DANUBE FOREST ECOSYSTEMS
BIODIVERSITY CHANGES IN THE 20TH CENTURY

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The term biological diversity, or biodiversity, came to the awareness of the world public from the well-known speech by Norwegian Prime Minister Brundtland in 1987 entitled "Our common future." This term, this ecological category, has been used by ecologists, scientists, and foresters for a long time.

In the central European region, it is especially European forestry and forest ecology that could continue the efforts of feudal rulers, who tried to ensure forest sustainability; sustainable forest production of wood and sustainable development on the basis of theoretical or practical knowledge. Forestry engineers completing their studies at the oldest university offering classes in forestry, the Mining and Forestry Academy in Banská Stiavnica - established in 1806 - have been the main intellectual group who worked with the natural biodiversity of the forests and placed it into their management plans.

At the end of the 19th century and at the beginning of the 20th century, when the principle of maximum wood production was the aim in several countries of Central Europe, the substitution of forest ecosystems with a natural tree species composition was carried out - in Slovakia beeches and beech stands were substituted by other tree species - mainly by the monocultures of spruce and pine. Later, came the basic change of tree species composition, namely to the decrease of forest biodiversity, also in the area of the alluvium of the Danube - not only in the Slovakian part.

Although the introduction concerned the changes in biodiversity of floodplain forests, it is necessary to add that the motive of the principle of biodiversity in forest management was the need of scientists to consider a forest as a complex. They were forced by their research energy to investigate, evaluate and justify the function of forest ecosystems. This, the so-called "ecosystem approach" of forest ecosystem studies, was used in the basic ecological research in the 1960s. Based on a UNESCO initiative, a network of international research plots was formed; for example the International Research Area in Báb by Nitra, Slovakia, and in Lednice, in the March river alluvium, in the Czech Republic. Within the framework of the International Biological Programme (IBP), supported by UNESCO, and later also on other research plots within the framework of the UNESCO programme, such as Man and the Biosphere (MAB), more or less complex research of each component of the complicated forest ecosystem in the Central European temperate zone was carried out. Scientists affirmed their hypotheses that every organism and non-living part of the ecosystem are mutually and completely bound, and they depend on each other.

The principle of biodiversity cannot be limited only to species diversity. In forest ecosystems, biodiversity concerns also the phenomenon of layers in the in-situ and age structure, biological tree diversity in stands, and other properties. This paper will deal mainly with the changes of species diversity, occurring during the 20th century. Information concerning the first three decades is rather scarce, but more concrete information and data are available for the latter part of the century. Technical information on current conditions is based on direct experience.

At the beginning of the 20th century the forest ecosystems in the alluvium of the Danube river in Slovakia were situated mainly in the interleveal area. Already in the first half of the 19th century, an Italian family, whose traditional profession was to build dikes in the Po river basin, water buildings and other water management measures, managed the building of dikes against floods between Vienna and Budapest. This meant that the majority of forest ecosystems had to adapt their tree species composition to the changed growing conditions caused by man-made dikes against floods. Due to their existence, floods came more often, water covered only a restricted area, and the flood-water level was higher than shallow water and it stayed longer in the flooded interleveal territory. The growing conditions in this area changed so much that the indigenous natural tree species disappeared, almost from the whole area, except for the area directly south of Bratislava. These tree species, especially oak, are tolerant to high flood-water levels, but they are not tolerant to relatively long-term flooding. In hardwood floodplain forest ecosystems south of Bratislava, where the terrain is situated higher and floods are seldom, oak, ash and other hardwood tree species retained the main stand-forming species.

Excellent, luxurious growing conditions - good moisture, good soil permanently fertilised by flood-water nutrients, very good climatic conditions - inspired the forest owners to change the tree species composition, in order to obtain wood of high quality quickly. Around the year 1935 were introduced poplar clones which were crossings of domestic poplars with North-American poplars. These hybrids excelled with quick growth, high productivity and short rotation periods. They need permanent and sustainable human intervention, starting with soil preparation, afforestation, planting of seedlings, intensive protection in the first years after planting, mechanical weeding - weed is a serious hindrance and competition for planted seedlings in aboveground and underground production space - intensive cleanings and thinning - these

quickly growing clones need illuminated and free crown from each side as they do not tolerate shadow in the crowns - and, at the end, clear felling. These poplar clones are not able to regenerate without the help of a forester - it must be the vegetative reproduction; the cloning. Poplar monocultures are a foreign element in the area. They have been planted on relatively large areas and the species diversity of these artificial forest stands was minimal. There is no other tree species in the tree layer, and the main stand was systematically destroyed in the shrub layer in its first decade of life. Therefore, the tree layer became the only natural and ecologically stable part of the ecosystem only in monocultures of higher age. This means that the shrub layer, being in transitional and hardwood floodplain forest ecosystems a natural component, did not exist in the first decade of the forest stand life.

Table 1. Tree species percent composition on the left and right side of the Danube between Bratislava and Komárno (1951) and Bratislava and Sap (1965)

Tree Species	1951 5410 ha	1965 6419 ha
	%	%
Needle tree species	-	1
Oak	3	2
Maple	1	2
Ash	9	9
Elm	6	7
Black locust	10	10
Alder	7	8
White poplar	22	-
Black poplar	5	43
Poplar clones	20	-
Willow	16	16
Other broad-leaved	1	2
Total	100	100

The change of tree species composition was carried out later, mainly in the upper part, after uncoordinated hydrotechnical interventions in the 1970s: excessive deepening of the Danube river-bed by about 1.5 m; putting aside the Biskupice arm; building a hydraulic screen near the Slovnaft oil refinery plant; building the watertight screen around Petrzalka, a part of Bratislava; building of water sources. This caused the drying up of approximately 500 ha of floodplain forests. The remaining forest ecosystems were destroyed, their structure disintegrated, and newly planted stands suffered. This process resulted in changes mainly in the Rusovce Forest Management Unit towards hardwood tree species - oak, hornbeam - while in the lower part of the floodplain forests - Gabcikovo and Samorin Forest Management Units - the percentage of tree species, typical for transitional and softwood, remain high.

Table 2. Tree species percent composition in the Rusovce Forestry Management Unit (1976 and 1991) and in the Samorín Forestry Management Unit (1991)

	Rusovice	Rusovice	Samorin
Tree species	1976 2875 ha	1991 1633 ha	1991 1492 ha
	%	%	%
Needle tree species	1	1	4
Oak and Turkey oak	5	43	1
Hornbeam	-	5	-
Maple	2	1	1
Ash	16	14	4
Elm	2	1	-
Black locust	10	6	5
Linden	-	1	7

Poplar white/black	27	5	-
Poplar clones	22-49	11	65
Willow	8	1	11
Alder	2	-	2
Other broad-leaved	5	11	-
Total	100	100	100

The percentage of poplar clones is significant and, at present, they represent 70-75 % of the area of the respective Forest Management Units. The Gabcikovo Forest Management Unit experienced only a slight reduction of the stand area, as a result of the building of the Gabcikovo hydro-power plant, but in the Samorin Forest Management Unit, large scale deforestation, on the territory of the present reservoir channel, and building plots were carried out.

A survey about the tree species composition in the forest management units Rusovce, Samorin, Gabcikovo is presented in Tables 1 and 2. The data is provided by the forest management plans.

The lower part of the area, bordered by the relief from Dobrohost to Sap/Palkovicovo, can be qualified, up to the beginning of the operation of the hydro-power plant, as an area with luxurious hydrological conditions. Such a situation was established in this area by the building up of the dike system in the second half of the 19th century. Growing conditions were suitable mainly for poplars and willows, while hardwood tree species, like oak and ash, were substituted by highly productive poplar clones. Also, natural white and black poplars were gradually substituted by poplar clones. The advantage of poplar clone cultivation is documented also by the tree species composition in the Gabcikovo and Samorin forest management units. High productivity - more than 20 m3/ha/year - and short cutting cycles supported the change of natural floodplain forests to intensively managed cultures of poplar clones.

At present, floodplain forests are, in these areas, only the refuge of their original distribution. Their largest area is situated in the inundation area - interleveal area. The existence of floodplain forests behind the dike area is not an exception and they are distributed also on sites where gravel banks emerge up to the soil surface and, therefore, make the forest soil unsuitable for other commercial activities. Forests in the study area can be divided into the following five groups:

– Dogwood-oak forests: These are represented by stands characterised by the occurrence of thermophilous tree species with a rich shrub layer. They occur only on a small area with shallow sandy soils on gravel terraces with a deep situated level of underground water. They are formed by vegetation types ranging from solitaires of groups of shrubs with steppe stands to forest steppes with different degrees of tree crown cover, and with relatively low growth. A characteristic feature is the lack of water determining the occurrence of xerophilous and thermophilous vegetation. On sandy soils, there is, characteristically, a slow transition towards the Quercetum - oak forest - group and, on gravel aggradation with thicker soil layers, occur areas of Ulmetum - elm - forest types, with prevailing English oak. After the graphiosis disaster, elm was almost extinct. The natural tree species was pubescent oak; at present it is English oak and, in a small degree, linden and hedge maple. From the higher shrubs, the most typical species is dogwood - mainly in clearer places - and other shrub species tolerating aridity and warmth: privet, blood-twig dogwood, hawthorns, barberry, buckthorn. From herbs, there prevail xerothermic grasses. This is a valuable forest ecosystem, important from a botanical as well as a zoological viewpoint, but its wood biomass production is of little practical importance.

– Elm-ash forest with hornbeam - hardwood floodplain forests: This forest group occurs mainly on gravel terrain or on compact areas on plain terrain, far enough from the river, so the underground water level is lower. Supply of soil profile by water depends on whether the active soil profile is at least temporarily influenced by the movement of the underground water level. From domestic tree species, prevail durmast oak with elm; at present, it is European ash, occasionally English oak, white poplar, little-leaf linden, hedge maple, bird cherry and, rarely, hornbeam. The shrub layer is well developed, and it forms a more or less compact layer of hazelnut, bloody dogwood, European evonymus, wayfaring tree and, rarely, European bladdernut. European dewberry is frequently found in the majority of the area. The herbaceous layer is developed mainly in places with lower shrub layer cover, where there prevail mainly nitratephilous species.

– Elm-ash forest with poplars - transitional floodplain forests/drier type: The boundary of these forests is given by their occurrence in areas without floods and they are situated only in localities irrigated by underground water raised during spring floods up to the surface, but at the same time sludge is not settled. In natural stands, the dominant species is elm together with narrow-leafed ash and English oak. There often occurs a mixture of domestic white, black and grey poplars. At present, in this group prevail poplar clones; domestic poplars, willow and English oak occur less. The shrub layer is formed mainly by bird cherry - occasionally as a tree - European elder, bloody dogwood, European eponymous and other shrubs tolerating waterlogging. The herbaceous layer is rich, pointed up with nitratephilous plants. Present stands are mainly the stands of poplar clones, because of the existence of optimal conditions for the cultivation of poplar monocultures.

– Oak-ash forest - transitional floodplain forests/wetter type: This group is found on terrains with higher ground water levels or periodical floods. It is situated on plains being slightly depressed in the macrorelief and the microrelief, and flooded originally every year in the spring. The optimum of its distribution is in the alluvium of the Danube. It forms a transition between elm-ash and willow-alder forests. Spring floods

aggravating originally the thin sledge layer were a significant soil forming factor. Originally, the dominant species was European oak. Later there was mixed ash, white, black and grey domestic poplar, and European aspen. At present, as in the previous group, prevail the above-mentioned different poplar clones, which enjoy optimal production conditions. Considering the long lasting floods, the shrub layer is not so rich as in the previous group. However, the herbaceous layer is rich and dense but with low qualitative species occurrence.

– Willow-alder forests - softwood floodplain forests: The distribution of this forest group is significantly influenced by the ground water level and, originally, by long-lasting floods. Although, from the viewpoint of soil, this group is diversified, from the viewpoint of cultivation it is sufficiently homogenous. In the Danube alluvium, the horizontal distribution is focused directly on the banks or blind arms, originally being often flooded. Soil types are gravelous - shallow banks - often without a developed soil profile, peat glees, humus glees - blind arms - and, essentially, with a poorly developed and short oxidation horizon. In natural stands, conserving more or less their natural character, prevail willows - mainly white and brittle - mixed with white and grey domestic poplars, and seldom alders. In more distant places from the main flow, European alder, willow and domestic poplars are often found. On drier places appear also poplar clones. Marsh species demanding permanently wet soils and tolerating the lack of soil air, are the dominant species in the herbaceous layer.

The construction of the Gabcikovo water plant and the turning away of the Danube to the derivation canal causes, in spite of hydrotechnical buildings for the elimination of its negative impacts, certain changes to the hydrological regime of the Danubian floodplain forests. It is very probable that further development of the present floodplain forests will depend mainly on the average water discharge, and respective height of the water level during the vegetation period in the old bed of the Danube. Therefore, it is necessary to call attention to the fact of a certain regrouping of the Danubian floodplain forests. In the future, it will be necessary to pay attention not only to their production functions - cultivation of poplar clones, in some cases to substitute softwood floodplain forests with hardwood ones - but also to non-production functions, such as recreation, landscape-protection, soil-protection and others.

Table 3. Tree species percent composition in the Gabcikovo Forestry Management Unit

Tree Species	1982 2035 ha	1992 2063 ha
	%	%
Oak	1	2
Maple	1	-
Ash	12	8
Black locust	1	-
Poplar white/black	6	6
Poplar clones	61	61
Willow	18	21
Alder	-	2
Total	100	100

First of all, it is necessary to stress that in the study area it is not possible to speak about natural tree species composition of floodplain forests, because far before the construction of the dam, the main tree species changed from transitional and softwood floodplain forest species to introduced poplar clone species (Table 3). To a certain extent, this fact was also influenced by other changes - deepening of the Danube bed after gravel production in the sixties and the practically complete extinction of elms after the graphiosis disaster.

The first, so-called functional forms of poplars have been sporadically planted in the surroundings of the Danube at the end of the past century, together with the building of dikes against floods. Later, especially after l938, came the stands of new clones of Euro-American poplars - Monilifera, Robusta, Serotina. This activity has continued and, at the beginning of the 1960s, large areas were planted with poplars. The present floodplain forests of the Danube, including the area between Gabcikovo and Sap, have been established mainly - approximately up to 80% - from the above-mentioned artificial poplar clones or cultures with a prevalence of I-214 and Robusta clones. Considering this fact, it is possible to characterise also the changes in occurrence of groups of forest types before and after the construction of the Gabcikovo hydroelectric plant (Table 4).

Table 4. Changes in the share of groups of forest types and their tree species composi-tion before and after the construction of the Gabcikovo power station. Original tree species composition describes the ideal status approximately 150 years ago.

Forest types	% Before construction	% After construction	Original Tree species composition

Dogwood oak forests	1.8	0.4	oak, linden oakdogwood, linden, maple
Elm-ash forests with hornbeam hardwood floodplain forests	32.6	25.6	elm, oak, ash, maple, domesticpoplars, linden,(hornbeam) poplar clones
Elm-ash with popular transitional floodplain forests	38.8	39.7	elm, oak, poplarclones, ash,domestic poplars,aspen
Oak-ash forests transitional floodplain forests	14.3	19.3	oak, ash, poplar domestic clonespoplars, aspen
Willow-alder forests softwood floodplain forests	12.7	15.0	willow, alderdomestic poplarspoplar clones

Before construction, the largest share had two groups of forests - in the upper part of the study area there were hardwood floodplain forests - 32.6 % - and, in the interleveal area, transitional floodplain forests - 52.9 %. Also, a relatively high percentage of the area had softwood floodplain forests, mainly in the lower part and other forests were situated at extremely dry sites, at a lower percentage - 1.8 %. After construction of the hydroelectric power station and the derivation canal - variant "C" - began, the extent of floodplain forests decreased approximately by 30%; this influenced also the representation of these forests. The extent of hardwood floodplain forests decreased from 32.6% to 25.6%, and the extreme sites decreased from 1.8% to 0.4%. However, the share of softwood floodplain forests and mainly of transitional floodplain forests increased by 3% and 7%, respectively. This means that these forests are floodplain forests which are cultivated as poplar clone monocultures.

The largest changes appeared in the upper part of the construction up to Dobrohost, while the forests in the interleveal area have been conserved relatively without changes. But the stands near the main flow area - drainage of underground waters by the Danube bed - as well as in the area situated upstream of the intake-structure near Dobrohost - triangle of the Danube river bed, i.e. derivation canal, reservoir, intake structure - are significantly damaged.

Comparing this situation with previous years, a negative reaction of all existing tree species is obvious, due to moisture insufficiency caused by the decrease of the underground water level, which led to the changes in growing conditions. The trees and shrubs react by early-summer discoloration of leaves, loss of leaves and drying out of crowns or of parts of these crowns. Here, the best solution would be the replacement of poplars and willows by domestic tree species which are well able to grow in sites characterised by lack of soil moisture.

The author wishes to thank to the VEGA grant agency for partial support of the work - grant No. 2/4140/97.

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