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PRODUCTION-ECOLOGICAL ANALYSIS OF HERB LAYER IN THE SOFTWOOD FLOODPLAIN FORESTS FORMED AFTER THE GABČÍKOVO WATERWORK CONSTRUCTION AND THEIR CHARACTERISTICS

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Abstract

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This paper is focused on phytocoenological characteristics and production analysis of herbaceous layer biomass of the softwood floodplain forests (*Salici-Populetum* (R. Tx. 1931) Meijer Drees 1936 association) and their phytocoenological characteristics. The sampling site was located in the young stands, which were formed after the Gabčíkovo Waterwork construction in 1992. Redirection of the major ratio of flow into the supply channel has caused essential decrease of water level in the old Danube riverbed. As a result of this, new bare sites have appeared having character of pioneer habitat. In the process of primary succession, new softwood floodplain forests have formed here within a few years. These stands are the subject of the study presented in this paper. We estimated herb layer biomass using indirect sampling modified for non-repeated field measurements (Kubíček, Brechtl, 1970). Total biomass of herbaceous layer was estimated to be 5577 kg ha^{-1}, the aboveground biomass was 4065 kg ha^{-1} while the belowground biomass was 1512 kg ha^{-1}. The results were compared with the data of Kubíček et al. (2009) and Kollár et al. (2010). Some attention was also paid to their phytocoenologic characteristics. Considering this, it seems that they represent full-value softwood floodplain forest of the *Salici-Populetum* association despite a bit higher occurrence of some synanthropic species. Such statement is supported by comparison with the data of Jurko (1958) and Šomšák (2003).

Key words: herb layer biomass, phytocoenology, *Salici-Populetum*, Danube, Gabčikovo Waterwork.

Introduction

The construction of the Gabčíkovo Waterwork has significantly changed the surrounding landscape as well as the Danube itself. A huge dam was built (Hrušovská zdrž), from which a major part of the flow was redirected into the supply channel, which serves for Gabčíkovo hydropower plant. As a result of this, part of the original Danube riverbed located under this dam (the so-called Old Danube) is supplied with much less water. Original mean discharge (2025 $m^3 s^{-1}$) was decreased to 200–600 $m^3 s^{-1}$. Thus, new terrestrial sites have appeared which have been colonized by vegetation in a short time. By the process of primary succession, new softwood floodplain forests of the *Salici-Populetum* (R. Tx. 1931) Meijer Drees 1936 association have formed in a few years. We estimated their area to exceed 50 ha (including shrub willow stands). Their occurrence is tied mainly with the part under rock-fill dam at Dunakiliti, which was built in 1995 to mitigate the water deficit (Mucha, 2004). In the last period, existence of these forests was criticized as they can reduce water discharge and so can be a risk for flood protection (e.g. Water Research Institute, 2008). In this contribution, we offer basic information on the herb layer biomass, phytocoenology and floristic composition of these stands.

Methods

Estimation of the herb layer biomass was made on the selected sample plots applying the methods of indirect sampling (Kubíček, Brechtl, 1970) modified for non-recurrent sampling (Kubíček, Jurko, 1975; Kubíček, Šimonovič, 1975; Kubíček, Šomšák, 1982). Phytocoenological relevés were sampled using Zurich-Montpellier school (Braun-Blanquet, 164). The names of plants comply with Marhold, Hindák (1998) except for taxonomically difficult aggregated species (marked as agg.). The area of the studied forests was estimated using the Google Earth version 6 (2010). Soil nomenclature is according to the WRB classification (FAO, 2006). The coordinates are listed in the WGS 84 system.

Study area

The study area includes floodplains along the old Danube (southwestern Slovakia). Its entire length is about 40 km. The altitude is about 200 meters a.s.l. It is situated in the central part of an intermountain depression, the Danube basin. The basin is formed by Late Tertiary and Quaternary sediments. The Danube river sediments (since the Mindel epoch) form the main aquifer consisting of highly permeable gravels and sands. Its thickness ranges from a few meters at Bratislava to more than 450 m at Gabčíkovo. Under this layer, there is a complex of low permeable or almost impermeable older Quaternary and mainly tertiary sediments (Lisický, Mucha, 2003). Tarábek (1980) defines climatic and geographic type as lowland climate with mild temperature inversion, dry to moderately dry and warm. According to the data provided by Slovak Hydrometeorological Institute, mean January temperature was about 0.14 °C, while in July it was 21.56 °C (period of 1999–2008). Annual precipitation (hydrometeorological stations in the cities of Gabčíkovo and Šamorín) belong to the lowest in Slovakia; it ranged from 509 to 540 mm in 1999–2008.

Characteristics of the sampled site

The plot represents a young (up to 20 years) and synanthropized softwood floodplain forest of the *Salici-Populetum typicum* subassociation that occurs on Gleyic Fluvisol. Value for pH in upper 10 cm: pH (H_20): 8.162, pH (KCl): 7.761 (Vojtková, 2012). Floristic composition is shown in Table 1, relevé 1. Date of sampling was 14 September 2011.

Results

Phytocoenological characteristic

All the stands that are the subject of this study represent the softwood floodplain forests of the *Salici-Populetum typicum* (R. Tx. 1931) Meijer Drees 1936 association. Their floristic composition is shown in Table 1. Tree layer is mostly dominated by *Salix alba.* Of other common species, *S. fragilis, Populus nigra*, *P. alba* and *Negundo aceroides* are worthy of mention. Other species are only admixed. Shrub layer is usually developed only weakly. Except for young willow trees, it is formed by species as *Swida sanguinea* and *Negundo aceroides.* Herb layer includes mainly hygrophilous

T a b l e 1. Phytocoenological table of the observed stands of the *Salici-Populetum* association (relevés No. 1–6).

Relevé No.	1	2	3	4	5	6	C	Šu	Šr	Ju	Jr
Trees and shrubs											
Salix alba (E_3)	4	4	4	2	2	1	V	IV	III	IV	III
Salix alba (E_2)	.	+	+	1	.	1	IV	0	II	0	0
Salix alba (E_1)	.	.	r	r	+	+	IV	0	0	0	0
Populus nigra (E_3)	+	1	2	1	2	2	V	II	I	II	III
Populus alba (E_3)	1	.	+	+	+	.	IV	0	0	II	I
Populus alba (E_1)	.	.	r	.	.	.	I	0	0	0	0
Salix fragilis (E_3)	.	.	.	2	1	3	III	II	0	I	0
Salix fragilis (E_2)	.	.	.	.	.	+	I	II	0	0	0
Negundo aceroides (E_3)	.	+	+	+	.	.	III	I	0	0	0
Negundo aceroides (E_2)	.	+	.	1	1	.	III	III	I	III	III
Negundo aceroides (E_1)	.	.	+	r	r	.	III	II	I	0	0
Alnus incana (E_3)	+	.	.	.	.	.	I	I	0	I	II
Alnus incana (E_2)	r	.	.	.	.	.	I	I	0	0	II
Alnus incana (E_1)	.	.	.	.	.	.	0	0	0	0	I
Populus x canescens (E_3)	.	r	.	.	.	.	I	I	II	I	0
Ulmus laevis (E_3)	.	.	.	1	.	.	0	0	I	I	0
Ulmus laevis (E_2)	.	.	.	1	.	.	I	0	0	0	0
Ulmus laevis (E_1)	.	.	.	+	.	.	I	0	0	0	0
Ulmus minor (E_2)	.	.	.	.	.	.	0	0	0	I	II
Swida sanguinea (E_2)	.	+	+	+	2	+	V	III	IV	III	IV
Swida sanguinea (E_1)	r	+	+	.	+	.	IV	I	III	II	II
Sambucus nigra (E_2)	r	.	.	.	.	.	I	IV	0	I	0
Sambucus nigra (E_1)	.	.	.	.	.	.	0	II	0	0	0
Humulus lupulus (E_2)	.	.	+	.	.	+	II	II	II	0	0
Humulus lupulus (E_1)	.	+	1	r	.	.	III	IV	IV	IV	III
Clematis vitalba (E_2)	.	.	.	+	1	.	II	0	0	0	0
Clematis vitalba (E_1)	.	r	.	.	.	.	I	I	0	0	0
Crataegus monogyna (E_2)	.	.	.	.	.	.	0	I	I	I	I
Padus avium (E_2)	.	.	.	.	.	.	0	0	0	I	II
Padus avium (E_1)	.	r	r	.	.	.	II	0	I	I	I
Viburnum opulus (E_2)	.	.	.	.	.	.	0	0	0	0	II
Euonymus europaeus (E_2)	.	.	.	.	.	.	0	0	I	I	0
Euonymus europaeus (E_1)	.	.	.	.	.	.	0	0	I	I	0
Fraxinus angustifolia (E_2)	.	.	.	.	.	.	0	0	0	0	I
Ribes nigrum (E_2)	.	+	.	.	.	.	I	0	0	0	0
Herb layer											
Arrhenatherum elatius	.	.	1	1	+	+	IV	0	0	0	0
Taraxacum sp.	.	r	r	r	.	.	III	0	0	0	0
Elytrigia repens	.	.	.	.	r	r	II	0	0	0	0
Galium mollugo agg.	.	.	r	.	.	+	II	0	0	0	0
Bromus sterilis	3	.	.	.	.	.	I	0	0	0	0
Chenopodium album	.	.	.	.	+	.	I	0	0	0	0
Chenopodium polyspermum	.	r	.	.	.	.	I	0	0	0	0
Stenactis annua	.	.	.	.	r	.	I	0	0	0	0
Fraxinus pennsylvanica	.	r	.	.	.	.	I	0	0	0	0
Lycopus europaeus	+	.	.	.	.	.	I	0	0	0	0
Pastinaca sativa	.	.	r	.	.	.	I	0	0	0	0
Physalis alkekengi	.	.	.	.	r	.	I	0	0	0	0
Plantago major	.	.	.	r	.	.	I	0	0	0	0
Senecio sarracenicus	r	.	.	.	.	.	I	0	0	0	0
Sisymbrium loeselii	.	.	.	.	r	.	I	0	0	0	0
Solanum lycopersicum	.	+	.	.	.	.	I	0	0	0	0
Vicia cracca agg.	.	+	.	.	.	.	I	0	0	0	0
Other species											
Rubus caesius	2	2	4	2	2	2	V	V	V	V	V

T a b l e 1. Phytocoenological table of the observed stands of the *Salici-Populetum* association (relevés No. 1–6), to be continued.

Relevé No.	1	2	3	4	5	6	C	Šu	Šr	Ju	Jr
Urtica dioica	3	+	2	3	1	2	V	V	IV	V	IV
Phalaroides arundinacea	2	2	1	1	+	1	V	V	III	V	V
Galium aparine	2	+	1	2	r	1	V	V	IV	IV	III
Glechoma hederacea	.	.	.	.	r	.	I	III	III	IV	III
Symphytum officinale	.	r	.	.	.	.	I	II	IV	III	III
Angelica sylvestris	.	.	.	+	.	r	II	III	I	IV	I
Aster novi-belgii agg.	1	3	.	1	.	3	III	V	V	0	I
Calystegia sepium	.	+	.	.	.	.	I	IV	0	II	III
Poa palustris	1	1	+	+	+	.	V	II	0	II	II
Agrostis stolonifera	+	.	.	.	.	.	I	I	0	IV	III
Impatiens glandulifera	1	.	.	+	r	1	III	IV	0	I	I
Equisetum arvense	+	r	r	.	.	r	IV	0	0	IV	II
Solidago canadensis	+	+	2	+	+	+	V	II	III	0	0
Cirsium arvense	.	r	.	.	r	.	II	III	I	I	I
Festuca gigantea	.	.	.	.	.	.	0	I	I	II	II
Impatiens parviflora	.	.	.	+	+	.	II	0	0	III	II
Solanum dulcamara	.	+	.	.	.	.	I	I	I	II	III
Arctium lappa	.	r	r	r	.	.	III	III	I	0	0
Deschampsia cespitosa	.	+	r	.	.	.	II	0	0	II	II
Ranunculus repens	r	r	.	.	.	.	II	0	0	II	II
Galium palustre	.	+	.	.	.	.	I	0	0	I	III
Aegopodium podagraria	.	r	.	.	.	.	I	II	I	I	I
Impatiens noli-tangere	.	.	.	.	.	.	0	0	0	II	II
Lysimachia nummularia	.	.	+	.	.	.	I	0	0	II	II
Myosoton aquaticum	.	+	.	.	.	.	I	II	0	I	I
Persicaria hydropiper	.	.	.	.	.	.	0	0	0	II	II
Poa trivialis	.	.	1	.	.	.	I	0	I	I	II
Solidago gigantea	.	.	.	.	.	.	0	0	0	II	II
Carex acutiformis	.	.	.	.	.	.	0	I	I	I	II
Persicaria maculosa	.	.	.	.	.	.	0	0	0	II	II
Roegneria canina	.	.	.	.	.	.	0	0	0	I	II
Circaea lutetiana	.	.	.	.	.	.	0	0	0	II	I
Iris pseudacorus	.	.	.	.	.	.	0	I	II	0	I
Rumex obtusifolius	.	.	.	.	.	.	0	I	I	I	I
Rumex sanguineus	.	+	.	.	.	.	I	0	0	II	0
Senecio ovatus	.	.	.	.	.	.	0	0	0	II	I
Stellaria media	.	.	.	.	.	.	0	I	0	I	II
Cardamine amara	.	.	.	.	.	.	0	0	0	II	0
Dactylis glomerata agg.	.	.	.	.	.	.	0	I	I	0	I
Galeopsis speciosa	.	.	.	.	.	.	0	0	0	II	I
Lamium maculatum	.	+	.	.	.	.	I	I	0	0	I
Lythrum salicaria	.	.	.	.	.	.	0	0	I	0	II
Phragmites australis	.	.	.	.	.	.	0	II	0	0	I
Rumex sp.	.	.	.	.	.	.	0	0	0	II	I
Arctium nemorosum	.	.	.	.	.	.	0	0	0	I	I
Lysimachia vulgaris	r	.	.	.	.	.	I	0	0	0	I
Pimpinella major	.	r	.	.	.	.	I	0	0	I	0
Scrophularia nodosa	.	.	.	.	.	.	0	0	0	I	I
Stellaria nemorum agg.	.	.	.	.	.	.	0	0	0	I	I
Aristolochia clematitis	.	+	.	.	.	.	I	I	0	0	0
Artemisia vulgaris	.	.	.	.	.	.	0	0	0	I	0
Bidens frondosa	.	.	.	.	.	.	0	0	0	I	I
Carduus crispus	.	.	.	.	.	.	0	0	0	I	I
Erysimum cheiranthoides	.	.	.	.	.	.	0	0	0	I	I
Myosotis palustris agg.	.	.	.	.	.	.	0	0	0	I	I
Parietaria officinalis	.	.	.	.	.	.	0	0	0	0	I

T a b l e 1. Phytocoenological table of the observed stands of the *Salici-Populetum* association (relevés No. 1–6), to be continued.

Relevé No.	1	2	3	4	5	6	C	Šu	Šr	Ju	Jr
Rubus fruticosus agg.	.	+	.	.	.	.	I	I	0	0	0
Scutellaria galericulata	+	.	.	.	.	.	I	0	0	0	0
Rumex aquaticus	.	.	.	.	.	.	0	0	0	0	I
Sonchus oleraceus	.	.	.	.	.	.	0	0	0	I	I
Stachys palustris	.	.	.	.	.	.	0	0	0	I	I

Explanations: C – constancy of species for original data; Ju, Jr – constancy for variant with *Urtica dioica* and *Rubus caesius* Jurko (1958); Šu, Šr – constancy for variant with *Urtica dioica* and *Rubus caesius* by Šomšák et al. (2003).
Heading to the phytocoenological table:
1. 7.5.2010 and 14. 9. 2011, E3: 60%, E2: 1%, E1: 95%, height: 16 m, old Danube riverbed close to the Dobrohošť village, 17°19′02.00" E″, 47°59′49.70″, Gleyic Fluvisols, Vojtková, Minarič, Kollár
2. 27.8.2010, E3: 70%, E2: 3%, E1: 75%, height: 18 m, old Danube riverbed close to the Bodíky village, 17°26′35.88″E, 47°54′11.06″, Gleyic Fluvisols, Vojtková, Minarič, Kollár
3. 4.7.2011, E3: 65%, E2: 5%, E1: 70%, height: 18 m, old Danube riverbed close to the Bodíky village, 17°26′29.21″ E, 47°54′19.19″ N, Gleyic Fluvisols, Vojtková, Minarič
4. 24.8.2011, E3: 60%, E2: 10%, E1: 85%, height: 15 m, old Danube riverbed close to the Vojka village, 17°23′51.00″E, 47°57′06.58″ N, Gleyic Fluvisols, Vojtková, Minarič
5. 24.8.2011, E3: 60%, E2: 30%, E1: 45%, height: 12 m, old Danube riverbed close to the Vojka, 17°24′32.60″ E, 47°56′33.00″ N, Gleyic Fluvisols, Vojtková, Minarič
6. 5.10.2011, E3: 50%, E2: 10%, E1: 80%, height: 22 m, 17°28′25.00″ E, 47°52′51.80″ N, Gleyic Fluvisols, Vojtková, Minarič, Kollár

and nitrophilous species. Of this, *Rubus caesius*, *Urtica dioica*, *Phalaroides arundinacea* and *Galium aparine* are the most abundant. In some stands, also invasive neophytes play an important role (*Aster novi-belgii* agg., *Solidago canadensis, Impatiens glandulifera*). Compared to data of Jurko (1958) and Šomšák (2003), these stands closely resemble variant with *Rubus caesius* and partly even variant with *Urtica dioica*. Table 2 also includes this excerpted data. Only small differences can be noticed. Studied stands seem to be more synanthropized. Of trees, there is distinctly higher abundance of invasive neophyte *Negundo aceroides*. Of herbs, there is an obvious higher share of synanthropic species. Of these species, *Arrhenatherum elatius* occurs constantly, less *Taraxacum* sect. *Ruderalia* and *Elytrigia repens*. Many of such species were recorded on occurrence only (occurrence of, e.g., *Lycopersicon esculentum* is interesting). Occurrence of these species is probably caused by relatively young age (remnants of succession) and by the accumulative-destructive activity of river. Thus, it can be concluded that despite relatively young age and partial synanthropization, the studied stands represent full-value softwood floodplain forests.

Biomass of herb layer

The data on the production-ecological analysis obtained from the softwood flood plain forests are summarized in Table 2. It contains the following information: Type of forest community, aboveground, belowground and total herb layer biomass (A, B, T) in kg ha^{-1}, and a ratio between above and belowground biomass (A/B).

In the herb layer, nitrophilous and hygrophilous species prevail both in cover and herb layer biomass. The species with high cover correspond well with the most productive species. There are two most decisive biomass production dominants: *Phalaroides arundinacea* and *Urtica dioica*.

Higher values were also found for *Rubus caesius* and *Aster novi-belgii* agg. (co-dominant species). Due to the date of production sampling (late summer), spring species are not included (*Bromus sterilis, Galium aparine*). Total biomass of herb layer was estimated here up to 5577 kg ha^{-1}. Of this, the aboveground biomass was 4065 kg ha^{-1}, belowground biomass 1512 kg ha^{-1}. These results were compared with the data published for similar vegetation of the region; willow softwood floodplain forests (Kollár et al., 2010) and *Populus x canadensis* monocultures (Kubíček et al., 2009) established on the softwood floodplain forest sites (see Table 3). The original data for total biomass resemble excerpted results for similar ecological conditions (poplar monocultures on the sites of *Salici-Populetum typicum* variant with *Urtica dioica* and *Salici-Populetum myosotidetosum*). On the other hand, lower biomass in the young willow stands reflects high cover of tree layer and probably also more hygrophilous conditions. The lowest biomass value for *Salici-Populetum typicum* variant with *Swida sanguinea* is caused by high cover of shrub layer.

T a b l e 2. Biomass of herb layer in the observed stands of *Salici-Populetum* association.
A – aboveground biomass [kg ha^{-1}], B – belowground biomass [kg ha^{-1}], T – total biomass (A + B) [kg ha^{-1}], A/B – ratio of aboveground and belowground biomass.

Species	**A**	**B**	**T**	**A/B**
Phalaroides arundinacea	1757	438	2195	4.01
Urtica dioica	1294	348	1642	3.72
Rubus caesius	350	515	865	0.68
Aster novi-belgii agg.	302	58	360	5.20
Impatiens glandulifera	134	29	163	4.54
Equisetum arvense	86	36	122	2.39
Phragmites australis	52	50	102	1.05
Agrostis stolonifera	67	26	92	2.60
Poa palustris	25	12	36	2.12
Total	**4065**	**1512**	**5577**	**2.69**

T a b l e 3. Comparison of original data for herb layer biomass with those by Kubíček et al. (2009) and Kollár et al. (2010).
A – aboveground biomass [kg ha^{-1}], B – belowground biomass [kg ha^{-1}], T – total biomass (A + B) [kg ha^{-1}], A/B – ratio of aboveground and belowground biomass.

Authors	Vegetation type	A	B	T	A/B
Original data	*Salici-Populetum typicum*	3884	1512	5577	2.59
Kubíček et al. (2009)	Poplar monoculture on the *Salici-Populetum myosotidetosum* site	3960	1369	5329	2.86
Kubíček et al. (2009)	Poplar monoculture on the *Salici-Populetum typicum* variant with *Swida sanguinea*	740	294	1034	2.52
Kubíček et al. (2009)	Poplar monoculture on the *Salici- Populetum typicum* variant with *Urtica dioica*	4106	1317	5423	3.11
Kollár et al. (2010)	Young (about 15 years) willow culture on the *Salici-Populetum myosotidetosum* site	877	385	1262	2.28
Kollár et al. (2010)	Young (about 25 years) willow culture on the *Salici-Populetum myosotidetosum* site	1131	164	1295	7.00
Kollár et al. (2010)	Old natural disintegrating willow (*Salix fragilis*) stand of the *Salici-Populetum myosotidetosum*	1895	1183	3078	1.60

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