VEGETATION AND SOIL AT THE TERRACES OF THE DŘEVNICE AND THE MORAVA RIVERS AFTER FLOOD

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Abstract

Šerá B., Cudlín P., Dušek L., Hofman J.: Vegetation and soil at the terraces of the Dřevnice and the Morava rivers after flood. Ekológia (Bratislava), Vol. 27, No. 4, p. 430–445, 2008.

A flood changed the character of the observed flooding terraces in the catchment area of the Dřevnice river and in an adjacent part of the Morava river in July 1997. The changes of the vegetation cover, selected soil parameters, and soil contamination were investigated before and after the flood. Changes of the vegetation cover were more perceptible in the human-modified part of the catchment area. The response of aboveground plant biomass to the flood was of various characters and took different time in dependence on the height of the water column, duration of flood, height of sediment and its structure. Inundation promoted propagation of both ruderal (R and CR strategists) and invasive species. However, many competitive plant species (C strategists) were promoted by the floods, too. Ruderal plants appeared mostly one year after the flood, while new invasive plants appeared often just three months after the flood. Almost all of vegetation changes have a reverse character in the investigated area. The changes of the soil properties were not evidently connected with changes of the plant communities. However, a significant increase of heavy metals and PAHs contamination in the soils was observed.

Key words: flood, vegetation change, invasive plant, life strategy, soil parameters, soil contamination

Introduction

Flood events belong to natural disturbances, which typically remove some or all organisms from an area and initiate a sequence of successive processes resulting in gradual recovery of initial ecosystem properties (Lake, 2000). Different plant associations at various distances from the river are affected by the flood in different ways (in connection with flood duration, soil erosion, egestion of upper soil horizons, height of the water column, deposited sediments, toxic substances in sediments). Their subsequent responses are also different (MacMahon, 1980; Merritt, Cooper, 2000).

The investigation of the relationship between the flood and vegetation is complicated by following changes in the composition of flora, number of species, cover of dominant plants, life form of plants, life history of plants, vegetative spread, etc (Hupp, 2000). It may cause minor or major fluctuation of some plant community covers with the same of species composition (Uherčíková, 1998). Seed dispersal is possible only from the upper to lower part of the river during flood. Fast seed dispersal in flooding terraces is possible only after water decline. As a rule, these annual plants (genus *Chenopodium, Atriplex, Bidens, Echinochloa* etc.), germinate promptly and can temporarily change the vegetative character of flooding terraces during several weeks or months. Each plant association tends to return to the primary state in a varying time period.

The flood even had a visible impact on riparian vegetation and soils. The reaction of riparian vegetation to catastrophic flooding was described several times (Hawkins et al., 1997; Kozlowski, 2000; Bloom, 1999; Uherčíková, Hajdúk, 1997). The examples of changes of the soil properties after flood events are also known (Brunet, 1997; Brunet, Astin, 1996, 1998, 1999, 2000; Brunet, Gazelle, 1995; Fabre et al., 1996; Lockaby et al., 1996). Also, incidents of flood - induced contamination of the ecosystem with PAHs (Bierawska et al., 1999; Witt, Trost, 1999), pesticides (Roy et al., 1995; Sponberg, Martin-Hayden, 1997; Chong et al., 1998), dioxins, and heavy-metals (Stewart et al., 1998; Alberting et al., 1999; Borůvka et al., 1996; Diaz-Barrientos et al., 1999; Martin, 1997; Lehmann et al., 1999) have been often described.

A catastrophic flood occurred in the Morava River basin in July 1997 (e.g. Uherčíková, Hajdúk, 1997). This extreme flood event caused an inundation of the banks for several days and water discharges actually measured were close to the ones observed once in 100 years. The flood was classified as a rare hydrological event (CHMI, 1998). The majority of the riparian parts of the rivers in the basin were flooded for several days.

We have executed a research at plots in the Dřevnice River basin and an adjacent part of the Morava river since the spring of 1997. The vegetation cover, soil chemistry, soil physics, and soil contamination data were measured just before the flood event. We concentrated on flood impact research after the flood in July 1997 due to the existence of unique data measured before and after the flood. The aims of this paper were a description of vegetation (damage of biomass, species, association levels) and soil (texture, chemistry – above all pollutants) changes after flood.

Methods

The investigation of vegetation, flood parameters, and soil changes was performed along an altitude transect from 180 to 362 m a.s.l. (II. VI. river ranks) in the Dřevnice catchment area and on an adjacent part of the Morava river since spring 1997. Nature condition of the investigated area is more detailed described in Šerá and Cudlín (2001) and Šerá et al. (2002). Fourteen permanent plots ranging in area from 24 to 150 m^2 were laid out in the different flooding habitats (Fig. 1). All permanent plots were affected by different flood parameters (height of water column,

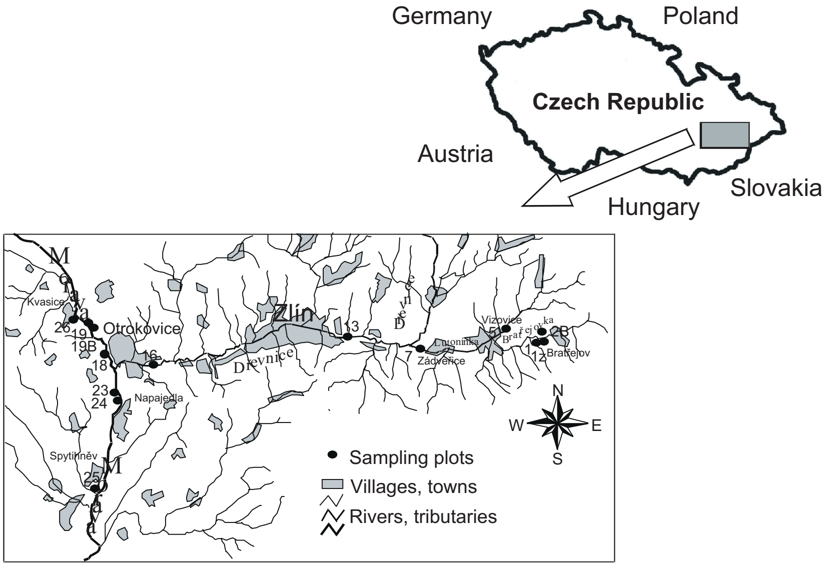

Fig. 1. The map of the fourteen plots of the soil sampling and vegetation research situated in the Dřevnice and the Morava basins.

height and structure of deposited sediments, flood duration, and erosion, in Šerá, Cudlín, 2001) during the flood in 1997. The recording of plant species occurrence and herbaceous cover was performed two months before, three months after and fourteen months after the flood in 1997.

We investigated four features of the vegetation response to the flood. Types of inspected plant communities are described in Šerá, Cudlín (2001). Visual investigation of the damage to the aboveground herbal biomass was performed. Three disturbance types of aboveground plant biomass were distinguished: A – without changes, B – damage of aboveground plant biomass and its fast following regeneration, C – damage of aboveground plant biomass and its successive regeneration. Successive change of vegetation (changes of plant cover, dominant species, and plant communities) was inspected. The occurrence of invasive plant species was recorded. In addition, research of Grime’s life strategy of plants and their occurrence in dependence on the flood in 1997 was carried out.

All plant names used were unified according to Marhold and Hindák (1998), phytocoenological associations to Moravec (1995), and Grime’s life strategy to Grime et al. (1988) and to Frank and Klotz (1988).

Soil samples were taken from the below-turf layer in permanent plots (depth 0–10 cm) two months before and three months after the1997 flood. Several sub-samples from each plot were mixed and homogenized, dried at laboratory temperature and sieved (2 mm) before analyses. Basic soil characteristics were determined which may influence the mobility of pollutants in the soil profile: soil reaction (pH), organic carbon content (Corg), total soil nitrogen (Ntot), $CaCO_3$ content, fractionation of humus substances (HA: FA), cation exchange capacity (CEC), clay content, and soil texture. Basic soil parameters were determined according to the standard operational procedures: total organic carbon content TOC (ISO 14235, 1998), total soil nitrogen Ntot (ISO 11261, 1995), soil pH_{KCl} and pH_{H2O} (ISO 10390, 2005), particle size analyses (ISO 11277, 1998). Humic compounds were extracted by sodium pyrophosphate and separated to humic and fulvic acids (HA and FA). Cation exchange capacity CEC was calculated as a sum of chemical equivalents of H^+ (from pH), Ca^{2+}, Mg^{2+} (by FAAS), and K^+ (by FAES) in soil extracts by Mehlichs II extractant.

T a b l e 1. Supposed response of the aboveground plant biomass in different types of vegetation on floodplain with different disturbance after flood, observed in the Dřevnice drainage area and in the adjacent part of the Moravia river in 1997 – 1998 (A – without changes, B – damage of aboveground plant biomass and its fast following regeneration, C – damage of aboveground plant biomass and its successive regeneration).

Flood disturbance			Reaction of terrace vegetation		
type	column [cm]	time [days] / structure [mm]	flooded forests	flooding terraces	alluvial meadows
water	low [< = 20]	short-term [< = 3]	A	A	A
		long-term [> 3]	A	A	B
	high [> 20]	short-term [< = 3]	A	B	B
		long-term [> 3]	B	B	C
sediment load	low [< = 5]	fine-grained [< = 2]	A	A	A
		coarse-grained [>2]	A	B	B
	high [> 5]	fine-grained [< = 2]	B	B	B
		coarse-grained [>2]	B	B	C

A soil concentration of heavy metals (Cd, Cr, Hg, Ni) was determined after aqua regia extraction (ISO 11466, 1996) of the soils using AAS. For organic pollutants, all soil samples were extracted with dichloromethane in Soxhlet extraction. Fractionation and clean-up was achieved on a silica gel columns; a sulphuric acid modified silica gel column was used for PCBs/OCPs samples. Samples were analyzed using a GC-MS for 16 US EPA PAHs (ΣPAHs), seven indicator PCB congeners (PCB 28, PCB 52, PCB 101, PCB 118, PCB 153, PCB 138, PCB 180) (ΣPCBs), p,p'-DDT, p,p'-DDD, and p,p'-DDE (ΣDDTs), α-, β, γ-, δ-hexachlorocyclohexanes (ΣHCHs) and hexachlorobenzene (HCB). Recoveries of PCBs, OCPs and PAHs were determined by spiking all samples with the surrogate standards prior to extraction.

Result and discussion

Damage of aboveground biomass

Disturbance type of the investigated plots is described in Table 1. Aboveground biomass was visually observed mostly without changes in the periphery of the flooded forests. The plant communities *Alno-Ulmion, Convolvulo-Agropyrion,* and *Petasition officialis* were recorded there. The aboveground biomass in the flooding terraces under ruderalisation process (often *Aegopodion podagrariae*) were damaged after the flood. Regeneration of plant was quite fast (3 months) in this habitat. The plots with heavy damage of herbaceous biomass were observed in alluvial meadows (*Alopecurion pratensis* or *Arrhenatherion*). Each of the plant communities in these three types of habitats tended to return to the primary conditions in different time periods (Uehlinger, 2000). Changes in plant cover were dialled only in the upper parts of the catchment area (10%); lower parts (river ranks V.–II.) were without cover changes. This result is in relation to a flood stress impact describing in Šerá and Cudlín (2001). The supposed response of three frequently observed habitat types to different flood conditions is shown in Table 2.

T a b l e 2. Response of plant communities in flooding terraces of the Dřevnice drainage basin and the adjacent part of the Morava river in 1997–1998.

River names	Tributary of Bratřejovka	Bratřejovka	Lutonínka	Dřevnice	Morava
Elevation	362 [m a.s.l.]	360 [m a.s.l.]	255 [m a.s.l.]	190 [m a.s.l.]	190 [m a.s.l.]
River rank	VI.	V.	IV.	III.	II.
Starting position, one month before flood June 1997	*Calthion* E1 = 95%	*Petasition officinalis* with *Brachypodium sylvaticum* E1 = 100 %	*Aegopodion podagrariae* E1 = 100%	*Arrhenatherion* s with transition to *Aegopodion podagrariae* E1 = 100%	*Phalaridetum arundinaceae* E1 = 100%
Three months after flood October 1997	*Calthion* E1 = 85%	*Petasition officinalis* with *Impatiens glandulifera* and *Brachypodium sylvaticum* E1 = 100%	*Bidention tripartiti* E1 = 100%	*Bidention tripartiti* E1 = 100%	*Bidention tripartiti* E1 = 100%
Fourteen months after flood September 1998	*Calthion* E1 = 95%	*Petasition officinalis* with dominance of *Impatiens glandulifera* and *Urtica dioica* E1 = 100%	*Aegopodion podagrariae* with transition to *Bromo – Hordeion murini* E1 = 100%	*Aegopodion podagrariae* with transition to *Arction lappae* E1 = 100%	*Phalaridetum arundinaceae* wit species of *Sisymbrion officinalis* E1 = 95%

Anthropic stress of the landscape →

Time ↓

Successive change of vegetation

The investigation of plant community changes led to the description of four response types. The first type included almost unchanged phytocoenological associations were observed in the VI. river rank. Plants growing in the as. *Calthion* changed only cover after flood (Table 2 – tributary of the Bratřejovka river). Unchanged association but changes in some dominant plant cover were registered in the second response type. This type was represented by the as. *Petasition officinalis* (Table 2 – the Bratřejovka river). The third type consisted of a temporary change of the whole plant associations. The as. *Aegopodion padagrariae* and as. *Phaladidetum arundinaceae* were changed during short time to as. *Bidention tripartiti* and than back after about one year. There were not as same species spectrum as before flood in the Lutoninka and the Morava rivers (Table 2). The last type of vegetation reaction was characterized by the particularly chance of the whole association (Table 2 the Dřevnice river).

The response of vegetation to the flood was magnified from the upper to the lower part of the river. Such vegetation is better resistant to flood (successful plant groups were selected during evolution) than more intensively cultivated vegetation along the lower part of the catchment area (Johnson et al., 2000). In the upper parts, the communities can be considered as less affected by human activity connected with the urbanisation and changes of land-use.

Life strategy of plants and flood impact

Monitoring of plant species occurrence before, soon after and one year after the flood enabled us to differentiate six categories of their response to the flood. Only species with clean-cut response (attributed to one or two categories) were included. All these categories and types of life strategies are summarized in Table 3.

Table 3. Grime's strategy distribution of the plant species in plant species response categories to flood impact (response category: 1 - occurrence of species on the plots, 0 - absence of species on the plots. Sequence of numeral characters from left to right: occurrence one month before, three months after and fourteen months after the flood).

Response category	Sequence of occurence	Strategy (%)							Number of species
		C	CR	R	SR	S	CS	CSR	
1	101	64	0	0	0	0	9	27	11
2	111	48	14	0	0	7	14	17	44
3	011	30	50	0	0	0	10	10	10
4	100	20	0	60	0	0	0	20	5
5	001	8	31	38	12	0	4	7	26
6	010	0	78	11	0	0	0	11	9

Category 1: Plant species, which were found before the flood and reappeared as late as one year after the flood (survival due to rhizomes), mostly CSR or CS strategists.

Category 2: Plant species, which were present continuously before and after the flood. They were mostly C strategists, also CSR, CR and CS strategists. It is interesting, that several S strategists (7%) survived the flood disturbance too.

Category 3: Plant species of this category appeared after the flood and were able to survive on the terraces for longer times. CR strategists (50%) formed big part of this category. The other species were C (CS and CSR) strategists. R, S or RS strategists were not present in this category.

Category 4: Plant species, which have not recolonized their localities after the flood, belonged mostly to the R strategy group (60%). However, small species number in this category (n = 5) does not allow us to generalize.

Category 5: Plant species, which were found on the permanent plots as late as one year after the flood, were attributed mostly to the R strategy group (38%), too. However, other species belonged to all remaining plant strategy groups.

Category 6: Plant species, which appeared soon after the flood and then not anymore. Mostly CR strategists were present in this category. Such plants were almost weeds from ruderal habitats. They had short life cycle, robust growth and higher demands on feed resources (e.g. solar energy, nutrient in the soil, water).

C, CR, CS, and CSR strategists were recorded mostly in all investigated categories of plant response to the flood. CS strategists were found less frequently compared to other mentioned strategists. Occurrence of R strategists was significantly dependent on the flood impact, because these plants occurred more frequently after the flood (categories 5 and 6). Most R strategists were recorded one year after the flood. The flood fetched along the seeds of R strategists. Most of these seeds germinated only after winter dormancy.

Invasive plant species and flood

Thirteen invasive species were recorded in the observed territory; one of them (*Bidens frondosa*) is quarantine weed (Hejný et al., 1973). None of them can be described as allochthonous expansionary weed (Jehlík, 1998). Only five species from eight invasive species, which could be attributed to any category of plant response to the flood (see above), appeared after the flood.

Rich occurrence of the species *Galinsoga parviflora* and *Tripleurospermum perforatum* was recorded. These annual plants often grow in all habitats and are a common element of various associations. Frequent occurrence of *Impatiens glandulifera* is more dangerous, because this species has exploded quickly in the last years. It is an annual, but its strategy (height 2 m, a lot of biomass, self- and water dispersal of seeds, long dormancy) is more competitive in comparison to autochthonous species of flooding terraces.

Significant differences among the number of invasive species were found in the upper and lower parts of the Dřevnice catchment area and in the investigated fluvial terraces of the Morava river (statistical test of ANOVA, $F = 4.84$, $P < 0.04$). The average numbers of the invasive species were 0.50 species per plot in the upstream (counted from four localities), 5.75 species in flooding terraces of the lower part of the Dřevnice river (from four localities), and 3.50 species in the fluvial terraces of the Morava river (from six localities). These results correspond with an anthropogenic load of the investigated fluvial terraces. There is not only the extensive industrial complex of Zlín–Otrokovice, but also a huge influence of human activities (deforestation, urbanization, gardens, small patches, etc.) in the lower part of the Dřevnice catchment area. These activities modified the vegetation and opened the space for the dispersal of invasive species.

The catchment area of the Dřevnice river, especially in the lower part, is characterised by the dominant growth of *Reynoutria japonica, Helianthus tuberosus* and *Aster* x *salignus*. These species are perennial and their expanding populations grow not only on the flooded terraces, but also at dumping places, along roads, in barrens, in ruderal places, etc. The dispersal of these strongly competitive species is warning and it is a very important fact in the observed territory (Sher et al., 2000).

Soil properties and their changes after flood

As it can be clearly seen from Table 4, some of the monitored parameters changed significantly. The changes caused by the flood are expressed with "+" and "-" system, that helps to simplify the description of changes. The differences during the flood were compared with representative S.D. of individual parameters obtained for all soils in the monitored area. Only 12 investigated plots were chosen for evaluation of soil changes corresponding to phytocoenological research.

The major soil type found in the examined area is Eutric Gleysol and Fluvi-eutric Gleysol (Table 4). The non-carbonate floodplain sediments form the soil substrate with different grain composition settling on an acidic gravel-sand platform or on Carpathian flysch rocks. At the genesis of floodplain soils, the turf procedure was periodically interrupted by accumulation of humus and mineral material was added. This material originated predominantly from humus horizons of zone soils from the surroundings of the floodplains which were transferred to the floodplains by water erosion on rough slopes as described in van der Peijl and Verhoeven (2000). Besides these lateral flows of material there were longitudinal flows along the rivers described e.g. in Jacobson et al. (2000). Both transport pathways can contribute changes to the soil chemistry, physics, and contamination especially during extreme flood events. There was probably minimal impact of the lateral flows on soil changes during the flood in lower parts of the Dřevnice river and in Morava river floodplain because of the lowland character of the landscape. The accumulated material originated probably from the upper parts of the rivers. An opposite situation probably occurred for Bratřejovka, Lutoninka, and the upper part of the Dřevnice river. Besides a loss of material from the riparian zone, there probably was an accumulation of material from lateral flows due to inclined slopes in the vicinity of the river. All described material flows were extremely amplified by the flood 1997. These flows induced most of the changes of the soil properties.

Although the soil texture is one of the most stable attributes of the soil, there was a shift in the soil texture during the flood. Most of the soils monitored displayed the shift towards

T a b l e 4. Representative physical and chemical properties of the soils (values measured before the flood in June 1997) and their changes after the flood in September 1997 („+ +“ or „- -“ represents significant increase or decrease of the parameter, respectively, that excesses the SD of the parameter; „+“ or „-“ represents increase or decrease, respectively, that excesses the 1/3×SD of the parameter; „=“ represents no significant change of the parameter (less than 1/3×SD of the parameter); bottom part of the table displays the increase or decrease frequency, respectively; HA:FA - humic acids:fulvic acids ratio; CEC – cation exchange capacity; L – loam; SL – sandy loam; CL – clay loam; LS – loamy sand).

Plots	pH(KCl)		Ntot [%]		CaCO3 [%]		Corg [%]		HA:FA		Ca [mmol. kg-1]		CEC [mmol. kg-1]		Clay [%]		Soil type	Texture class	
																		before	after
1	6.70	- -	0.53	- -	0.83	- -	3.23	- -	0.67	+	235	- -	305	=	4.6	+ +	Eutric Gleysol	L	L
2b	6.01	+ +	0.30	- -	0.08	+	2.21	=	0.91	=	123	+	195	=	4.3	=	Fluvi-Eutric Gleysol	SL	LS
7	7.29	=	0.13	+ +	1.28	+ +	1.55	+	0.79	+ +	152	+ +	209	+	3.6	+	Fluvi-Eutric Gleysol	LS	SL
13	7.16	=	0.16	=	1.28	+	1.58	- -	0.77	+	194	=	192	=	3.9	=	Fluvi-Eeutric Gleysol	SL	LS
16	7.26	=	0.22	-	1.23	+	1.68	- -	0.67	+	193	=	188	=	3.3	=	Eutric Gleysol	LS	LS
18	6.79	+	0.21	+	0.20	+ +	2.04	-	0.73	+	112	+ +	324	+ +	4.1	+	Fluvi-Eeutric Gleysol	SL	CL
19	5.31	+ +	0.23	+	0.13	=	2.38	=	0.62	+ +	101	+ +	301	+	6.3	-	Eutric Gleysol	L	L
19b	6.60	+	0.24	=	0.13	+	1.73	=	0.82	+	103	+ +	295	+	4.8	=	Eutric Gleysol	L	CL
23	6.65	+	0.27	-	0.40	+	2.11	- -	0.83	-	120	+	198	-	4.1	=	Eutric Gleysol	SL	LS
24	6.69	+	0.30	-	0.68	+	2.75	- -	0.62	+	181	+	248	- -	5.1	-	Fluvi-Eeutric Gleysol	L	SL
25	6.80	+	0.26	- -	0.50	+ +	2.63	- -	0.76	=	173	+	225	- -	4.3	-	Fluvi-Eeutric Gleysol	L	SL
26	6.68	=	0.30	-	0.28	+	2.03	=	0.68	-	122	+ +	251	=	3.2	=	Fluvi-Eeutric Gleysol	L	LS
Increased		7		3		10		1		8		9		4		3			
Decreased		1		7		1		7		2		1		3		3			

more light soil texture. However, the relative clay content was observed to increase in the upper parts and to decrease in the lower parts of the catchment area (Table 4). Shifts in texture composition could apparently be related to the influence of the flood that brought material from the upper parts of the rivers or from the slopes (see above the principles of material transport). The new material was to some extent mixed with the original sediments. These shift can be ecologically significant, because it is known, that soil texture affects water and nutrient retention (Arshad et al., 1996) and contaminant fates in the soil (Jones, Jarvis, 1981).

Soil pH(KCl) values became more neutral in most samples. Similar trends caused with increased soil moisture were described several times in literature (van Oorschot et al., 2000). Soil pH changes probably correspond with increased Ca content in soils, probably. The important role of pH in the fate of pollutants in the soil is usually connected with low pH values. Any risk caused with pH changes for riparian ecosystem is not probable.

Changes of the mobility and extractability of the soil elements (Ca) induced by short–term flooded conditions are not probable, because these changes were not observed until several week of flooded conditions (Larson et al., 1991). Surprisingly, there was an observed increase of both Ca^{2+} and $CaCO_3$ (Table 5). Our observations contrast the decalcification described for soils subject to waterlogging (van den Berg, Loch, 2000). However, all soil monitored are classified as poorly calcareous, which can be the result of their long-term decalcification. The flood probably brought a new particulate material with higher Ca content. Consequently, the short-term enrichment of the soil Ca can occur. The whole CEC of the soils almost increased, too.

Periodical flooding influences nutrient dynamics in the soils in riparian ecosystems (Spink et al., 1998). Both periodical and one-time floodings were often observed to decrease C and N amount in the soil (Lockaby et al., 1996; Hagedorn et al., 2001). We observed similar results. Total nitrogen content revealed rather inconsistent changes, although it decreased in the majority of soils. A similar trend was also observed in the case of organic carbon content, which decreased almost in all soils. Moreover, it is possible that the gleysols are predisposed to increased carbon and nitrogen losses when flooded, and to increased leachability of carbon and nitrogen from periodically flooded soils (Wang, Bettany, 1995). There was probably the loss of the light organic matter, according to the increase of the HA:FA ratio.

Soil contamination before and after the flood 1997

The soil contaminant levels were compared with the maximum acceptable concentrations for soils published in the edict of the Czech Ministry of Agriculture (1994). There were high levels of Zn and Cd observed at plots 23 and 25 (Table 5). Levels of all heavy metals, with the exception of Hg were increased after the flood in most of the soils (Table 5). Similar observations were described in several studies of the flood impact (Lehman et al., 1999; Alberting et al., 1999; Diaz-Barrientos et al., 1999). The highest increases of metal content were observed rather in Morava riparian plots (plots 19b, 23), caused probably by possible sources of contamination in the upper parts of the river basin. Increased heavy metal levels

T a b l e 5. The soil contamination with selected heavy metals and persistent organic pollutants before (B – in June 1997) and after (A – in September 1997) the flood 1997. Only the differences exceeding the 1/5 × SD of concentration for heavy metals and 1/3 × SD of concentration for POPs are scored.

Plots	Zn [mg.kg-1]		Pb [mg. kg-1]		Cr [mg. kg-1]		Ni [mg.kg-1]		Cd [mg. kg-1]		Hg [mg. kg-1]		ΣPAHs [ng. g-1]		ΣPCBs [ng. g-1]		ΣHCHs [ng. g-1]		ΣDDT [ng. g-1]		HCB [ng. g-1]	
	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A
1	78.4	81.4	23.4	24.5	44.7	46.3	47.3	52.8	0.32	0.30	0.08	0.09	259	388	12.4	3.5	1.1	0.6	1.2	0.7	1.8	1.1
5	61.4	83.6	10.0	18.6	33.6	52.6	31.8	50.4	0.11	0.21	0.03	0.09	2 975	1 733	17.8	14.5	0.9	1.2	2.9	2.9	2.5	2.2
7	73.7	86.1	14.1	21.7	20.6	27.5	29.5	37.3	0.13	0.18	0.05	0.06	4 297	16 538	35.6	23.6	1.7	0.4	8.8	63.8	4.0	3.4
13	75.9	86.4	16.8	16.8	29.7	28.5	34.5	32.3	0.18	0.23	0.07	0.05	5 321	12 853	43.5	41.6	1.2	2.6	41.6	12.8	4.7	35.3
16	86.3	83.3	14.4	14.7	30.3	28.2	25.0	22.0	0.23	0.25	0.14	0.12	19 263	9 968	84.8	48.9	3.9	2.7	10.2	4.2	12.2	3.3
18	96.3	169.0	19.5	22.8	31,0	43.7	27.3	40.0	0.33	0.45	0.19	0.20	2 604	8 078	19.9	37.7	1.0	0.5	11.1	7.2	4.4	2.9
19b	75.9	192.0	18.6	25.9	29.7	75.3	25.2	62.8	0.33	0.39	0.13	0.29	1 122	8 684	9.6	24.0	3.7	0.8	4.3	6.6	3.4	2.9
23	89.1	136.8	23.1	19.2	41.3	63.5	29.3	27.5	0.23	0.33	0.12	0.24	12 587	12 822	20.5	345.8	1.3	5.3	8.0	11.6	6.7	7.8
24	110.5	123.5	22.2	22.1	55.5	53.4	34.3	28.3	0.63	0.55	0.17	0.15	6 659	11 592	91.2	71.5	1.6	1.2	7.5	26.3	8.7	3.3
25	182.0	143.0	29.0	24.5	118.8	96.7	33.8	34.3	1.10	0.55	0.35	0.19	9 007	14 190	108.7	67.5	3.2	2.6	12.6	7.1	20.1	3.4
26	82.5	110.0	15.6	20.5	75.6	31.8	25.8	30.0	0.21	0.33	0.14	0.17	1 562	7 507	43.1	57.9	0.9	1.6	3.7	105.4	4.3	3.3
Increased	8		6		5		6		7		4		7		1		3		1		1	
Decreased	1		2		2		3		2		3		1		2		5		0		3	

can constitute a risk for riparian ecosystems, especially if connected with increased metal mobility in soil profiles affected by flooding as described in Borůvka et al. (1996).

The changes of the levels of persistent organic pollutants (POPs) in the soils were also often founded to be significant (Table 5). Acceptable concentrations of the PAHs were exceeded in all soils with the exception of plot 1. PCBs content in soils was higher only at plots 16 and 25. HCH and DDT contents were not above the limit in any soil. The positive changes of soil concentrations of PAHs, as well as negative changes of PCBs and pesticide concentrations were observed. The PAHs levels increased up to eight times in the soils, as observed in plot 19b. Bierawska et al. (1999) and Witt and Trost (1999) described increases of the PAHs levels in soils affected by catastrophic flood, too. However, they observed that PAHs and C_{org} contents were positively correlated, whereas there was a negative relationship recorded in our research. The PCBs and also pesticides content in soils decreased in most of soils after the flood. No similar decreases were described in studies of pesticides in flooded sites (Chong et al., 1998; Roy et al., 1995). However, there was an extreme increase of PCBs and pesticides recorded at plot 23. Moreover, the DDT content in soil from plot 26 was increased 30 times after the flood.

Summary

The 1997 flood that occurred in the Morava basin gave us the unique possibility to study the changes of riparian ecosystems during the extreme flood event. The flood apparently changed the vegetation of the flooding terraces and it revealed the impact on soil properties and contamination. Changes of the vegetation communities were more perceptible in the human-modified part of the catchment area. The response of vegetation to the flood was magnified from the upper to the lower part of the river. In the upper parts, the plant associations can be considered as less affected by man activity. Inundation promoted propagation of both ruderal (R and CR strategists) and invasive species. However, many competitive plant species (C strategists) were promoted by the flood, too. Ruderal plants appeared mostly one year after the flood, while new invasive plants appeared often just three month after the flood. Almost all of the vegetation changes have a reverse character in the investigated area.

The soil properties changed significantly after the flood. Especially, there were an increase of Ca and a decrease of carbon and nitrogen content in the soils observed. The clay content in soil was changed after the flood, dependency on the type of investigated terraces. In short, there were probably occurred both retention of the particulate material and loss of soluble materials. However, the possibility that these changed soil properties impacted the vegetation cover during the monitoring period is negligible. Moreover, we can expect that the majority of the possible stress experienced by plants growing on the floodplain is due to other than soil factors.

The heavy metal content in soils increased at most of plots after the flood. Generally, the heavy metal levels were below the acceptable limits. There was observed strong contamination by persistent organic compounds of the floodplain soils. Concentrations were often above the maximal permissible levels for the agriculture soils in the Czech Republic. PAH content was increased after the flood, while the PCB and pesticides content decreased in most soils. However, we agreed with the known fact that the flood had a strong impact on the soil contamination status. There was no plain trend of a relationship between characteristics of soil flooding and heavy metal contamination observed.

Translated by D. Simek

Acknowledgements

We are obliged to D. Simek for her linguistic revision of the paper. This work was supported by the GA CR grants No. 526/98/1147, No. 103/99/1470, by the by MSMT project INCHEMBIOL 0021622412, and by the Research Intention of ISBE AS CR No. AV0Z60870520.

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Appendix

Six categories of plant species with specific relation to flood in the Dřevnice catchment area and in adjacent part of the Morava river in 1997–1998. Occurrence in dependence on the flood was documented. Plant species with clear-cut response (attributed to one or two categories) were included.

Category 1. Species, which were found on the permanent plots before flood and one year after flood.

Aegopodium podagraria, Achillea millefolium, Alopecurus pratensis, Anthriscus sylvestris, Arrhenatherum elatius, Asarum europaeum, Bromus inermis, Bromus sterilis, Cerastium holosteoides, Cichorium intybus, Crepis biennis, Dactylis glomerata, Geranium pratense, Lolium perenne, Myosotis nemorosa, Papaver rhoeas, Pastinaca sativa, Phleum pratense, Plantago lanceolata, Sanguisorba officinalis, Symphytum officinale, Veronica chamaedrys, Vicia sepium

Category 2. Species, which grew on the permanent plots before, three months after and one year after flood.

Achillea millefolium, Arctium minus, Astragalus glycyphyllos, Brachypodium sylvaticum, Briza media, Bromus erectus, Carduus acanthoides, Carex nigra, Carex panicea, Chaerophyllum aromaticum, Chaerophyllum bulbosum, Cirsium arvense, Cirsium oleraceum, Colchicum autumnale, Crepis biennis, Dactylis glomerata, Elytrigia canina, Elytrigia repens, Equisetum arvense, Festuca gigantea, Ficaria verna, Filipendula ulmaria, Galeobdolon luteum, Galium aparine, Galium mollugo, Geranium pratense, Glechoma hederacea, Glyceria maxima, Helianthus tuberosus, Holcus lanatus, Humulus lupulus, Impatiens *glandulifera, Juncus articulatus, Juncus effusus, Juncus inflexus, Lamium maculatum, Lathyrus pratensis, Leontodon hispidus, Lolium perenne, Lysimachia nummularia, Lysimachia vulgaris, Lythrum salicaria, Malachium aquaticum, Melilotus officinalis, Mentha longifolia, Petasites hybridus, Phalaris arundinacea, Plantago lanceolata, Poa pratensis, Prunella vulgaris, Ranunculus acris, Ranunculus repens, Reynoutria japonica, Rumex acetosa, Sanguisorba officinalis, Scirpus sylvaticus, Solidago gigantea, Symphytum officinale, Taraxacum sect. Ruderalia, Trifolium arvense, Trifolium pratense, Trifolium repens, Urtica dioica, Vicia cracca, Vicia sepium*

Category 3. Species, which were found on the permanent plots only three months after and one year after flood.

Acer negundo juv., Apera spica-venti, Bidens frondosa, Bidens tripartita, Capsella bursa-pastoris, Carduus crispus, Chenopodium album, Chenopodium ficifolium, Convolvulus arvensis, Conyza canadensis, Echinochloa crus-galli, Galinsoga parviflora, Impatiens glandulifera, Impatiens parviflora, Juncus effusus, Lamium maculatum, Lamium purpureum, Lysimachia nummularia, Medicago sativa, Melilotus alba, Mentha arvensis, Mentha longifolia, Potentilla reptans, Potentilla supina, Prunella vulgaris, Scrophularia nodosa, Sinapis arvensis, Sisymbrium loeselii, Sisymbrium officinale, Sonchus oleraceus, Symphytum officinale, Tanacetum vulgare, Thlaspi arvense, Veronica anagalis-aquatica

Category 4. Species, which grew on the permanent plots only before flood and then were never found after flood.

Centaurea jacea, Festuca pratensis, Lamium album, Leontodon hispidus, Myosotis arvensis, Potentilla anserina, Vicia tetrasperma

Category 5. Species, which were found on the permanent plots only one year after flood.

Acer negundo juv., Alliaria petiolata, Allium scorodoprasum, Alopecurus aequalis, Atriplex nitens, Ballota nigra, Bidens frondosa, Bidens tripartita, Bromus hordeaceus, Bromus sterilis, Capsella bursa-pastoris, Carduus crispus, Cerastium holosteoides, Chamomilla recutita, Chelidonium majus, Chenopodium ficifolium, Chenopodium pedunculare, Chenopodium polyspermum, Conyza canadensis, Daucus carota, Galinsoga cilliata, Galium aparine, Glechoma hederacea, Gnaphalium uliginosum, Holcus lanatus, Hordeum murinum, Impatiens glandulifera, Impatiens parviflora, Lactuca serriola, Lamium maculatum, Lapsana communis, Lycopus europaeus, Matricaria maritima, Melandrium album, Oxalis fontana, Papaver rhoeas, Poa annua, Reynoutria japonica, Rumex maritimus, Setaria glauca, Silene noctiflora, Sinapis arvensis, Sisymbrium loeselii, Sisymbrium officinale, Sonchus oleraceus, Stachys sylvatica, Triticum aestivum

Category 6. Species, which grew on the permanent plots only three months after flood.

Amaranthus retroflexus, Bidens tripartita, Brassica napus, Capsella bursa-pastoris, Chenopodium album, Chenopodium ficifolium, Echinochloa crus-galli, Galinsoga parviflora, Helianthus annuus, Lamium album, Lamium purpureum, Matricaria maritima, Poa pratensis, Poa trivialis, Setaria viridis, Solanum nigrum, Sonchus arvensis, Stellaria media, Thlaspi arvense, Veronica anagalis-aquatica, Veronica persica