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VEGETATION SUCCESSION ON TWO PERMANENT PLOTS IN EAST CROATIA IN THE PERIOD 1978—1991

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The vegetation succession was surveyed on two permanent plots in eastern Croatia in the period 1978—1991. One of these plots started from an abandoned pasture, the other from arable land. Although they were geographically very near each other, vegetation develops toward different wood communities on these plots, due to different ecological conditions. After fourteen years the vegetation reached nearly the same stage as the wood vegetation, considering the number of woody individuals as well as their height and cover.

Introduction

Since the very early concept of succession by Warming (1896), Cowles (1901) and Clements (1916) (Kershaw 1973) to recent investigations (Falinski 1986, Gittins 1981, Londo 1980, Van Dorp 1985 and others) efforts have been made to investigate the vegetation succession on different habitats.

After long preparations (Ilijanić 1965, 1975, Ilijanić and Meštrov 1975, Rauš 1976) the net of permanent plots started to organize in 1977 all over the territory of Croatia. Different ecosystems were involved: woods, agriculture, waters, grasslands in different phytogeographical regions, at different altitudes and edaphic conditions. Different starting stages were included in vegetation development.

Permanent plots were organized successively, so we now have 100 plots in Croatia. Some of them were investigated over a longer period (Rauš 1984, Rauš et al. 1979, 1980), while the others were not surveyed in details. Two of them, Muško Ostrvo and Durgutovica, were examined in the period 1978—1991 from the standpoint of vegetational succession.

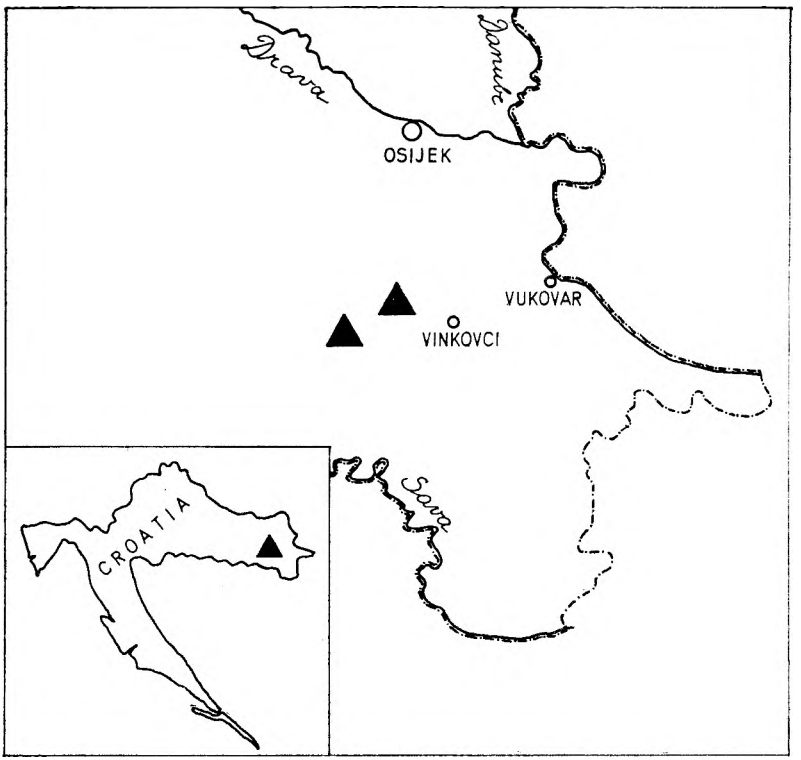

Fig. 1. Geographical position of permanent plots of Muško Ostrvo and Durgutovica

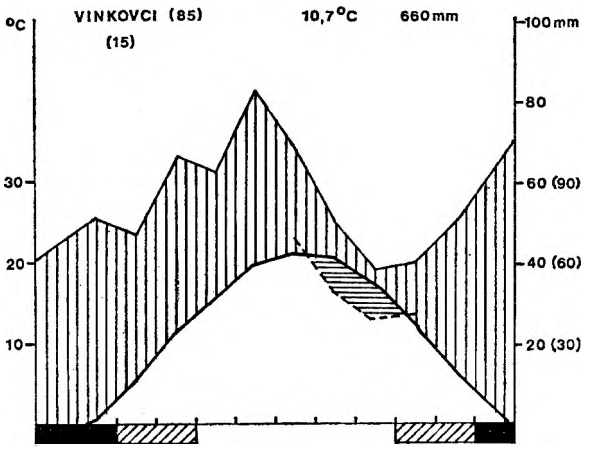

Fig. 2. Climate diagram for the nearest meteorological station at Vinkovci

Subject of Investigation

These two plots, each of 1 ha, are situated in the eastern part of Croatia, Muško ostrvo in UTM quadrat CR 01 and Durgotovica in UTM quadrat CR 11 (Fig. 1). This is a flat lowland area with somewhat rolling contours.

The climate of the region is moderate continental and its characteristics are shown on the climate diagram (Fig. 2).

The permanent plot of Muško Ostrvo is situated on the border between a forest complex and pastures at an altitude of 87 m a.s. In 1978 one part of the abandoned pasture was planted by oak acorns and since then 1 ha of area started to exist as a permanent plot. The surrounding old forest belonged previously to the association *Genisto elatae-Quercetum roboris* Ht 38 (*Alno-Quercion roboris* Ht 37, *Populetalia* Br.-Bl. 31, *Alno-Populetea* Fk. et Fb. 64). The pastures when in use, belonged to the association *Trifolio-Agrostietum stoloniferae* Marković 72 (*Agropyro-Rumicion crispi* Nordhagen 40, *Agrostietalia stoloniferae* Oberd. 67, *Molinio-Arrhenatheretea* Tx. 37). The composition of the flora of these pastures before abandoning was as follows: *Trifolium fragiferum, Trifolium repens, Ranunculus sardous, Agrostis stolonifera, Prunella vulgaris, Leontodon autumnalis, Rorippa sylvestris, Potentilla reptans, Mentha pulegium, Lolium perenne, Plantago major, Taraxacum officinale.*

In 1978, at the time of oak planting this part of pasture had already been abandoned for several years, so the composition of the flora differed from the original. Nearly all the herbaceous species composing Table 1 were noted. Hectars and hectars of pastures near the plot had also been abandoned and successively planted by oak and sporadically by white willow.

The permanent plot of Durgutovica started from arable land at the same time. The last crop was wheat in 1978 with accompanied weeds: *Matricaria chamomilla, Centaurea cyanus, Papaver rhoeas, Galium aparine, Stellaria media, Arabidopsis thaliana, Veronica persica, Veronica hederifolia, Viola arvensis, Consolida regalis, Sinapis arvensis and Ranunculus sardous.* The plot is situated on the border between a forest, mainly the association *Carpino betuli-Quercetum roboris* Rauš 81, (*Carpinion betuli illyricum* Ht. 56, *Fagetalia* Pawl., *Querco-Fagetea* Br.-Bl. et Vlieg. 37) and arable soil. The altitude is 107 m a.s. On the northern edge of the plot there is a hydroamelioration canal, while rotation crops border the southern edge.

These permanent plots are only a few kilometers away from each other.

Methods

The composition of the flora was made up for both permanent plots by standard vegetational recording (Braun-Blanquet 1964). After ten years (1987) all the woody species on the transect area of 100×10 m were noted and counted. Also, the height of woody species was measured along the 100 m long transect. The cover of woody species was recorded on an area of 1000 sq.m (100×10 m). The same investigations, without counting, were repeated in 1991.

The water content of the soil was measured on both permanent plots in 1989.

Some physical and chemical properties of soil were recorded. Sedimentation method was used to determine the soil class (Gračanin, Ilijanić 1977), humus content was determined by Kotzmann's method, $CaCO_3$ by volumetric method, pH by digital pH-meter in water and KCl suspensions.

The plant names were taken according to Ehrendorfer (1973).

Results and Discussion

The composition of the vegetation on the permanent plots are shown in Table 1, according to vegetational records made in 1989. A comparison of these plots shows that the composition of the flora varies considerably and the community coefficient after Sørensen (Braun-Blanquet 1964) is small (CC=31%). A greater number of species occurs at Muško Ostrvo, due to microrelief variety, than at Durgutovica plot, where the soil surface is flat. Comparing the plant composition over the period mentioned above neither fluctuation nor succession was obvious in the herbaceous layer at Muško Ostrvo, while the plant composition on Durgutovica plot was not investigated successively from the beginning.

In 1987 trees and bushes were scattered relatively uniformly over the transect on the Muško Ostrvo plot (Fig. 3). Absence of woody plants was visible between 80 and 90 m because of the canal transecting the area. Southward from the canal, at a somewhat higher position than in the northern part bushes and trees were better developed, covering most of the surface. The northern, lower part is less overgrown by woody plants.

A similar feature is visible in Fig. 4, showing the height of woody plants on the 100 m long transect at Muško Ostrvo. Both the density and diameter were greater in the north-south direction, i. e. from a lower to a higher microrelief position. This difference in altitude is less than 0.5m but rather significant for vegetational development.

Figure 5 presents the cover of woody plants at the Durgutovica plot, and Fig. 6 shows the height of woody plants on the 100 m long transect in 1987. In comparison with the Muško Ostrvo plot there were higher and larger bushes on average in 1987. The same figures show the situation in 1991. Obviously, the situation was quite different in 1991. The area investigated at Muško Ostrvo was nearly 100% overgrown by woody plants, and that of Durgutovica was overgrown about 80%. The speed of succession increased with time. It would be interesting to compare the speed at different intervals and stages of succession, both with regard to overgrowing and tree height.

Tables 2 and 3 show the distribution of each woody species within small quadrats (10×10 m) and Table 4 shows comparatively the share of woody species at both permanent plots in 1987. Obviously, only few of them are common to both plots. Some of them are frequent at one but sparce at the other plot, while others are infrequent at both plots.

Quercus robur, the most abundant species at the Muško Ostrvo plot was certainly planted, but only to induce the expected succession toward oak wood, the same or similar to those in the surrounding wood complex. The development of natural oak wood is very slow. The acorn is too heavy to be spread by wind or birds, so the conquering of bare soil proceeds step by step from wood margins or from solitary old oaks left after cutting. Over the plot of Muško ostrvo 3500 acorns per hectar were planted and about a quater survived. In addition to *Quercus robur* there

were also some indicators of wet soils (*Salix cinerea*) as well as the characteristic species of transitional shrubby vegetational type of the association *Corno-Ligustretum* (*Ligustrum vulgare, Prunus spinosa, Crataegus monogyna, Cornus sanguinea*). There was a considerable number of *Amorpha fruticosa,* an adventitious plant spreading in depressions along the roads and on forest borders, causing trouble, especially on new plantations.

Carpinus betulus absolutely prevailed on the Durgutovica plot. The share of other woody species was very small. The seeds of *Carpinus betulus* were planted by themselves, flying over from the nearby wood.

There are rather few available data about successions on such habitats to compare with. Some experience by Čolić (1960) and Matić (1990) was used. The data by Matić (1990a) concern a similar type of forest vegetation but the succession started after a complete forest destruction.

The difference in plant composition and succession between these two plots seems to be caused primarily by different water regime of the soil. We started to search for ground water table up to a depth of 2.5 m in January 1989. We supposed that at the Muško Ostrvo plot we could expect it near the soil surface, drawing such conclusion from the fact that the surrounding forest belong to the very moist type, ass. *Genisto elatae-Quercetum roboris* and the locality name Muško Ostevo (Man's Island) may recall the situations when access to the wood was possible by boat only. Over the last fourteen years we have never noted surface water and only once in 1989 (May) the ground water table was at a depth of 2.5 m while during the other months it was obviously much deeper. One reason for such a picture is that 1989 was very poor in precipitations, and the other reason lies in the hydroamelioration canal system in the wider area. Draining the excessive water for agricultural purposes, these canals, unintentionally, drain the forests as well.

Table 5 shows the soil water content of both plots in 1989. Durgotovica plot was obviously drier than Muško Ostrvo, coinciding with the drier type of vegetation developing there. The mean humidity value of vegetation (Landolt 1977) was 3.21 for Muško Ostrvo, and 2.61 for Durgutovica. The dispersion of moisture classes was much greater at Muško Ostrvo, and 2.61 for Durgutovica. The dispersion of moisture classes was much greater at Muško Ostrvo that at Durgutovica due to microrelief features (canal).

Soil moisture was low for both plots, with values much closer to the value of unavailable water than to the value of field capacity, indicating the very unfavourable water status of the soil in that dry year (particularly summer). Total yearly precipitations in 1989 were 529 mm, while the annual mean is 660 mm at the nearest meteorological station at Vinkovci (Fig. 2).

The soil properties are shown in Table 6. There were clays and loams at both plots. The soil reaction and humus content were somewhat higher at Muško Ostrvo that at Durgutovica plot, while the values of $CaCO_3$ were similar.

These results about the O-stage and vegetational succession at these two permanent plots point at their differences, in spite of geographical vicinity. More detailed longterm investigations of soil water regime are required, as well as permanent dynamics surveys. Also, complex ecological and biocenological surveys are desirable, including detailed pedological analyses, microbial activity, invertebrate and vertebrate population and others, to fulfil the aim of permanent plots.

Tab. 1. Composition of the flora on the permanent plots Muško Ostrvo and Durgutovica in 1989

Species	Muško Ostrvo	Durgutovica
Agrostis tenuis Sibth.	2	·
Dispacus fullonum L.	1	·
Galium verum L.	1	·
Galium mollugo L.	1	·
Lycopus europaeus L.	1	·
Carex hirta L.	1	·
Poa pratensis L.	1	·
Cornus sanguinea L.	1	·
Ligustrum vulgare L.	+	·
Fraxinus angustifolia Vahl	+	·
Sonchus arvensis L.	+	·
Potentilla reptans L.	+	·
Amorpha fruticosa L.	+	·
Lychnis flos-cuculi L.	+	·
Verbena officinalis L.	+	·
Galium palustre L.	+	·
Mentha arvensis L.	+	·
Pulicaria vulgaris Gaertn.	+	·
Althaea officinalis L.	+	·
Agrostis stolonifera L.	+	·
Juncus articulatus L.	+	·
Juncus inflexus L.	+	·
Eleocharis palustris (L.) Roem. & Schult.	+	·
Symphytum officinale L.	+	·
Teucrium scordium L.	+	·
Lysimachia nummularia L.	+	·
Cirsium vulgare (Savi) Ten.	+	·
Lycopus exaltatus L.	+	·
Salix purpurea L.	+	·
Ranunculus repens L.	+	·
Lythrum salicaria L.	+	·
Poa compressa L.	+	·
Rumex acetosa L.	+	·
Alopecurus pratensis L.	+	·
Cerastium holosteoides Fries emend Hyl.	+	·
Myosotis arvensis (L.) Hill.	+	·
Ranunculus sardous Cr.	+	·
Scutellaria hastifolia L.	+	·
Carex otrubae Podp.	+	·
Poa palustris L.	+	·
Juncus effusus L.	+	·
Dactylis glomerata L.	+	·
Conyza canadensis (L.) Cronq.	+	·
Centaurea jacea L.	+	·
Rumex obtusifolius L.	+	·
Festuca pratensis Huds.	+	·
Carex tomentosa L.	+	·
Carex distans L.	+	·
Mentha aquatica L.	+	·
Taraxacum officinale Web.	+	·
Carex praecox Schreb.	+	·
Rorippa sylvestris (L.) Bess.	+	·
Euphorbia lucida L.	+	·
Rumex conglomeratus L.	+	·
Lathyrus nissolia L.	+	·

▶

Species	Muško Ostrvo	Durgutovica
Plantago lanceolata L.	+	·
Epilobium montanum L.	+	·
Mentha pulegium L.	+	·
Agrimonia eupatoria L.	+	·
Atriplex oblongifolia W. & K.	+	·
Dianthus armeria L.	+	·
Leontodon saxatilis Lam.	+	·
Ambrosia artemisiifolia L.	+	·
Allium angulosum L.	+	·
Salix cinerea L.	+	·
Senecio jacobea L.	+	·
Erigeron annuus (L.) Pers.	+	·
Tragopogon pratensis L.	+	·
Vicia cracca L.	+	·
Lathyrus hirsutus L.	+	·
Plantago major L.	+	·
Juncus gerardii Loisel.	+	·
Cynodon dactylon (L.) Pers.	+	·
Pyrus pyraster Burgsd.	+	·
Epilobium parviflorum (Schreb.) With.	+	·
Calamagrostis epigejos (L.) Roth	+	5
Rubus sp.	1	2
Cirsium arvense (L.) Scop.	2	1
Quercus robur L.	3	+
Vicia tetrasperma L.	1	2
Daucus carota L.	1	+
Euphorbia stricta L.	1	+
Solidago gigantea Ait.	+	1
Epilobium tetragonum L.	1	·
Achillea millefolium L.	+	+
Prunella vulgaris L.	+	+
Agropyron repens (L.) PB.	+	+
Centaurium erythraea Rafn	+	+
Picris hieracioides L.	+	+
Eupatorium cannabinum L.	+	+
Rosa arvensis L.	+	+
Populus tremula L.	+	+
Poa trivialis L.	+	+
Prunus spinosa L.	+	+
Populus alba L.	+	+
Verbascum nigrum L.	+	+
Tanacetum vulgare L.	+	+
Crataegus monogyna Jacq.	+	+
Geranium columbinum L.	+	+
Convolvulus arvensis L.	+	+
Carpinus betulus L.	·	4
Fragaria vesca L.	·	2
Clematis vitalba L.	·	2
Salix caprea L.	·	2
Holcus lanatus L.	·	1
Hypericum perforatum L.	·	1
Vicia sp.	·	+
Crepis sp.	·	+
Anthemis arvensis L.	·	+
Lapsana communis L.	·	+
Trifolium arvense L.	·	+
Solanum dulcamara L.	·	+
Stachys germanica L.	·	+

Species	Muško Ostrvo	Durgutovica
Urtica dioica L.	·	+
Clinopodium vulgare L.	·	+
Juncus conglomeratus L.	·	+
Astragalus glycyphyllos L.	·	+
Campanula patula L.	·	+
Rumex crispus L.	·	+
Scrophularia nodosa L.	·	+
Vicia grandiflora L.	·	+
Thymus serpyllum L.	·	+
Acer campestre L.	·	+
Artemisia vulgaris L.	·	+
Chamaecytisus hirsutus (L.) Lk.	·	+
Erigeron annuus (L.) Pers.	·	+
Euphorbia cyparissias L.	·	+
Galium aparine L.	·	+
Geranium dissectum L.	·	+
Rubus caesius L.	·	+
Lychnis coronaria (L.) Desr.	·	+
Viola arvensis Murray	·	+
Potentilla argentea L.	·	+

Tab. 2. Number of woody individuals in small quadrats (10 × 10 m) within the transect (100 × 10 m) on the Muško Ostrvo plot in 1987

species	quadrat number										total 1000 sq. m
	1	2	3	4	5	6	7	8	9	10	
Quercus robur	105	106	65	98	74	76	84	85	93	166	925
Cornus sanguinea	13	11	6	17	1	1	4	19	0	10	82
Amorpha fruticosa	2	8	7	0	1	1	1	0	7	9	36
Salix cinerea	1	4	3	3	0	0	8	0	4	3	26
Prunus spinosa	1	0	4	2	0	0	0	0	0	0	7
Populus alba	0	1	2	1	0	2	0	1	0	0	7
Pyrus pyraster	3	0	0	0	0	0	0	2	0	0	5
Crataegus monogyna	1	2	0	1	0	0	0	0	0	0	4
Populus tremula	0	0	0	1	0	0	0	0	0	0	1
Rubus sp.	0	1	0	0	0	0	0	0	0	0	1
Rosa arvensis	1	0	0	0	0	0	0	0	0	0	1
Salix purpurea	0	0	0	0	0	0	1	0	0	0	1
Fraxinus angustifolia	0	0	0	1	0	0	0	0	0	0	1
Ligustrum vulgare	0	1	0	0	0	0	0	0	0	0	1
Total/quadrat	127	134	87	124	76	80	98	107	104	188	1125

Tab. 3. Number of woody individuals in small quadrats (10 × 10 m) within the transect (100 × 10 m) on the Durgutovica plot in 1987

species	quadrat number										total 1000 sq. m
	1	2	3	4	5	6	7	8	9	10	
Carpinus betulus	135	235	82	156	201	82	56	76	48	64	1135
Salix caprea	18	20	5	2	5	1	4	3	1	4	63
Acer campestre	0	9	0	3	4	6	10	20	1	1	54
Rubus sp.	18	0	0	0	0	2	6	0	0	2	28
Prunus spinosa	0	0	4	1	0	0	0	0	0	0	5
Quercus robur	1	0	0	0	0	1	0	0	0	0	2
Populus tremula	2	0	0	0	0	0	0	0	0	0	2
Rosa arvensis	0	0	0	1	0	0	0	0	*h*1	0	2
Total/quadrat	174	264	91	163	210	92	76	99	51	71	1291

Tab. 4. Number of woody individuals on 1000 sq. m of permanent plots (1987)

species	permanent plot	
	Muško Ostrvo	Durgutovica
Quercus robur	925	2
Prunus spinosa	7	5
Populus tremula	1	2
Rubus sp.	1	28
Rosa arvensis	1	2
Salix purpurea	1	—
Fraxinus angustifolia	1	—
Ligustrum vulgare	1	—
Crataegus monogyna	4	—
Pyrus pyraster	5	—
Populus alba	7	—
Salix cinerea	26	—
Amorpha fruticosa	36	—
Cornus sanguinea	82	—
Acer campestre	—	54
Salix caprea	—	63
Carpinus betulus	—	1135
Total	1125	1291

Tab. 5. Soil water content (%) on permanent plots in 1989

depth	12 Jan.	23 May	26 July	28 Sept.	date 26 Oct.	23 Nov.	20 Dec.
				MUŠKO OSTRVO			
0 cm	44.52	41.75	14.00	24.69	39.13	42.70	49.70
50 cm	23.82	22.88	17.98	26.80	21.03	26.53	23.55
100 cm	17.67	28.35	17.71	18.14	16.83	22.31	19.43
250 cm	19.24	water	22.19	23.75	20.37	19.09	22.64
				DURGUTOVICA			
0 cm	46.06	30.24	5.37	9.82	17.91	40.12	19.24
50 cm	20.56	22.13	12.64	15.77	16.16	16.96	15.93
100 cm	22.85	22.87	18.71	19.09	17.91	18.06	33.89
250 cm	22.45	23.43	19.82	21.63	20.74	21.35	20.54

Tab. 6. Some physical and chemical properties of soil on permanent plots

Plot	Sample no	Depth cm	Soil class	pH H_2O	pH KCl	Humus %	$CaCO_3$ %
MUŠKO OSTRVO	1	0— 5	loamy clay	7.53	7.03	3.45	0.55
		50—55	clay	7.75	6.68	1.58	0.27
	2	0— 5	sandy clay	6.90	6.45	4.20	0.27
		50—55	clay	7.20	6.52	2.78	0.28
	3	0— 5	loamy clay	6.20	5.82	3.93	0.27
		50—55	clay loam	7.10	6.45	2.60	0.14
	4	0— 5	loamy clay	7.20	6.90	3.97	0.63
		50—55	clay loam	7.92	6.95	0.56	7.10
	5	0— 5	sandy-clay loam	6.55	6.32	6.05	0.27
		50—55	sandy clay	7.45	7.05	0.90	0.70
DURGUTOVICA	1	0— 5	clay loam	5.80	5.30	2.70	0.27
		50—55	loamy clay	6.15	5.50	1.63	0.14
	2	0— 5	clay loam	5.54	4.98	5.55	0.27
		50—55	loamy clay	5.72	5.32	1.65	0.42
	3	0— 5	clay loam	5.55	5.00	5.00	0.28
		50—55	loamy clay	5.95	5.00	1.41	0.83
	4	0— 5	loam	5.70	5.05	3.52	0.27
		50—55	loamy clay	5.88	4.95	1.41	0.83
	5	0— 5	clay	7.55	6.70	2.20	0.83
		50—55	clay loam	6.79	6.00	1.57	0.14

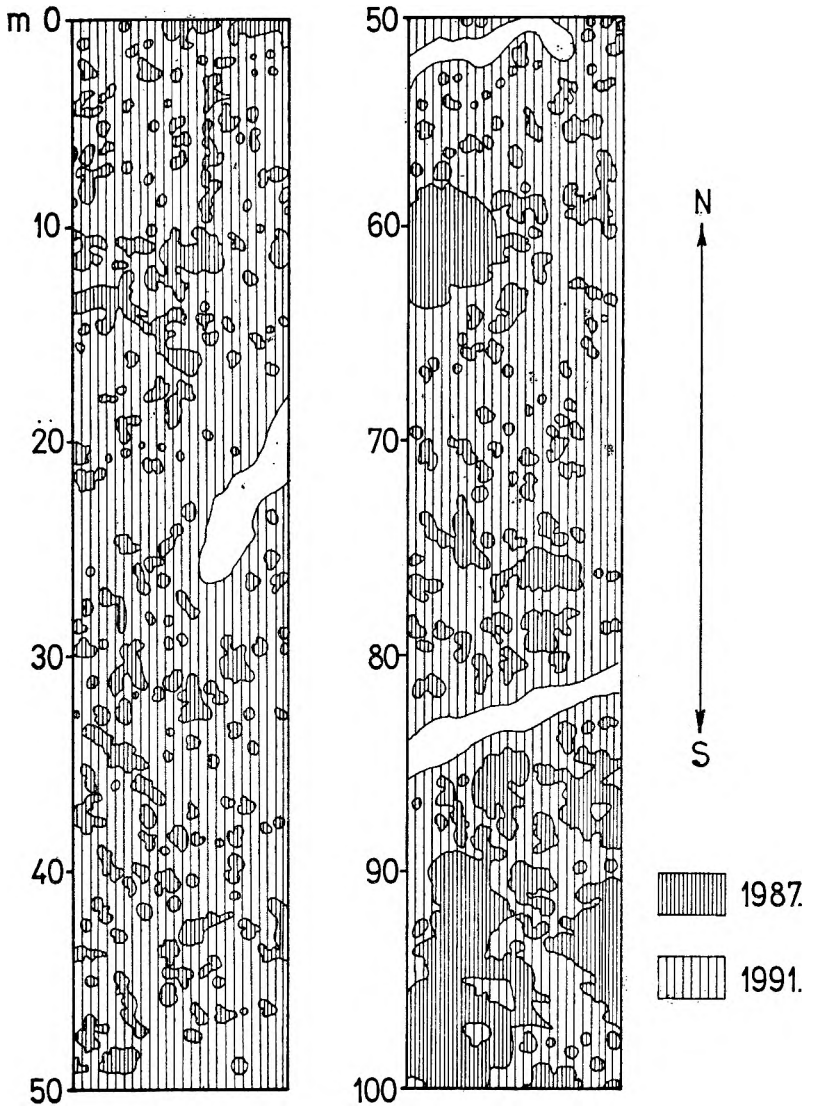

Fig. 3. Cover of woody plants over the transect (100 × 10 m) on the Muško Ostrvo plot in 1987 and 1991

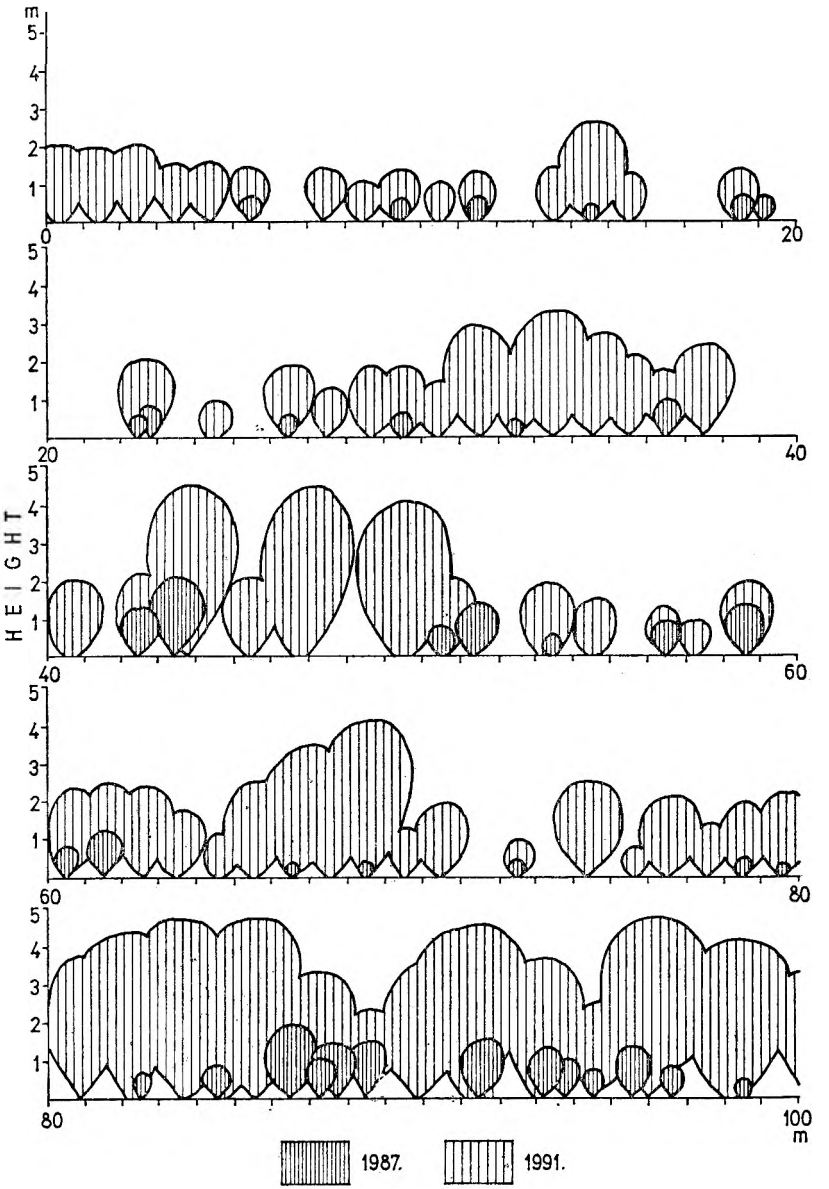

Fig. 4. Height of woody plants along the 100 m transect (N—S) on the Muško Ostrvo plot in 1987 and 1991

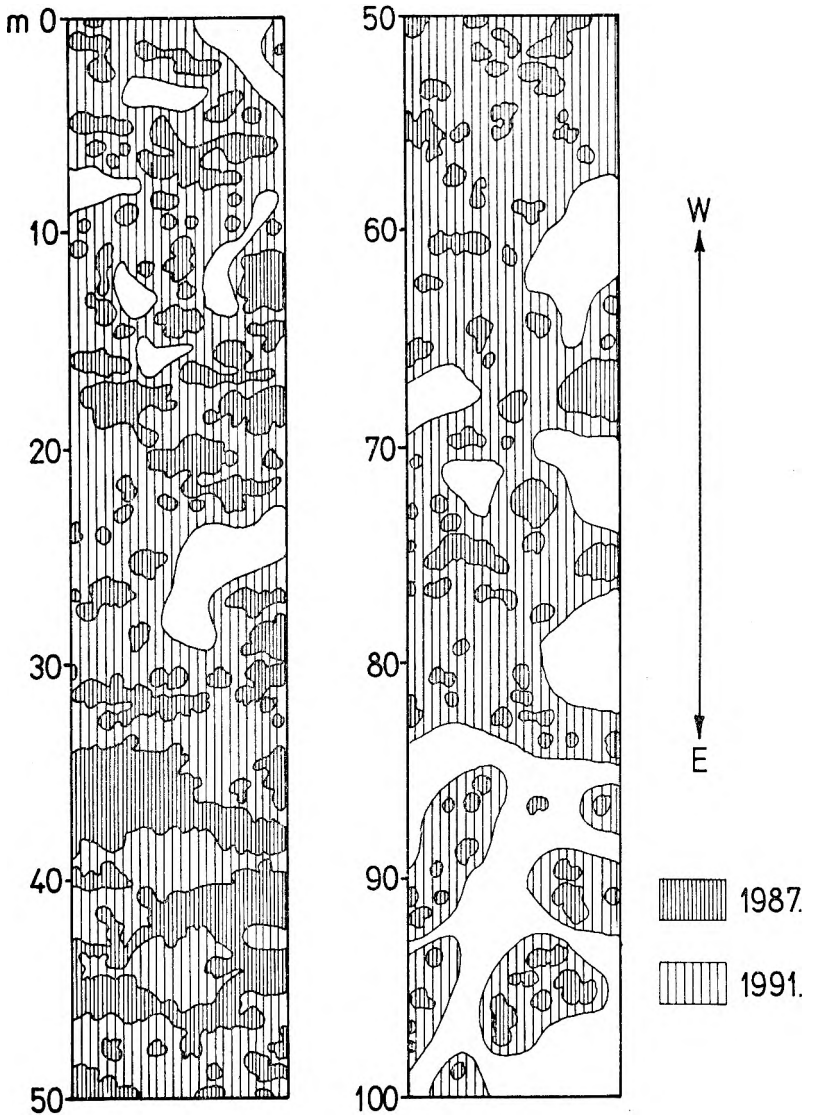

Fig. 5. Cover of woody plants over the transect (100 × 10 m) on the Durgutovica plot in 1987 and 1991

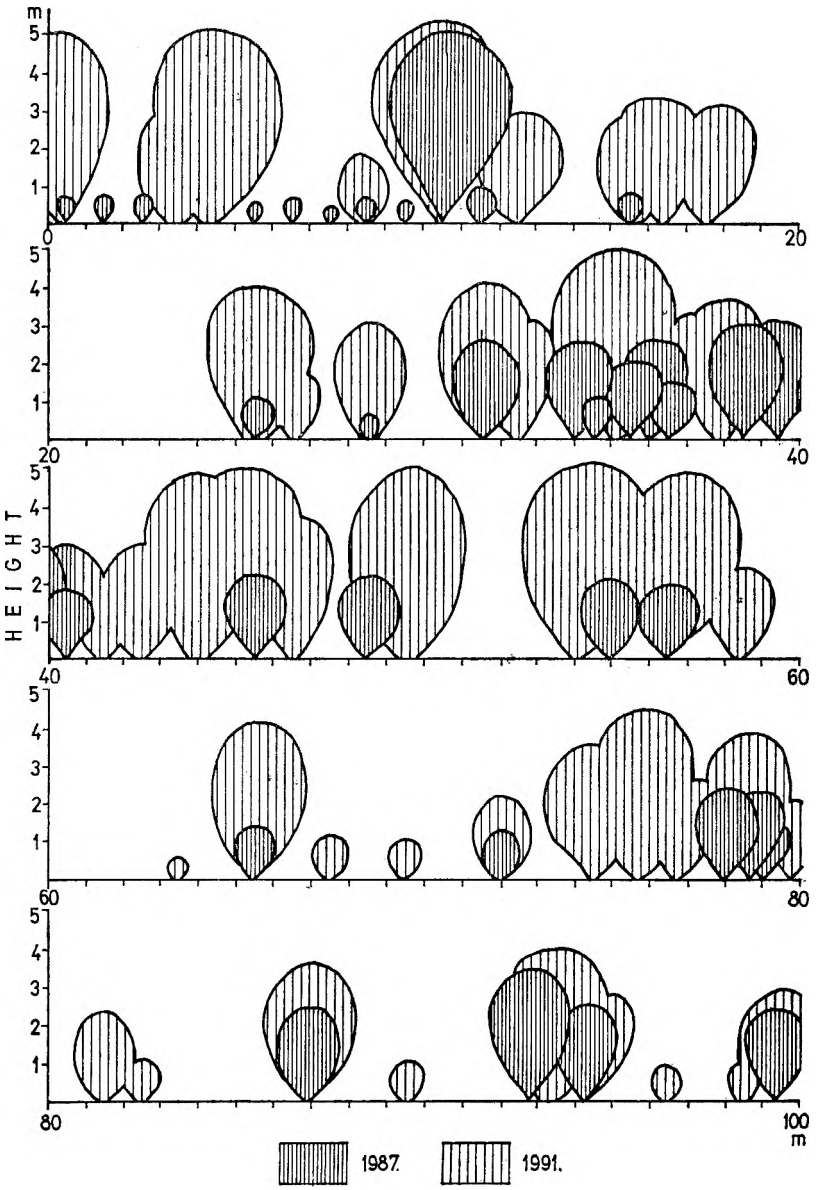

Fig. 6. Height of woody plants along the 100 m transect (W—E) on the Durgutovica plot in 1987 and 1991

Conclusions

The first fourteen years of permanent plots of Muško Ostrvo and Durgotovica and investigations of 0-stage as well as of the basic vegetational succesion in this period have shown that

1. although the plots started from different vegetational types (Muško Ostrvo from abandoned pasture, Durgutovica from arable land), both successions developed toward the wood vegetation, although obviously to different communities;

2. the speed of wood succession and overgrowing increased with age on both plots.

3. *Quercus robur* prevails on the Muško Ostrvo plot (925 specimens per 1000 sq. m), and *Carpinus betulus* prevails on the Durgutovica plot (1135 specimens per 1000 sq. m). There are not many species common to both plots. These differences mirror the differences in the nearby forest vegetation and habitat differences as well.

4. Soil moisture was lower at Muško Ostrvo than at Durgotovica, although all the values were low for 1989, due to low precipitations. Throughout 1989 the ground water table at Muško Ostrvo plot was deeper than expected, considering the nearby old forest belonging to the association *Genisto elatae-Quercetum roboris.*

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SAŽETAK

SUKCESIJA VEGETACIJE NA DVJEMA TRAJNIM PLOHAMA U ISTOČNOJ HRVATSKOJ U PERIODU 1978—1991.

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Od osnivanja mreže trajnih ploha 1978. godine do 1991. praćena je sukcesija šumske vegetacije na dvjema plohama u Slavoniji, kraj Vinkovaca. Plohe su udaljene jedna od druge samo nekoliko kilometara.

Na plohi Muško ostrvo sukcesija je počela od napuštenog pašnjaka, zasađenog žirom lužnjaka, *Quercus robur*. Na plohi Durgutovica, koja se u usporedbi s prethodnom nalazi na 20 m višem terenu, sukcesija je krenula od oranice. Nakon dvanaest godina očito je da sukcesija na obje plohe kreće prema šumskoj vegetaciji, iako prema različitim zajednicama.

Premda na početku sađen, lužnjak je zadržao dominantnu ulogu na plohi Muško ostrvo s 925 primjeraka/1000 m². Nasuprot tome, na plohi Durgutovica dominira *Carpinus betulus* sa 1135 primjeraka/1000 m².

Mjerenja vlažnosti tla u 1989. godini pokazuju da je ona bila veća u Muškom ostrvu nego u Durgutovici, iako je razlika bila mnogo manja od očekivane. Naime, samo jednom se nivo donje vode u Muškom ostrvu nalazio na dubini od 2,5 m, a inače je bio dublje, suprotno očekivanjima za tip šuma (*Genisto elatae-Quercetum roboris*) unutar čijeg kompleksa se nalazi trajna ploha. To se, s jedne strane, može pripisati maloj količini oborina te godine i, s druge strane, odvodnji vode sustavom hidromelioracijskih kanala čija mreža presijeca šumu te okolne poljoprivredne površine i pašnjake.

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