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THE HETEROGENEITY OF SOIL PROPERTIES AND BIODIVERSITY IN FLOODPLAIN FORESTS OF SOUTHERN MORAVIA IN NATURAL CONDITIONS AND UNDER ANTROPOGENIC IMPACTS

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Abstract

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Heterogeneity of soil conditions and biodiversity of plant communities of floodplain forests is a result of site conditions and long-term anthropogenic impacts. The aim of the paper was to assess the heterogeneity and properties of organic and organomineral soil horizons and main components of phytocoenoses. The accumulation of organic residues in forest floor shows important heterogeneity in mixed stands of pedunculate oak and ash and also in ash and oak monocultures. The floodplain forest regeneration using a clear-felling system and soil/site preparation by ploughing and accumulation of decaying wood in nature reserves are the most important effects. The chemistry of leaf litter and temperature and moisture conditions of the soil surface condition also the rate of decomposition of organic residues within a year. The litter decomposition proceeds fastest at ash and hornbeam and the largest decrease of organic matter at all kinds of litter occurs in winter. In addition to forest floor, heterogeneity was also assessed of organomineral soil horizons A and the concentrations of C and N and pH values were monitored in the horizons. Although this soil layer was affected by the plant cover and various methods of land use from about the beginning of the 13th century, there are differences conditioned by the present effects of forest management. To assess the plant component of phytocoenoses two series of plant relevés were monitored, namely in the course of time and in area, which made possible to assess the diversity of vegetation from the aspect of changes in the hydric regime of soils and from the aspect of changes in the response to forest management. By means of the analysis of the vegetation composition at the level of species, ecological and other properties of the phytocoenose components relationships were demonstrated between the effect of man and the quantitative and qualitative vegetation heterogeneity.

Key words: floodplain forests, soil heterogeneity, biodiversity

Introduction

Generally, soils of floodplain forests are markedly differentiated according to the place of the alluvia creation as divided by Mezera (1956), namely "lowland floodplains and floodplain vegetation of uplands". Soils of alluvia in upland and particularly mountain drainage basins are characterized by considerable dynamics in the deposition and translocation of soil substrates largely of the gravel composition. Soils of Bohemian and Moravian lowland alluvial plains are created most often on the youngest Holocene and contemporary alluvia of Bohemian and Moravian rivers (Mezera, 1956). The widest alluvial area at the lower reach of the Morava river in southern Moravia occurs at the confluence of the Dyje and Morava rivers.

Processes of the stream change and its drag force, which occur in upland drainage basins and particularly in the mountain foothills nearly permanently are in progress also in lowland areas. Owing to bank erosion, transport and deposition of sediments, creation of meanders, sometimes amply furcated river branches either connected with a main stream or the creation of cut-off meanders and oxbow lakes, which can change even the main stream direction, of course, all this occurs in longer time intervals. Mezera (1956) mentions that the deposition of fine material at floods occurs very quickly at some places in lowland regions as it was found, e.g., in floodplains of the Dolní Pomoraví area at surveying the Strážnice Forest District in 1942. Landmarks set at surveying the forest district in 1901 were found up to 80, 50 and 95 cm under the soil surface at the forest management plan inspection in 1942 and 1943.

In addition to these more or less natural processes including sediments at floods, heterogeneity of the soil environment of lowland alluvia is considerably affected by changes in the groundwater level, anthropogenic effects, particularly river channelization and various methods of management, particularly the regeneration of floodplain forests and changes in their species composition.

Floodplain forests of southern Moravia rank among important ecosystems not only in the Czech Republic but also throughout Europe. Their uniqueness consists in the enormous species diversity of fauna and flora preserved at an area of 9.5 thousand hectares. Geological bedrock consists of recent Holocene sandy to clayey sediments of various thicknesses, mainly 1 to 2 m, and underlying Pleistocene water-bearing sands. The mineral strength of soils corresponds to the geological composition of the drainage area of watercourses. The Dyje river and its tributaries have their drainage area in the area of poor rocks of the Česko-Moravská vysočina upland crystalline complex whereas the Morava river in the flysch area of the Carpathians with rocks rich particularly in calcium. Soils are created by the sedimentation of particles (clayey or coarse particles with various amounts of nutrients and humus) in watercourses and during floods also on a flooded area. On relatively small areas, both shallow and very deep soils occur as well as soils with low porosity and soils showing sufficient porosity. Soil texture largely varies depending on the watercourse speed and distance from the river bed.

The area of a floodplain forest in the Rajhrad game preserve at the Svratka river alluvium can be demonstrated as an example of the soil heterogeneity from the aspect of soil texture in an alluvium area (Fig. 1). We can see that soils of sandy character are distributed around the original river bed where the river drag force was most intense. Thus, loamy and clay-loam soils are distributed in the alluvium wider area.

In addition to the high spatial heterogeneity of soils in floodplain forests considerable vertical heterogeneity of a soil profile has been created owing to the transport and sedimentation of the mineral and organomineral soil material. So called "buried horizons" with an increased content of organic matter are particularly marked. These horizons occur even in several layers tracing the history of the plant cover occurrence and repeated silting by new deposits (vertical grain-size distribution). Prax (2004) mentions that "the apparent monotony of soil conditions created on soil sediments is diversified by so called hrúdy", i.e. mostly sporadic elevations of fine blown sand, which date back to the last glacial period (Ice Age). Thus, they were blown from the surface of Pleistocene river terraces or other surface sediments more than ten thousand years ago. These "hrúdy"(elevations) were often melted to a wider area creating thus suitable site conditions for the occurrence of pine stands.

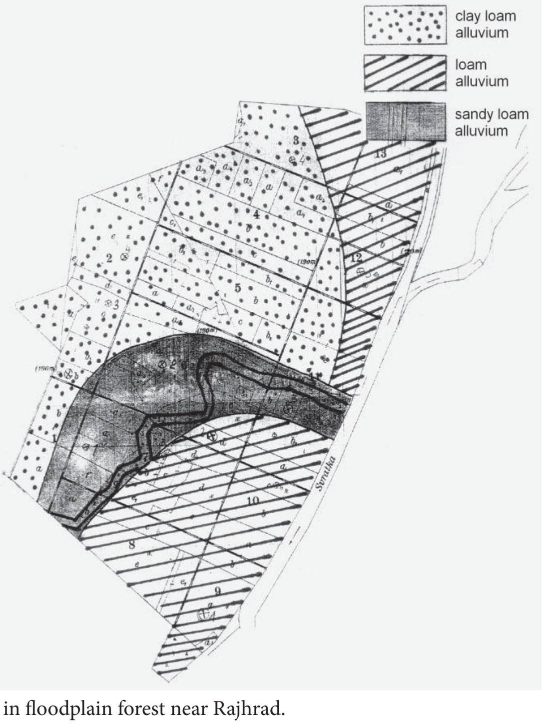


Fig. 1. Texture of alluvium in floodplain forest near Rajhrad.

Heterogeneity of soils is largely demonstrated by the classification of soils particularly at the level of subtypes and varieties (Němeček et al., 2001). Our aim was to assess the heterogeneity of upper soil layers and plant communities at lower levels depending particularly on present anthropogenic factors.

The floodplain forest ecosystems are characterized by favourable temperature and moisture regimes with the high supply of soil nutrients. These factors show favourable effects on the development of plant and animal populations, high biodiversity and fast geochemical cycle (Vašíček, 1985).

Many authors dealt with the floodplain forest vegetation of southern Moravia. It is not possible to omit phytocoenological-typological papers of Horák (1961). Maděra (2001) continued in these papers monitoring vegetation changes in consequence of the changed moisture regime of soils, further Vašíček (1990), Ambros (1992) and Štykar (1993), papers of Vicherek et al. (2000) etc. Examined areas are situated in south-Moravian valley basins at the Dyje and Morava rivers, from the phytogeographic classification in the thermophytic region and from the biogeographic classification in the Dyje-Morava bioregion. The Lednice part occurs in the group of geobiocoene types *Ulmi-fraxineta carpini* inf., the Tvrdonice part occurs at a transition to the group of geobiocoene types *Querci roboris-fraxineta* inf. The aim of our research was to determine diversity at the level of main components of phytocoenoses within the developmental stages of a biocyclocene in relation to forest management and diversity of abiotic conditions.

Although natural conditions of alluvia are affected by man since the Neolithic period (Ložek, 1973, 2007), at present, realization of some water-management measures on the Dyje river has caused disturbances in the natural dynamics of the development of floodplain ecosystems (Buček, Lacina, 1994). Changes in moisture conditions refer to the nature of a waterlogged hydric series. It becomes evident by the recess and disappearance of hydrophilic species and the appearance of a leading hydric series, so called "grove species" (Buček et al., 2004; Maděra, 2001) and changes in the growth of trees (Čermák, Prax, 2001).

Study area

The area of floodplain forests in southern Moravia (Fig. 2) is situated at the confluence of the Morava and Dyje rivers and covers about 15,000 ha. The mineral composition of the soils corresponds to the geological composition of the catchment area the sediments come from. This considerable variability of soils is conditioned by the dynamic processes of alluvium formation and by the diversity of the stand species composition.

The mean annual temperature of 9 °C ranks the region among warmest in the Czech Republic. The mean annual precipitation is 524 mm, which fell to 452 mm per annum in the period after 1973. Altitude: 165 m.

In the studied area, research plots were established with an aim to record main differences in the condition of the soil surface layers:

Plot 1: Lednice na Moravě, altitude 164 m, marked as *Ulmeto-Fraxinetum-Carpineum* (Vašíček, 1985), stand: pedunculate oak (74%), narrow-leaved ash (24%), hornbeam, linden.

Plot 2: Vranovice, altitude 170 m, stand: Slavonian oak (*Quercus robur*) with the dominant vegetation of stinking nettle (*Urtica dioica* L.), up to 80% cover.
Plot 2a: Vranovice, altitude 170 m, an artificially established stand of narrow-leaved ash (*Fraxinus angustifolia* Vahl.), age 25 years.
Plot 2b: Area with clear-felling regeneration of pedunculate oak, soil/site preparation.
Plot 3: National Nature Reserve Ranšpurk and an additional plot in a neighbouring commercial forest.
Plot 4: National Nature Reserve Cahnov and additional plots in a neighbouring commercial forest.
Plot 5: Tvrdonice, a plot with ash and plots reforested with pedunculate oak.

Vegetation developmental stages of a floodplain forest were studied in the "Lednice" research area and its surroundings and on plots in Forest District Tvrdonice. The Lednice part consists of one plot (Plot 1) in a closed mature stand of a natural composition (marked L1) and three plots on clear-felled areas in adjacent parts (marked L2, L3, L4), which can be considered as parallel plots. The first plot is placed in the oldest "clearing" where trees already begin to appear; however, undesirable trees are suppressed using silvicultural measures. The second plot was established on a clearing where a target species was planted (pedunculate oak) the clearing being rather young for the vegetation. The third plot was placed on a newly felled clearing yet without the presence of new woody vegetation coming from any origin. The Tvrdonice part (Plot 5) consists of three plots: the first one is situated in a mature stand (marked T1) open through regeneration processes, the second one occurs in a thicket of an artificially established stand (alternate forest and farm crops) of pedunculate oak (marked T2) and the third plot was established in a closing thicket of the same oak stand, however, without farm forestry in the past (marked T3).

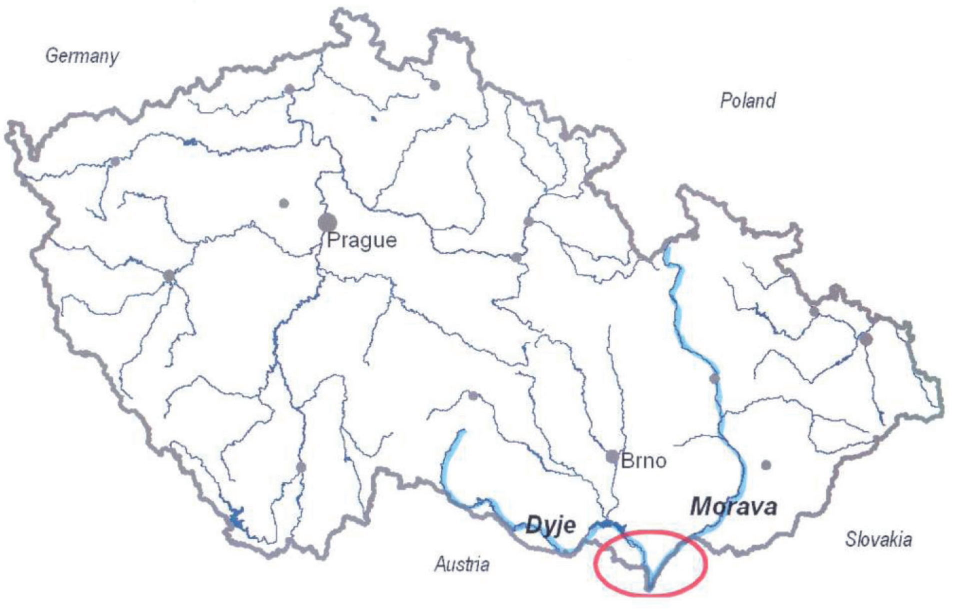


Fig. 2. Study area.

Methods

1) Determination of the organic matter accumulation in forest floor: plot 50x50 cm, in 5 or 10 repetitions, desiccated at 60 °C, weight determined in kg/ha.
2) C and N in forest floor samples: finely ground samples in the LECO CNS-200 (MI USA) analyzer.
3) Soil reaction measured using the OP-208/1 digital pH meter.
4) Statistical evaluation of data in the Statistica program (Stat-Soft Inc., Tulsa USA).
5) The study of biodiversity. Phytocoenological relevés (Zlatník, 1978; Randuška et al., 1986) were a basic tool for the collection of data on vegetation. Information concerning properties of plant species was adopted from Ambros and Štykar (2004). Vegetation indices were determined according to papers of Jurko, Moravec and Slavíková (Jurko, 1990; Moravec et al., 1994; Slavíková, 1986). To calculate ecological spectra and characteristics of a non-ligneous understorey the plant cover was used. The calculation was implemented by means of the geobiocoenological database program "TYP". At the ecological evaluation of the vegetation cover it is possible to start from a fact that there are certain relationships between the vegetation composition and the abiotic environment (Ambros, 1987). Therefore, the method of phytoindication is used in this paper. Nevertheless, it is necessary to take into consideration that plants demonstrate conditions of that part of the biocoenose space/area where their organs occur (Zlatník, 1978). Various authors try to express indication possibilities of plant species by means of symbols (letters, digits or signs) on the basis of knowledge of their behaviour in the field (Zlatník, 1970, 1978; Ellenberg, 1992; Ambros, 1986; Ambros, Štykar, 2004 etc.). These examinations use partly also data determined by physical or chemical analyses. The application of ecological or vegetation characteristics (ecological groups of species, life forms etc.) is based on the degree of cover of particular species with corresponding properties. The Zlatník scale of plant cover is used (Zlatník 1953 ex Randuška et al., 1986), which is the adapted scale of Braun-Blanquet.

Results and discussion

Heterogeneity of organic and organomineral soil horizons

The weight of forest floor

Generally, the form of forest floor in a floodplain forest is mull but owing to local conditions and particularly due to the species composition of forest stands and methods of management (methods of forest regeneration), it shows various dynamics of decomposition processes, which reflects also in the quantity and properties of this layer (Fig. 3).

For the more exact determination of the forest floor accumulation we used to determine its weight in kg DM per ha. Due to relatively intensive decomposition processes marked changes occur at forest floor in floodplain forest during the year. Klimo (1985) quantified this factor in an oak-ash stand on a plot predominated by oak and on a plot predominated by ash:

Date of sampling	$t.ha^{-1}$ DM of leaves and detritus	
	oak	ash
1 December 1972	4.3	6.9
1 April 1973	2.9	4.0
1 July 1973	2.4	2.1
1 October 1973	2.1	0.7

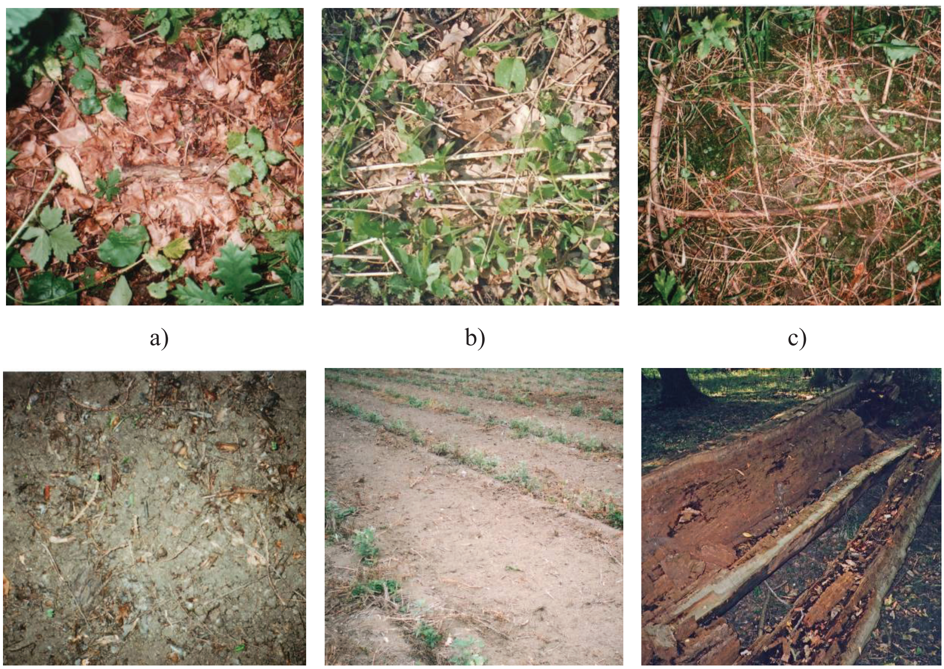
These changes are even more marked if we assess only the fall of leave weight because detritus appears to be the more stable component of forest floor. On the same plot, Klimo (1985) noted the mean weight of forest floor 6.2 t.ha^{-1} (maximum value after leaf-fall) and 2.3 t.ha^{-1} as a minimum value before the start of new leaf-fall.

In 2006, we determined the maximum weight of forest floor layers on the same plot (Plot 1), which is much higher than values determined in 1972:

Layer L1 (new leaf litter)	1.86 t.ha^{-1}
Layer L2 (last year's leaf litter)	2.84 t.ha^{-1}
Layer F (detritus)	3.86 t.ha^{-1}
Σ	8.57 t.ha^{-1}

Layer L1 consists of new leaf litter, which means that the annual minimum value is 6.7 t.ha^{-1}. This value is very high and we can state that it was affected by the deposition of organic material at spring floods in 2006 when flood water carried away large amounts of leaves and particularly detritus, which was evident at a value of detritus (3.86 t.ha^{-1}).

It means that also within a relatively homogenous mixed stand, considerable hoterogeneity of the forest floor accumulation can occur due to biogroups of trees dominated by oak



a) b) c)

d) e) f)

Fig. 3. Forest floor: a) oak-ash stand, b) oak stand with the stinking nettle cover, c) ash stand, d) hornbeam stand, e) clear-felled area, f) decomposing wood in a nature reserve.

and ash as well as owing to the transport and deposition of organic material at the flood water flow.

For the purpose of comparisons values of weight of forest floor were determined in a pure pedunculate oak stand (Slavonian oak) with the marked undergrowth of nettle, a younger ash monoculture (aged about 30 years) and areas regenerated using a clear-felling system (Plots 2, 2a, 2b).

The maximum accumulation 6.8 $t.ha^{-1}$ of forest floor in the Slavonian oak stand did not markedly differ from a stand in Plot 1 (oak, ash). Similarly, a maximum value (before the start of new leaf fall) 4.9 $t.ha^{-1}$ if we deduct stalks of nettle from the value 2.3 $t.ha^{-1}$, the minimum supply is again consistent with the oak-ash stand as determined in 1972 (Klimo, 1985). Different situation was noted in the ash stand (Plot 2a) where the maximum value of forest floor was 2.68 $t.ha^{-1}$ (2.38–2.68 $t.ha^{-1}$), in May of the following year, the value amounted to 1.6 $t.ha^{-1}$ and before new leaf fall, only residues of ligneous litter and leaf petioles occurred on the soil surface.

The condition of surface humus in forest reserves Ranšpurk and Cahnov was also compared with surrounding commercial stands. In the Ranšpurk reserve, Vrška (2006) described rather marked heterogeneity of forest types and plant communities. The surface humus in both reserves was described as fast decomposing mull. At sampling surface humus (L1) in the Ranšpurk reserve in a summer season the mean value of 2871 $kg.ha^{-1}$ was determined. This value did not markedly differ from values in a neighbouring commercial stand of oak, namely 2992 $kg.ha^{-1}$.

Of course, basic differences between the reserve and the oak commercial stand consist in a fact that the given summer sampling was noted particularly at places with the occurrence of old oak trees and rather considerable part was covered by decomposing stems markedly affecting the soil surface.

Even more marked condition of the surface humus was noted in the Cahnov reserve (sampling on 3 October 2007) when the understorey of old oak trees consisted particularly of hornbeam. In this autumn season, the layer of forest floor did not already occur on the soil surface. The same situation was found in the commercial forest of a hornbeam monoculture where only residues of dry fallen hornbeam branches lay on the soil surface. Of course, the long-term marked removal of surface humus is caused by the clear-felling regeneration of a forest and following prospective farm forestry. For example, on the Tvrdonice clear-felled area reforested by oak, the continuous cover of forest floor originates after about 10 years.

As for the forest floor heterogeneity we can remark that the main factor is the species composition of forest stands, which is furthermore emphasized by the creation of pure stands as a result of the clear-felling regeneration of a forest. The importance of differences particularly between stands of oak and ash is also demonstrated by the dynamics of decomposition processes during the year as determined by the method of litter bags. It has been found that the fastest decomposition of litter in a floodplain forest occurs, generally, in ash and hornbeam stands during the winter season (Table 1).

T a b l e 1. The percent of the organic matter loss after decomposition during the year.

Date of measurement	% loss		
	Mixed stand of oak and ash	Oak with the undergrowth of nettle	Ash
11/12	100	100	100
15/3	48	60	75
15/6	51	62	81
15/9	66	64	92

C and N concentration of forest floor

Heterogeneity of C and N concentration in forest floor becomes evident both vertically in layers L1, L2 and F, which is dependent on decomposition processes and in space/area depending on factors, which manifested themselves also on values of the forest floor accumulation. As an example of vertical heterogeneity we mention values from Plot 1 (mixed forest of oak and ash) and values from Plot 2 (oak with the undergrowth of nettle) (Table 2).

T a b l e 2. C and N concentration in forest floor layers.

Locality	Forest floor layer	%	
		C	N
Plot 1 – mixed stand of oak and ash	L 1 L 2 F	46.3 43.9 36.6	1.45 1.84 1.87
Mean		42.1	1.7
Plot 2 – oak stand with the undergrowth of nettle	L 1 L 2 L 2*	45.6 41.9 44.2	1.2 1.2 1.3
Mean		43.9	1.2

Note: L 2* – stalks of nettle.

Table 2 shows different trends with the increasing decomposition of organic residues of carbon and nitrogen. C concentration in layers L1, L2 and F gradually decreases while N concentration increases although, in case of Plot 2, nowise markedly. Higher concentrations of N in Plot 1 are evidently affected also by the presence of ash litter.

The space heterogeneity of the C and N concentration in forest floor samples was determined at randomly selected samples of litter taken on Plot 1 from the L1 horizon where leaves of oak and ash were sorted separately.

Because it refers to a mixed stand it was necessary to set aside other species from observation in order to able to compare results obtained with samples from Plot 2 and Plot 3. At Vranovice, leaves from Plots 2 and 3 were sampled and stalks of nettle were analysed. The content of carbon and nitrogen was determined. At samples from Ranšpurk, mixed leaves of litter (*Quercus* sp., *Carpinus* sp., *Acer* sp.) were sampled and analysed.

T a b l e 3. The content of C, N and C/N in forest floor samples .

Plot	L layer		
	N %	C %	C/N
1 Lednice – mixed stand (*Quercus* sp.)	1.18	50.40	42.70
1 Lednice – mixed stand (*Fraxinus* sp.)	2.05	49.90	24.40
2 Vranovice – oak (*Quercus* sp.)	1.35	50.68	37.70
3 Vranovice – ash (*Fraxinus* sp.)	1.46	42.82	29.46
4 Ranšpurk – reserve	1.77	45.70	26.20
5 Ranšpurk – commercial forest	1.46	46.80	32.09

Data in Table 3 show higher values of N in the L1 layer of ash as compared with oak and thus also more favourable C/N ratio. C concentration does not prove marked differences. Results from the Ranšpurk reserve show more favourable data on the concentration of N and C/N ratio as compared with the surrounding oak commercial forest.

Concentrations of C and N and pH values of soil A horizons

At the evaluation of heterogeneity of upper organomineral soil horizons it is necessary to start from a fact that their properties are conditioned by the long-term development of sedimentation processes on the one hand and, on the other hand, by actual effects, particularly by the economic exploitation of the area by man. The main sedimentation of loamy soils through levelling the broken relief culminated with the start of colonization and deforestation of extensive areas of uplands (Poláček, 1999) as from the 13^{th} century. In the alluvium of the Morava and Dyje rivers, land use markedly changed. The species composition of forest stands partly changed as well as their area, there were extensive meadows and pastures and arable land. These facts affected the character of the upper soil horizons.

T a b l e 4. Concentration of C, N and pH values of A horizons .

Plot	Stand	C %	N %	pH H_2O
1 – Lednice	mixed stand of oak and ash	7.0	0.56	5.6
1a	clearing, 1 year	4.7	0.55	5.7
1b	clearing, 2 years	1.3	0.12	6.6
2 – Vranovice	oak stand	3.7	0.23	7.3
	ash stand	4.2	0.37	6.9
	clearing	4.2	0.24	7.4
Tvrdonice	ash – 90 years	9.4	0.69	6.1
	clearing – oak 8 years (no forest farming)	3.4	0.30	6.8
	clearing – pedunculate oak (forest farming)	4.3	0.32	6.6
Ranšpurk	reserve	12.8	0.84	6.3
	decomposing stems	37.5	1.41	4.9
	commercial forest (oak)	10.2	0.81	6.2
Cahnov	reserve	7.3	0.6	6.6
	decomposing stems	31.3	0.9	5.7
	commercial forest (hornbeam)	7.1	0.5	6.5

The heterogeneity of properties of actual horizons is very high. The variation coefficient of carbon and nitrogen concentration is 52 and 48%, respectively. The variation coefficient of pH values is 10.5%. Decomposing wood in forest reserves shows the greatest effect on the content of carbon. Its concentration reaches about 30% there. Among stands of the various species composition, the concentration ranges between 7 and 12%. Significant differences occur only as compared with upper soil horizons of clearings where values of C concentration range within the limits 1–4%.

Nitrogen concentrations in A horizons range between 0.12 and 0.24% on clearings, particularly in the first years after regeneration and under stands of various species composition without significant (0.8–0.6%) differences. The highest concentration occurs again under decomposing stems (1.4–0.9%).

There are no significant differences among stands of various species composition. They range mostly within the limits 5.6–6.9 pH. A moderate trend of decreasing the pH values show A horizons at Plots Vranovice with the undergrowth of nettle where pH values range from 6.9 to 7.4 including a clearing (Table 4).

Heterogeneity of main components of a phytocoenose

Vegetation of changed stages under the effect of river regulation

Ecologically significant changes can be monitored by means of phytoindication with respect to the soil moisture regime. Plants demanding soil moisture (wet series) and tolerating flooding recede or even disappear (Fig. 4). It refers to the irreversible change of the floodplain forest environment after the Dyje river channelization if floods are not restored or otherwise replaced. From the aspect of ecological stability, it refers to an example of the ecosystem resistance related to the ecological succession towards drier communities of floodplain forest or forest of leading hydric series.

This condition will exist until new changes in the locality/area water regime will not occur. In consequence of the absence of floods and decreased soil moisture the larger development of a root layer occurs and, thus, the lower access of sunlight to the herb layer synusia.

Mean cover of selected species of the herb layer synusia:

Year	1969	1979	1982	1989	1990
Carex acutiformis	1.4	0.5	0.3		
Carex remota	2.0	1.5	0.6	1.0	0.5
Deschampsia caespitosa	4.8	3.9	3.0	0.5	0.5
Festuca gigantea	4.5	1.0	1.2	0.3	0.1
Iris pseudacorus	1.0	0.2	0.1		
Carex sylvatica	3.5	7.5	5.5	1.8	1.8
Bidens melanocarpus	1.0				
Carduus crispus	0.5				
Lysimachia vulgaris	0.5				
Galium palustre	1.5				

Lycopus europaeus	0.7
Lythrum salicifolia	2.0
Polygonum hydropiper	1.0
Valeria officinalis	0.5

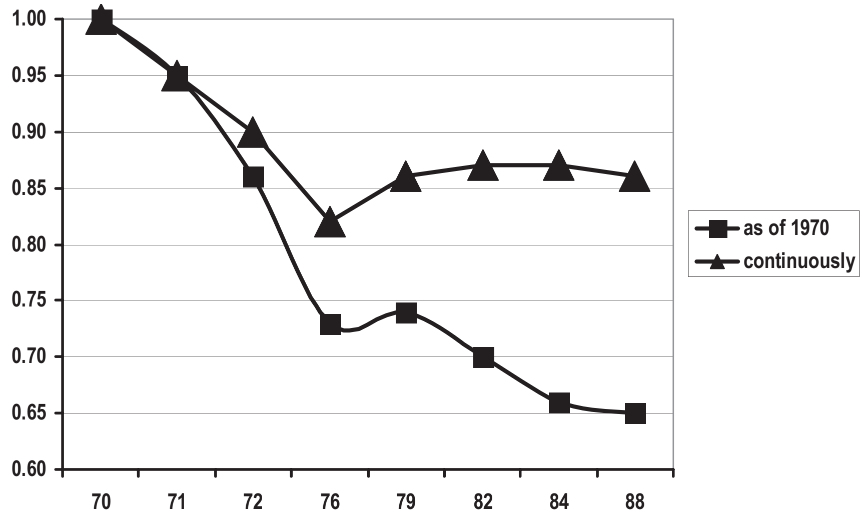


Fig. 4. Indexes of species similarity.

Based on the comparison of species spectra by means of the similarity index (according to Sörensen) it is possible to come to a conclusion on changes in diversity. There are evidently marked differences between years before and after the end of periodic floods. On the other hand, particular years before the termination of floods similarly as years after the year 1979 differ only little with one another (see Fig. 4).

As for a comparison with the initial condition (1969) after the marked fall of the index values of species similarity till the year 1976, further decline is already lower and after 1984, it is nearly imperceptible. This development of the index refers to obvious changes in the floodplain forest environment character after the termination of periodic floods in 1972 and to changes in the composition and structure of the undergrowth synusia with the gradual ceasing the changes in the moisture regime on the research area (sees also Fig. 5).

Vegetation of the ecosystem developmental stages at the site of a hard-wooded floodplain forest under the impact of forest management

The stage of maturity – in the Lednice part (Plot L1), is represented by a pedunculate oak stand (*Quercus robur* L.) with the developed lower storey particularly of small-leaved linden

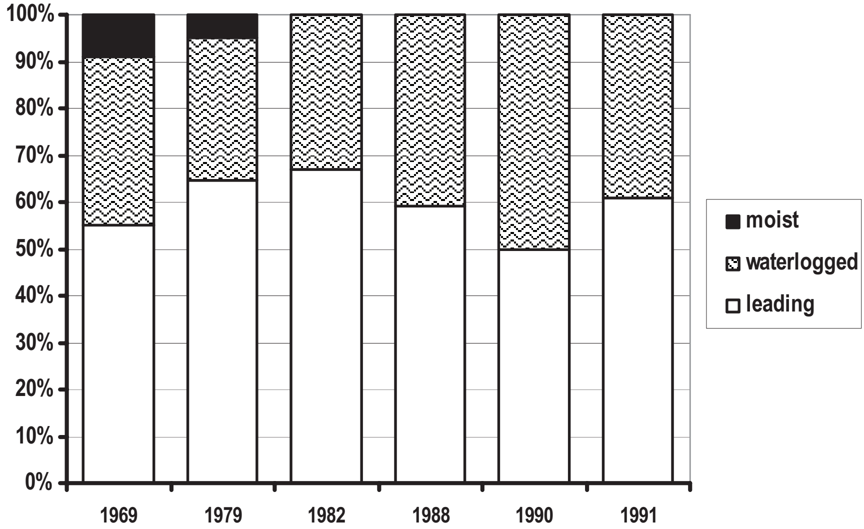


Fig. 5. Indication of moisture conditions.

(*Tilia cordata* L.). Although the storey of oak shows an interrupted or even broken canopy these open places are occupied in the stand understorey (in addition to *Tilia cordata* L. also *Fraxinus angustifolia* V a h l., *Swida sanguinea* L., *Ulmus carpinifolia* G l e d., in advance growth also other species such as *Acer campestre* L., *Euonymus europaeus* L. or rarely also *Quercus robur* L.). Generally, the undergrowth synusia covers 35 or 40% sample plot. At present, it begins to be significantly shaded by higher woody storeys including shrubs. Following dominants or subdominants are characteristic: *Urtica dioica* L., *Lamium maculatum* L., *Geum urbanum* L., *Glechoma hederacea* L., *Pulmonaria officinalis* L., *Stachys sylvatica* L., in spring aspect *Ficaria verna* L., *Corydalis cava* (L.) S c h w e i g g e r et K o e r t e, *Anemone ranunculoides* L., *Veronica hederifolia* L. In total, some 36 species of higher plants were determined, however, as for neophytes, it was only one species, namely *Impatiens parviflora* DC., which did not reach the plant cover negatively affecting the synusia composition or structure (up to 1% plant cover of the whole examined area). The situation was similar in the surroundings of the research plot in the original stand. In the Tvrdonice part (Plot T1), the stage of maturity is demonstrated by a plot in the (oak)-ash stand with the moderate lower storey of pedunculate oak (*Quercus robur* L.). Advance growth is insignificant as for its cover. The undergrowth synusia shows the sufficient amount of light infiltrating through higher storeys of trees covering 100% examined area. Dominant or subdominant species are: *Rubus caesius* L., *Carex gracilis* M.A.C u r t i s and *Glechoma hederacea* L. The proportion of *Stenactis annua* (L.) L e s s. coming from the surroundings disturbed by forest regeneration processes on large clear-cut areas significantly increases. In total, 25 species were determined.

The stage of regeneration – started by the stage of a clear-cut area, namely felling a mature stand of pedunculate oak and narrow-leaved ash with admixed species in the close vicinity of a research plot. A simple vertical structure is characteristic of the stage of regeneration by clear-felling. It means the absence of other storeys of the tree synusia than Storey V (advance growth, self-seeding) or a lower storey of trees. Through the implementation of clear felling the stage of disintegration was replaced during one growing season. The first stage is the initial stage (from preparation through colonization to the synusia development) both under conditions of soil/site preparation or without the preparation (Plots L3 and L4 of the Lednice part). These silvicultural measures cause (from the aspect of undergrowth vegetation) different starting conditions in upper soil layers, however, the ability of plant species (particularly those of ruderal character) to colonize incurred niches is very intense under these conditions of floodplain forests even in case the full-area preparation of site/soil when only a certain time delay occurs as for the cover development of this layer. The advanced stage (Plot L2 of the Lednice part) is a developmental stage when the area is totally covered by vegetation. It is important that both the undergrowth synusia ("non-ligneous") and also the developing synusia of trees participate in this situation. In this developmental moment, these two components occur in the same vertical space and herb, grass and other species create strong competition pressure on the new determinant layer. A period of this pressure can be various being also conditioned by forestry activities. However, the undergrowth synusia remains always a leading power, however, the synusia of trees covers certain, namely even considerable parts of the area (about 20% cover of the tree synusia on Plot L2). As soon as trees begin to overgrowth the undergrowth synusia, species of the undergrowth synusia begin to recede and the reconstruction of its species spectrum will take place in such a way that light-demanding species or species with r-strategy disappear (however, it is not an absolute rule). Once the trees reach closed canopy we can speak about another stage, namely the stage of growing up. Plot T3 in the Tvrdonice part occurs at the turn of these stages.

The stage of growing up is represented by a stand in Plot T2 in the Tvrdonice part. It refers to a young-growth stand with the full canopy of pedunculate oak (*Quercus robur* L.). Lateral light from strips of only closing stand parts significantly penetrates into the thicket. The undergrowth synusia is developed on about 20% research plot with 10 species of higher plants.

Compared to Plot T3, the synusia of trees is already closed and the undergrowth synusia is suppressed as for plant cover and requirements for nutrients, water etc. Moreover, its development (although small) is made possible by a fact that regeneration elements (strips) are of small width. The stand in Plot T2 is an example of the fast transition to the stage of regeneration, namely a clear-felling stage with the time-limited development of the undergrowth synusia in the unsubordinated position toward either a non-existing or only developing sinusia of trees.

Basic structural and species characteristics are given in the following diagram (see Fig. 6).

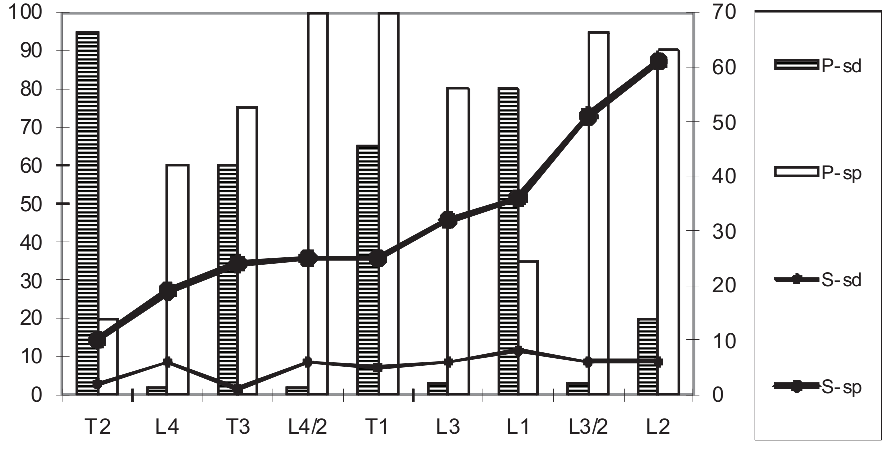


Fig. 6. Cover and number of species of particular synusiae.
Notes: P – cover of the whole synusia, S – number of species of higher plants of the whole synusia, sd – synusia of trees, sp – undergrowth synusia, L1, L2, L3, L4, T1, T2, T3 – research plots, L3/2 – record from the following year, L4/2 – record from the following year.

The smallest number of species can be monitored on plots in the stage of growing up (T2) and on plots approaching the stage (T3) and also on a new clear-felled area where mowing the forest weed was carried out a season ago (L4). In the second year, the number of species increased both on the area of clearings L4 and L3 and the number of species on Plot L3 approaches that on Plot L2, ie an old clearing showing the highest number of species of all monitored plots. It is caused by the occurrence of some species of the original forest stand as well as species of clear-felling stages; the undergrowth synusia creates two storeys there. Forest stands represented by Plots L1 and T1 show generally high number of species at Plot L1. This stand demonstrates natural condition both in the composition of the tree synusia and in the composition of the undergrowth synusia. The way of its origin and tending should guarantee a subsequent stand of similar composition at least potentially and, therefore, it should be studied!

On the contrary, a stand on Plot T1 shows the smaller number of species their cover distribution being very unilateral (marked dominants). A stand on Plot L1 is nearly the stand of allochthonous species which cannot be said on Plot T1. Stages of the clear-felling regeneration demonstrate the high proportion of ruderal species, allochthonous species or species of invasive character. It refers to following species: *Stenactis annua* (L.) N e s s, *Aster lanceolatus* W i l l d., *Impatiens parviflora* DC. etc.

Many species in co-dominant or sub-dominant position occur on a developmentally-old clearing (Plot L2), eg: *Deschampsia caespitosa* (L.) B e a u v., *Dactylis polygama* H o r v á t., *Brachypodium sylvaticum* (H u d s o n) Be a u v., *Rubus caesius* L., *Glechoma hederacea* L., *Cirsium vulgare* (S a v i) T e n., *Lamium maculatum* L. On the contrary, on developmentally-young clearings, only one dominant species occurs after the short time of colonization (either from a seed bank or by various transfer from neighbouring areas), in this case *Echinochloa crus-galli* (L.) P. B e a u v. as a species occupying disturbed places of ruderal character tolerating even treading down, namely both on Plot L3 (record No. L3/2) and Plot L4 (records No. L4/2). The first record from Plot L3 does not show it as a dominant species as well as the first record from Plot L4 although the plot was thoroughly mowed there in the first year of monitoring.

Particularly under conditions of the geobiocoene type groups of floodplain forest vegetation shows vigorous growth in all parameters, which applies to both ligneous and herb species. To shorten or eliminate a period when the undergrowth synusia becomes a determinant component is, therefore, particularly important.

The proportion of life forms:

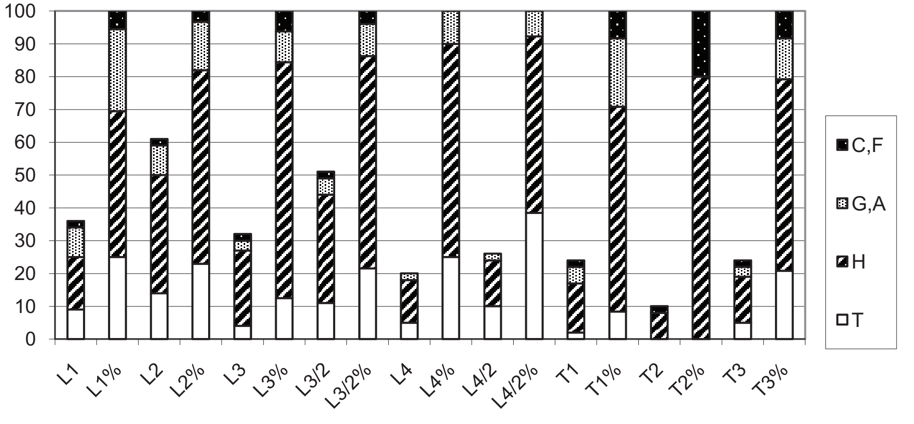


Fig. 7. Life forms of the undergrowth synusia.
Notes: C – chamaephytes, F – phanerophytes, G – geophytes, A – aquaphytes, H – hemicryptophytes, T – therophytes; absolute number: L1, L2, L3, L4, T1, T2, T3 – research plots, L3/2 – record from a following year, L4/2 – record from a following year; relative number – plot %.

Synanthropy of communities is illustrated as follows:

A limited extent of the paper does not allow the more detailed analysis of analytical data mentioned above. Nevertheless, it is worth mentioning nearly the ubiquitarian character of therophytes (see Fig. 7), namely also on Plot L1, ie in a mature stand with a preserved tree species composition. Also here, disturbances of the main forest canopy (although occupied by overtopped species in vertical direction) together with effects of surroundings result in the occurrence of therophytic plants, which were an exception in a closed forest stand. The number and the relative proportion of this life form show the rate of the disturbance of the existing vegetation cover. Reasons of the disturbance can be different at various places (see Fig. 7).

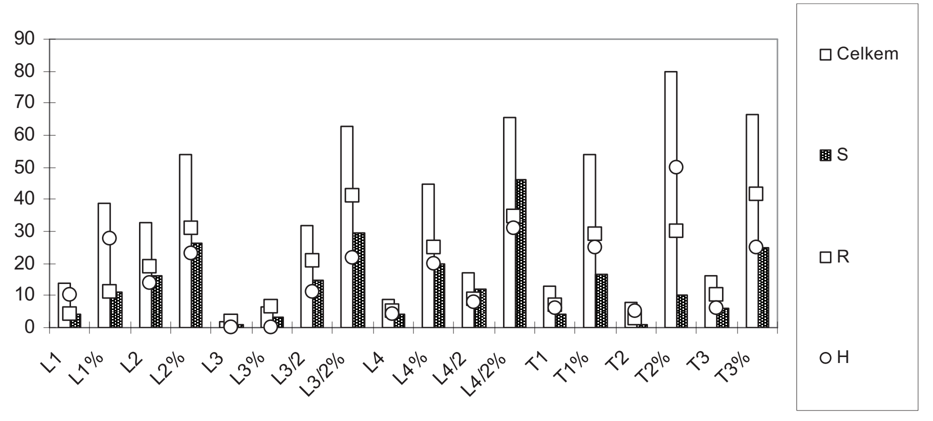


Fig. 8. Synanthropy of the undergrowth synusia.
Notes: S – species occurring only in synanthropic communities, R – ruderal species, H – species of forest edges and shrubs (also of ruderal character); absolute number: L1, L2, L3, L4, T1, T2, T3 – research plots, L3/2 – record from the following year, L4/2 – record from the following year; relative number – plot %.

Fig. 8 shows the rate of synathropic vegetation – the category gives the number and proportion of species showing synanthropic relationships (either primary or secondary). It is possible to note an increase of their abundance in the clear-felling stage. This fact is marked if we observe a category of species occurring only in synanthropic communities when this rate culminates in the second phytocoenological relevé of Plot L4. Although the phase of the clear-felling stage of regeneration creates new conditions for the growth and development of plant species it is necessary to think of this fact (increased biological diversity of the higher plant vegetation) critically, namely with respect to the character of species coming into the composition of community segments at these plots, viz. from the aspect of the inner structure of these coenoses and relationships between its populations as well as from the aspect landscape size.

Conclusion

1) The heterogeneity of soils in floodplain forests can be assessed at various levels. At the level of soil subtypes, particularly with respect to the variability of grain size distribution and water regime as well as at the level of organic and organomineral soil horizons where both natural and anthropic effects were brought into effect.
2) Heterogeneity of the forest floor weight can be best assessed at the end of summer when effects of variously fast decomposition and the condition and the species composition of stands are integrated.
3) Significant differences in the forest floor accumulation can be found between stands of oak and ash (hornbeam).

4) The forest floor accumulation can be also affected by the transfer of organic residues in the course of water flow at floods.
5) The significant loss of organic substances by decomposition processes occurs generally in a period from autumn to spring.
6) In the process of the decomposition of organic residues, the carbon concentration gradually decreases from L1, L2 and F and the nitrogen concentration increases.
7) Properties of the A horizon show higher stability as against forest floor. They can be markedly affected by decomposing wood in nature reserves, increasing the carbon and nitrogen content and decreasing the pH value.
8) Based on time series it is possible to conclude that plants demanding soil moisture and tolerating waterlogging receded or disappeared, namely in response to the termination of periodic floods caused by river channelization. It is also proved by changes in the species spectrum of plants approaching the composition of coenoses of a leading hydric series. More intensive development of the shrub layer takes place.
9) The entrance of therophytic, ruderal, often neophytic and invasive plant species is made possible by the destruction of existing vegetation as well as of the part of diaspores in soil due to the use of a clear-felling system amplified by the whole-area preparation of soil/site. Clear-felling stages of regeneration always mean increasing the biodiversity (of plants) for forest ecosystems and landscape, however, the structure and origin of these plants can be various from other aspects (originality, nature etc.) and even unacceptable for certain social needs. Moreover, the vegetation diversity has to be assessed in the landscape structure and scale.

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