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Distribution of North American ash species in the Drava River basin and Danube basin (Croatia)

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There are two North American ash species which have been acclimatized in north Croatian forest ecosystems: the white ash (*Fraxinus americana* L.) and the green ash (*F. pennsylvanica* Marshall). In the lowlands forests of the Drava River basin and Danube basin a total number of 960 subcompartments with North American ash species were established. According to the collected dendrological material the green ash was determined in twenty subcompartments. In those subcompartments the white ash was not found. Accordingly, the distribution of an important neophyte for wood production in the Drava River basin and Danube basin has been mapped for the first time. North American ash species are present in small, mostly isolated depressions where they were planted at the beginning or in the middle of the 20th century. Also, they spontaneously spread to many locations and with other pioneer species colonize swamps and river islets. In these locations the green ash has a pioneer and reclamation role in preparing habitats for the arrival and success of the native narrow-leaved ash (*F. angustifolia* Vahl). The timber value of North American ash species is small because the trees are usually bent by wind, snow and ice. Also, the trees of North American ash species were more often pulled down than the trees of native species.

Key words: lowland forest, exotic species, neophyte, ash, *Fraxinus americana, Fraxinus pennsylvanica,* distribution, Drava, Danube, Croatia

Introduction

Many exotic species (for example: black locust – *Robinia pseudoacacia* L., black walnut – *Juglans nigra* L., white ash – *Fraxinus americana* L., green ash – *F. pennsylvanica* Marshall, ashleaf maple – *Acer negundo* L., silver maple – *Acer saccharinum* L., tree of heaven – *Ailanthus altissima* (Mill.) Swingle, eastern white pine – *Pinus strobus* L., Douglas-fir – *Pseudotsuga menziesii* (Mirb.) Franco, common baldcypress – *Taxodium distichum* (L.) Rich., white fir – *Abies concolor* (Gordon et Glend.) Lindl. Ex Hildebr.) were introduced in Croatia for wood production and urban forestry. Some of them, like the black locust, green ash or ashleaf maple became acclimatized in forest ecosystems, but

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there is no detailed information about their distribution. Hence the mapping of the distribution of North American ash species (white ash and green ash) became a part of research into those species naturalized in lowland forests in Croatia. STREPAČKI (1931), ŠPANOVIĆ (1954), FUKAREK (1956), DEKANIĆ (1974), RAUŠ (1975, 1976, 1992, 1993), RAUŠ and ŠEGULJA (1983), RAUŠ ET AL. (1985), MAJER (1994) reviewed the presence of white ash and green ash in Croatia. KREMER and BORZAN (2001) mapped the distribution of North American ash species in the Kupa River basin, Sava River basin and in part of Danube basin. With the extension of the research into the whole Danube basin and Drava River basin, the distribution of North American ash species in Croatia has been almost completely mapped.

Study site

The research was carried out in the lowland forest region of the Danube basin and Drava River basin under the management of five forest administration units (Bjelovar, Koprivnica, Našice, Osijek, and Vinkovci) of the company Croatian Forests Ltd., Zagreb (Fig. 1).

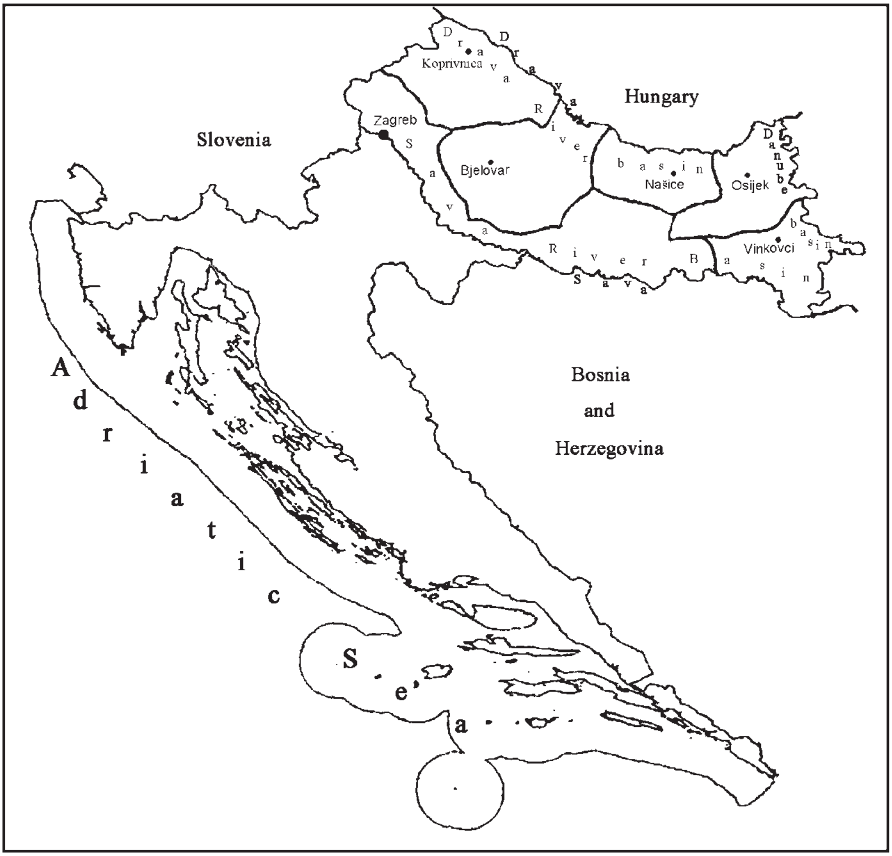

Fig. 1. Map of Croatia with borders of five forest administrations units of Croatian Forests Ltd. where the research was carried out.

According to Koppen's classification, the climate of the western part of the study area belongs to the climatic type Cfwbx. This is a moderately warm, rainy climate without a dry period and with precipitation uniformly distributed throughout the year. There are no dry periods, but the least rain falls in the cold part of the year. This climate type extends north of the line Karlovac–Topusko and west of the line Virovitica–Daruvar. The climate of the eastern part of thearea studied belongs to the climatic type Cfwb "x". It is also a temperate rainy climate, but with one pronounced precipitation maximum. The summers are warm, a dry period is absent, but precipitation gradually decreases towards the east. A strong influence of cold easterly winds in the winter period is present. The climatic characteristics of the meteorological stations Đurđevac, Donji Miholjac and Osijek are shown on figure 2 (SELETKOVIĆ 1996).

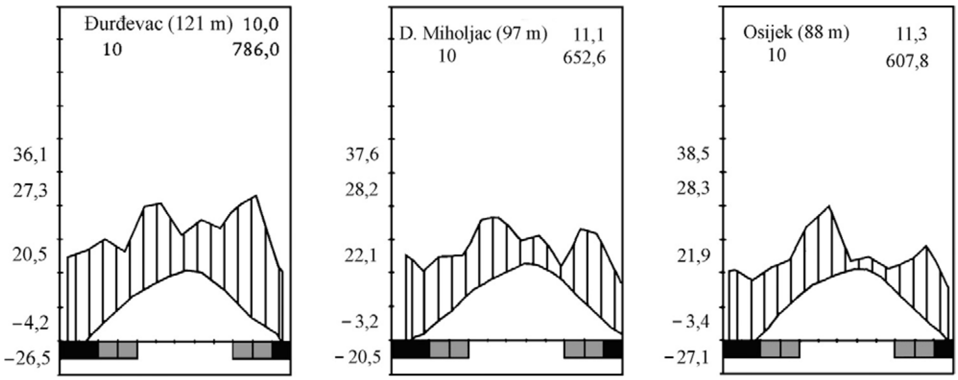

Fig. 2. Climate diagrams for the meteorological stations Đurđevac, Donji Miholjac and Osijek for the period 1983–1992 (SELETKOVIĆ 1996).

According to climatic characteristics, the monthly rain factor (KFm), humidity (H) and thermal climatic character (TK) were computed (MARGETIĆ 1983) and are shown in table 1.

Annual air temperature for the meteorological station Đurđevac is 10.0 °C. The mean air temperature in the coldest month (January) is –0.1 °C, while in the warmest month (July) it is 20.4 °C. The absolute minimum recorded was –26.5 °C, and the absolute maximum 36.1 °C. The average annually precipitation is 786 mm (during the vegetation period 413.8 mm). The minimum precipitation is in December (42.2 mm), while the maximum in November (86.2 mm). According to Lang's annual rain factor (Kfg = 78.6) the climate is semi humid, while according to Gračanin's thermal climatic character the climate is moderately warm (Tab. 1). The winds most often come from the west and northwest.

Annual air temperature for the meteorological station Donji Miholjac is 11.1 °C. The mean air temperature in the coldest month (January) is 0.1 °C, and in the warmest month (July) 22.2 °C. The absolute minimum recorded was –20.5 °C, and the absolute maximum 37.6 °C. The average annual precipitation is 653 mm (during the vegetation period 354.5 mm). The minimum precipitation is in December (31.3 mm), while the maximum is in June (73.5 mm). According to Lang's annually rain factor (Kfg = 58.8) the climate is semiarid, and according to Gračanin's thermal climatic character the climate is moderately warm (Tab. 1).

Tab. 1. Average monthly and annual air temperature (T), precipitation (O), relative air humidity (RV) (SELETKOVIĆ 1996), monthly raining factor (KFm), humidity (H) and heat climate character (TK) for meteorological stations Đurđevac, Donji Miholjac and Osijek for period from 1983 to 1992.

Month	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Annual
						Đurđevac							
T (°C)	–0.1	0.4	5.4	10.6	15.3	18.1	20.4	19.7	15.4	9.9	4.2	1.2	10.0
O (mm)	49.6	53.2	61.0	51.1	80.0	81.6	62.5	72.3	66.3	80.1	86.2	42.2	786
RV (%)	83	80	77	74	75	77	77	78	82	85	87	85	80
KFm	496	133	11.3	4.8	5.2	4.5	3.1	3.7	4.3	8.1	20.5	35.2	78.6
H	ph	ph	h	sa	sh	sa	a	sa	sa	h	ph	ph	sh
TK	n	n	uh	ut	t	t	v	t	t	ut	uh	h	ut
						Donji Miholjac							
T (°C)	0.1	1.0	6.0	11.8	16.4	19.3	22.2	21.8	17.4	11.2	4.8	1.3	11.1
O (mm)	50.0	40.5	49.7	50.0	71.2	73.5	57.9	61.5	40.4	64.7	61.9	31.3	653
RV (%)	89	87	80	74	73	74	69	71	76	82	90	92	80
KFm	500	40.5	8.3	4.2	4.3	3.8	2.6	2.8	2.3	5.8	12.9	24	58.8
H	ph	ph	h	sa	sa	sa	a	a	a	sh	h	ph	sa
TK	n	h	uh	ut	t	t	v	v	t	ut	uh	h	ut
						Osijek							
T (°C)	–0.1	0.6	6.2	11.8	16.5	19.0	21.8	21.1	16.9	11.3	4.7	1.4	11.3
O (mm)	46.7	36.8	45.2	49.1	71.5	81.5	47.7	50.5	42.8	48.2	57.1	30.7	608
RV (%)	86	81	73	68	69	70	67	68	72	76	84	86	75
KFm	467	61.3	7.3	4.2	4.3	4.3	2.2	2.4	2.5	4.3	12.1	21.9	53.8
H	ph	ph	h	sa	sa	sa	a	a	a	sa	h	ph	sa
TK	n	h	h	ut	t	t	v	v	t	ut	uh	h	ut

Annual air temperature for the meteorological station Osijek is 11.3 °C. The mean air temperature in the coldest month (January) is –0.1 °C, and in the warmest month (July) 21.8 °C. The absolute minimum was –27.1 °C, and the absolute maximum 38.5 °C. The average annual precipitation is 608 mm (during the vegetation period 343.1 mm). The minimum precipitation is in December (30.7 mm), and the maximum in June (81.5 mm). According to Lang's annually rain factor (Kfg = 53.8) the climate is semiarid, and according to Gračanin's thermal climatic character the climate is moderate warmly (Tab. 1). A strong influence of cold easterly winds in the winter period is present. The winds most often come from the west and northwest.

The geological substrate is made up of gravel, sand, clay and loam deposited in the Pannonian Sea in the Tertiary and river detritus in the Quaternary. In the eastern part of the studied area there is a considerable presence of flat marly areas formed by the wind bringing large quantities of fine-grain dust of marl or loess during the diluvium. The researched area contains the very remarkable »Vukovar plateau«, a 30×14 km plateau between Vukovar and Šid with up to 24 m high layers of loess (RAUŠ 1969). According to site of deposition there are two types of loess, swamp and terrestrial loess. Swamp loess is more compact and yellowish with a bluish shade. Terrestrial loess developed in dry places and has typical loess characteristics (greyish-yellowish colour, unstable small grain structure, perforations and trend of vertical breaking). It is loosely, permeable for water and has 18 to 26% of $CaCO_3$ (KALINIĆ 1974).

The Danube forms meanders and permanently expands its bed. This process is much easier because the river banks are constituted from weakly associated sands. The undulating shape of the relief along the Danube is also caused by water at high water level presses and soaks the river banks. When the high water withdraws the sodden bank will fall into the Danube. This process is the most expressed when the mainstream is close to the bank. In this way, the Danube has enlarged the islets in the river or even formed completely new islets (ŠPANOVIĆ 1954, MAJER 1994). The Danube valley is especially extennsive in Baranja. The Drava River also forms bends, river islets and sandbanks (RAUŠ and ŠEGULJA 1983).

The alluvial and swampy gleyic (eugleyic) soils were developed on alluvial substrates in the valleys of the Drava and Danube. Two types of soil, the gravel-sandbanks and rankers with horizon structures A-R or A-C-R were formed on the youngest river sediments. Continuous sedimentations of new particles stop the process of the formation of a of humus horizon. The older alluvial substrates, sands and loess form the alluvial plateau of Danube with more developed soils. On those substrates alluvial soils (fluvisols) were formed with the horizon structure A or (A)-I-II-... and fluvial meadow soils (humofluvisol) with the horizon structure A-C-G. They have different depth to the gravel; they are carbonate, gleyic or not gleyic, with sandy, loamy or clay texture. Meadow semi-gleyic soil type (semigley) with the horizon structure A-(B)v-C-G or A-C-G and pseudogley-gley type (A-g-G) were developed in the transitions from depressions to micro-elevations, or shallow recesses in micro-elevations (MAYER 1992). Humogley (Aa-G_{so}) was developed above the swamp loess and closely related sedimentations in forest depressions (ŠKORIĆ 1986). The gravel content is much greater in the area of Varaždin than in the lower part of Drava River basin where the sand and clay dominate. According to MAYER (1992) in the central part of the Drava River basin the most frequent soils are eugleyic soils: amphigley (Aa-G_r-G_{so}-G_r), hypogley (Aa-G_{so}-G-$_r$) and epigley (Aa-G_r-G_{so}).

In hydrographic terms, the entire area is very well developed, which has a good effect on the vegetation. Beside the largest rivers, the Drava and the Danube, there are many smaller rivers and streams (for example the Čađavica, Karašica, Vučica andVuka).

Materials and methods

The first study phase was based on compiling information from the management plans of all the management units covering the lowland forest regions under the management of five Forest administration units (Bjelovar, Koprivnica, Našice, Osijek, and Vinkovci) of Croatian Forests Ltd. According to the management plans, subcompartments that contain North American ash species were identified. In the management plans North American ash species are known under one name – »American ash«. Accordingly, twenty subcompartments were randomly selected for the collection of dendrological material. Fertile twigs with leaves and fruits were collected in August and September when they are completely developed. Dendrological material was collected from trees on the edge of forest which had at least one continuously well insolated side and a well developed crown. Good lighting enables complete development of leaves and fruits, so that the genes which determine their shape and size can be revealed (FRANJIĆ 1996, TRINAJSTIĆ and FRANJIĆ 1996, KOVAČIĆ 1998). The area, standing volume (if existing) and soil types were also obtained from the management plans.

Gauß-Krüger co-ordinates were used for mapping the distribution of North American ash species. The co-ordinates of the centre of each subcompartment were read off from the forest management maps. The Gauß-Krüger co-ordinates were then raised as data points in ArcView 3.3 software, and overlaid with the MTB 10F' × 6F' grid (NIKOLIĆ et al. 1998).

Results

In the lowland forests of the Drava River basin and the Danube basin 960 subcompartments in total with North American ash species were established. The area and the standing volume of North American ash species are given in table 2. American ash species are present as single trees in a large part of the studied area. For this reason their growing stock is small.

Tab. 2. Overview of the representation of the North American ash species in the Drava River basin and Danube basin.

River basin	Number of sub-compartment	Area (ha)	Standing volume (m^3)	
			North American ash	All species
Drava River basin	197	2227	2208	481144
Danube River basin	763	5478	55912	1035264
Total	960	7705	58120	1516408

The distribution of introduced North American ash species in the Drava River basin and Danube basin is presented for the first time (Fig. 3). Circles mark subcompartments where the North American ash species are present according to management plans without exact specification of whether this refers to white or green ash. Crosses mark the twenty subcompartments where the presence, according to the collected dendrological material, of the green ash was determined. The green ash was found in all those subcompartments. The white ash was not found.

In the researched area North American ash species are present in small, mostly isolated depressions where they were planted at the beginning or in the middle of the 20th century. They were planted and grew in swamps where the native narrow-leaved ash could not survive. Also, North American ash species spread spontaneously to many other locations. It is often the case in the Danube basin and low part of Drava River basin, but much less common in the upper part of Drava River basin. Indeed, North American ash species are present today in the Danube basin mostly in places where they were spontaneously spread by seeds. That is, flood water spreads the seeds of North American ash species (and other pioneer species) to all parts of Danube basin. In such places, such as swamps and river islets, North American ash species grow together with other pioneer species (white poplar –

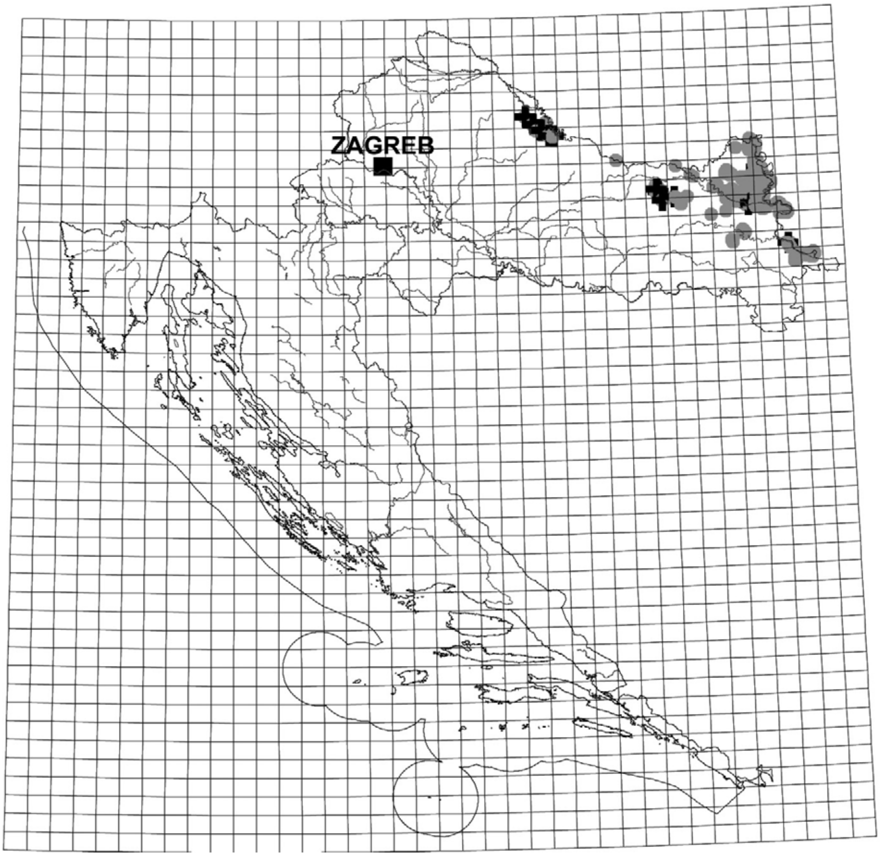

Fig. 3. Spatial distribution of American ash species in Croatia with the MTB 10F' × 6F' grid. Circles denote its presence according to the management plans, Crosses denote the presence of the green ash.

Populus alba L., black poplar – *P. nigra* L., white willow – *Salix alba* L., ashleaf maple – *Acer negundo* L., European white elm – *Ulmus laevis* Pall, white mulberry – *Morus alba* L.). Because of that, North American ash species have a reclamation role in preparing habitats for species with more valuable wood such as narrow-leafed ash. In better habits, North American ash species lose in competition with native species. The timber value of North American ash species is small because they are usually bent by wind, snow and ice. Also, the trees of North American ash species were more often pulled down than the trees of native species.

Discussion

Only the green ash was determined in the research area of the lowland forests in the Drava River basin and Danube basin. The presence of white ash was not confirmed. This result confirmed the conclusion of KREMER and BORZAN (2001), KREMER (2004), and

KREMER et al. (2005) that it is the green ash that is primarily present in the Croatian lowland forests today. Green ash is widely distributed because it is better adapted to sites that are subject to periodical flooding and to poorly drained backwater sites (TAYLOR 1972, BEAN 1973, BAKER 1977, DIRR 1988). Because of those reasons it is probable that the white ash has retreated from wet sites. On the other hand, the green ash, as a pioneer species, has spread to river islets and in swamps.

Practically, only hydromorphic soils (fluvisol, humofluvisol, amphigley, hypogley, epigley, and semigley) are present in the subcompartments with North American ash species in the researched area of Drava River basin and Danube basin. Hydromorphic soils show the signs of periodical or continuous flooding (MARTINOVIĆ 2000). Additional soil moisture is provided by down-slope water, flooding from waterways, and groundwater. Hydromorphic soil types were formed depending on the kind of water saturation. For example, in hypogley the gleying process was caused by high groundwater, in epigley by surface water, and in amphigley by a combination of ground and surface water. More rarely pseudogley and pseudogley-gley soil types are present in subcompartments with North American ash species.

Soil type and varied micro-relief (micro-elevations and micro-depressions) have a big effect on vegetation; forestry vegetation is developed on micro-elevations, swamp vegetation in the micro-depressions.

A different type of vegetation is developed on each soil type. In the Danube basin on alluvial, carbonate, gleyic soils in pools the association *Salicetum-purpureae* Wend.-Zel. 1952 is present. The forest association *Salici albae – Populetum nigrae rubetosum caesii* RAUŠ 1973 is developed on the non gleyic soil type at the transitions from micro-depressions to moist micro-elevations or on micro-elevations. On the poorly developed non gleyic or middle gleyic soil types on micro-elevations or at the transition from a micro-depression to a quite moist micro-elevation the association *Populetum nigro-albae* Slavn. 1952 is present. The association *Galio-Salicetum albae* RAUŠ 1973 is developed on the same soil type, but in micro-depressions. On poorly developed soils in pronounced depressions the association *Scirpo-Phragmitetum* W. Koch 1926 is developed. The forest association *Fraxino-Ulmetum laevis* Slav. 1952 is present on well developed, non gleyic or poor gleyic soil type (RAUŠ 1976). The same associations are present in the Drava River basin (RAUŠ 1992).

All those associations are created from pioneering species which prepare a habitat for the arrival and success of the native species, primarily the narrow-leaved ash. The pure and mixed plantations of North American ash species were developed in these unfavourable habitats. From that, it is clear that North American ash species have a reclamation role in the Danube basin and the lower part of the Drava River basin.

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