will lead to more rapid spread of flood waves and reduced the country's capacity to absorb water. Finally, it should be noted that the system of arms and depressions continuous with development. Finally, it should be noted that the river system in the PLA Litovelské Pomoraví subject to continuous development and for detailed study of the area is necessary to obtain an accurate digital terrain model (DTM) for the whole river system territory, including river basins. Technology applicable for the relief and vegetation type (forest) is LIDAR (Light Detection And Ranging). Price for that service in necessary accuracy will be in milions CZK (Czech crown). Paper with its results can be used for further studies in PLA Litovelské Pomoraví.

References

Binder, R. 1969: *Zahrádzanie bystrín a lavín.* Príroda, Bratislava.

Kirchner, K., Ivan, A. 1999: Anastomózní říční systém v CHKO Litovelské Pomoraví. *Geologické výzkumy na Moravě a ve Slezsku* 6/1998 , 19-20.

Koutný, L. 2003: *Zkušenosti z povodní na Moravě.* Brno, Mendlova zemědělská a lesnická univerzita.

Králová, H. (ed.) et al. 2001: *Řeky pro život.* Brno, ZO ČSOP Veronica.

Krešl, J. 1999: Vliv lesa na utváření odtoku při přívalových a dlouhotrvajících deštích. *Lesnická práce – časopis pro lesnickou vědu a praxi* 11/1999.

Kutílek, M. 1978: *Vodohospodářská pedologie.* Praha, SNTL/ALFA.

Máčka, Z. 2001: *Geomorfologický posudek na revitalizační opatření na Štěpánovské smuze a smuze Hatné-Plačkov (CHKO litovelské Pomoraví).* Brno, Akademie věd České republiky – Ústav Geoniky – pobočka Brno.

Mitášová, H., Mitáš, L. 1993: Interpolation by regularized spline with tension: I. Theory and implementation. *Mathematical Geology* 6/1993, 641-655.

Štibinger, J., Jičínský, K., Horáček, V. 1998: *Metodické pokyny pro terénní stanovení koeficientu filtrace dvouválcovou metodou.* Praha, Česká zemědělská univerzita.

Válek, Z. 1977: *Lesní dřeviny jako vodohospodářský a protierozní činitel.* Praha, Státní zemědělské nakladatelství.

Résumé

Retence v lužním lese v Litovelském Pomoraví

Výsledky analýz potvrdily již dříve existující výzkumné závěry, že lužní krajina jako přirozený rezervoár vody skutečně funguje a navíc výrazně zvyšuje schopnosti retence vody i mimo povodňové situace. Zadržení vody v krajině je nesporně důležité pro celkovou srážkoodtokovou bilanci a pozitivně ovlivňuje místní klimatické podmínky. Od určité úrovně výšky hladiny se efekt retence vody v depresích neprojeví (velká povodeň), přesto je stále patrná vyšší hodnota zadržené vody. Porovnání obou verzí zavodňování (bez smuh, ramen a depresí a s mapovaným stavem) pomáhá objasnit vliv terénních úprav krajiny (redukce a vyplnění

depresí, tvorba protipovodňových valů, aj.), které byly realizovány při redukci lužního lesa na louky, pastviny a pole.

Stejně tak jako objem periodicky zaplavovaných koryt je pro retenci vody v krajině důležitá infiltrace vody do půdy. Jak potvrdily zjištěné hodnoty celkového objemu vsáklé vody do půdy, vyplývající i z doložených tabulek a grafů, vykazují půdy lužního lesa větší intenzitu, tedy rychlost infiltrace vody do půdy, ale také hodnotu kumulativní infiltrace, tedy celkové množství vsáklé vody než je tomu u nivních luk. Svůj význam při retenci vody v krajině hraje nepochybně i intercepce, tedy zachycení srážek vegetací. Nejvyšších hodnot intercepce sice dosahují smrkové kultury, je nutné si ale uvědomit, že strom se nepodílí na retenci vody v krajině pouze intercepcí. Z komplexního hlediska vycházejí lépe dřeviny jako dub, topol, lípa, vrba, habr, olše a další, jejichž kořenový systém je rozsáhlý a usnadňuje pronikání vody do půdy.

Na základě výše uvedených faktorů hraje lužní krajina se systémem periodicky zaplavovaných depresí a na ně přilehlé trvalé travní porosty nezastupitelnou roli v retenci povodňových vod. Poslední dochovalé fragmenty nivní krajiny demonstrují možnosti přirozeného řešení povodňových situací. Vzhledem k míře ovlivnění krajiny a zejména regulaci všech vodních toků je model návratu k meandrujícím řekám spíše fikcí. Na druhou stranu existují oblasti, kde návrat k původnímu říčnímu vzoru může být realizovaný a obnovená funkce nivy pomůže v problematických režimech vodních stavů. Na závěr je nutné podotknout, že říční systém v Litovelském Pomoraví podléhá neustálému vývoji a pro detailní výzkum celé oblasti je nezbytně nutné získat přesný digitální model terénu (DTM) pro celé území včetně říčních koryt. Technologie použitelná pro daný reliéfu a vegetace (lesní porosty) je omezená na letecké laserové skenování povrchu. Cena vzhledem k daným specifikám i časovému omezení by se pohybovala v řádu milionů korun. Práce svými výsledky může sloužit pro další výzkumy v oblasti CHKO Litovelské Pomoraví.