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Anthropogenic changes in the meadow vegetation in the Rudawa river valley near Zabierzow (S. Poland)

Stefan MICHALIK

1. INTRODUCTION

During the last decades great changes in the vegetation of the river valleys have taken place in Poland. In this paper these problems are shown using the example of Rudawa river valley near Zabierzow, which was described by PAWLOWSKI (1928), WITKOWSKI (1975) and MICHALIK (1980).

The meadow complex under study is located in the southern part of the Cracow Upland, 15 km west of Cracow, at the bottom of a tectonical depression. The Rudawa river forms a vast valley here with a bottom 1-1.3 km wide. Soils of a silt character formed of alluvial loess formations and characterized by low retentiveness occur there. The Rudawa river is enriched at this part with small stream and numerous water leakages located on the verge of the flat valley bottom. As a result of this hydrological situation, almost the whole valley bottom was formerly marshy. Sixty years ago the communities of wet sedge meadows and swamps of the *Phragmitetalia* order, as well as wet meadows of the *Molinietalia* order and the fens of the *Scheuchzerio-Caricetea* class were dominant in that area. The communities of standing water of the *Potamogetonetalia* order (PAWLOWSKI 1928) were widely spread. At present, the last disappearing stands of these communities are preserved only in a few places. Their species composition is markedly impoverished and, most probably, they will die out within a couple of years.

2. MATERIAL AND METHODS

The studies had three aspects: 1) appraising the changes in the area of the meadow complex using maps and aerial photographs from various times, 2) evaluating the distribution of plant communities on the base of phytosociological maps scaled 1:10000 made in 1966, 1975, 1990, 3) in various types of plant communities, every five years, a list of species found on permanent plots of 100 m² was made, and the percentage of the whole plant biomass constituted by each species during the meadow flowering season in the beginning of June was estimated. The ground water level was also measured.

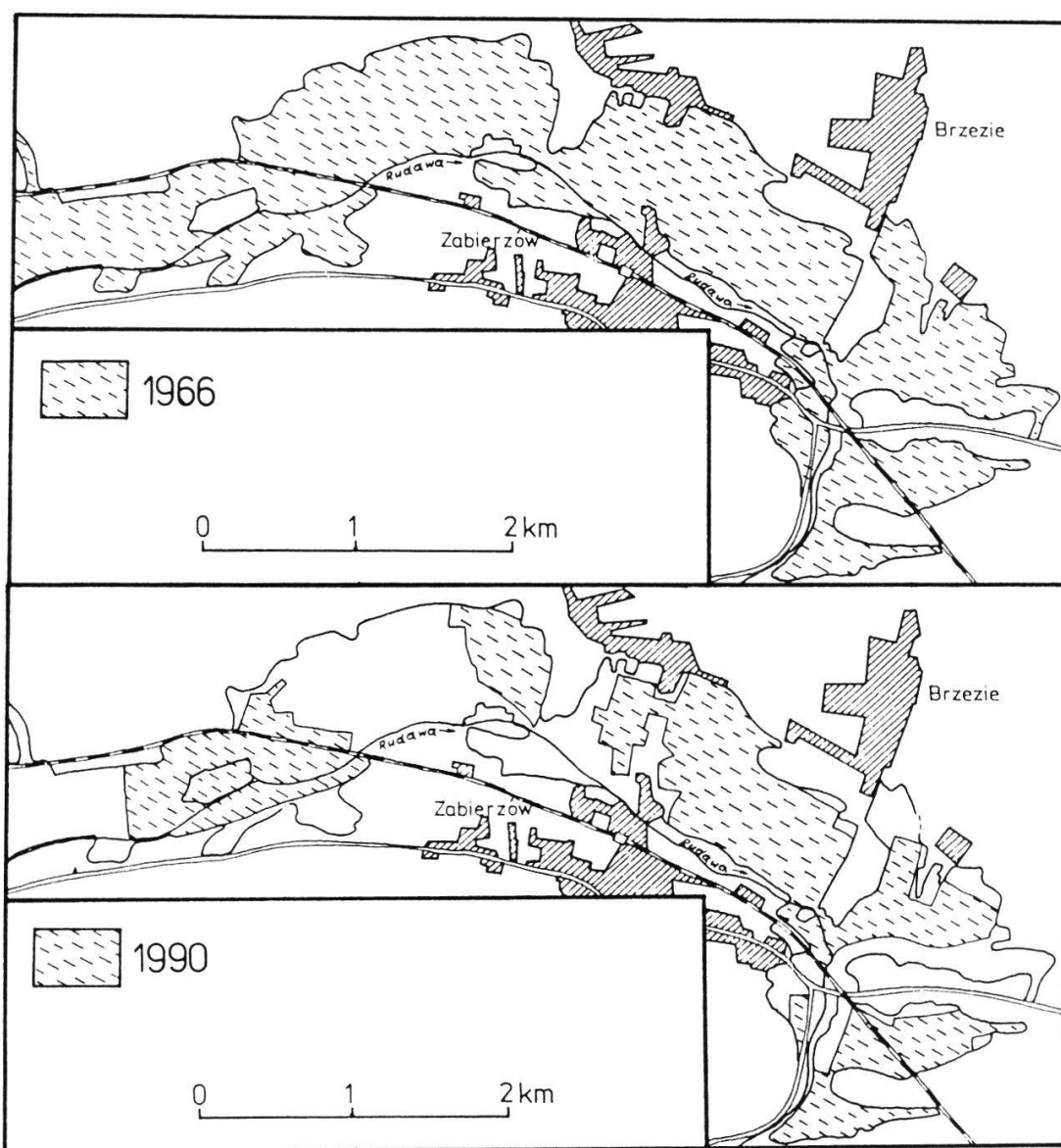


Fig. 1. The decrease in the area of the meadow complex in the Rudawa river valley near Zabierzow.

Table 1. Changes of the floristic composition and percentage of species in the biomass of the water and swamp vegetation, as a result of drainage.

| Year | 1966 | 1970 | 1976 | 1980 | 1985 | 1990 |
|---|------|------|------|------|------|------|
| Cover of herb layer (%) | 80 | 90 | 95 | 100 | 100 | 100 |
| Ground-water level (cm) | +50 | +20 | -30 | -70 | -70 | -70 |
| Ch. Potamogetonetea, Potamogetonetalia | | | | | | |
| <i>Hottonia palustris</i> | 7.0 | 5.0 | - | - | - | - |
| <i>Myriophyllum spicatum</i> | 5.0 | 5.0 | - | - | - | - |
| <i>Ceratophyllum demersum</i> | 4.0 | 3.0 | - | - | - | - |
| Ch. Phragmitetea, Phragmitetalia | | | | | | |
| <i>Glyceria fluitans</i> | 1.0 | 2.0 | - | - | - | - |
| <i>Hippuris vulgaris</i> | 3.0 | 3.0 | - | - | - | - |
| <i>Sparganium erectum</i> | 5.0 | 1.0 | - | - | - | - |
| <i>Iris pseudacorus</i> | 10.0 | 8.0 | 0.5 | - | - | - |
| <i>Alisma plantago-aquatica</i> | 3.0 | 2.5 | 0.2 | - | - | - |
| <i>Equisetum fluviatile</i> | 11.0 | 13.0 | 0.5 | 0.1 | - | - |
| <i>Butomus umbellatus</i> | 3.0 | 3.0 | 0.5 | 0.1 | - | - |
| <i>Glyceria plicata</i> | 10.0 | 14.0 | 10.0 | 8.0 | 5.0 | 3.0 |
| <i>Phalaris arundinacea</i> | - | - | - | 2.0 | 10.0 | 7.0 |
| Ch. Molinietalia, Calthion | | | | | | |
| <i>Scirpus sylvaticus</i> | 14.0 | 10.0 | 15.0 | 5.0 | 3.0 | 2.0 |
| <i>Caltha palustris</i> | 8.0 | 10.0 | 2.0 | 0.5 | 0.2 | 0.2 |
| <i>Equisetum palustre</i> | 4.0 | 6.0 | 2.0 | 1.0 | 1.0 | 0.6 |
| <i>Myosotis scorpioides</i> | 4.0 | 5.0 | 1.0 | 0.2 | 0.2 | 0.5 |
| <i>Cirsium rivulare</i> | - | - | 12.0 | 17.0 | 6.6 | 3.0 |
| <i>Lychnis flos-cuculi</i> | - | - | 4.0 | 10.0 | 5 | 4.0 |
| <i>Deschampsia cespitosa</i> | - | - | 0.2 | 1 | 2 | 0.5 |
| Ch. Arrhenatheretalia | | | | | | |
| <i>Arrhenatherum elatius</i> | - | - | - | 0.5 | 2.0 | 3.0 |
| <i>Dactylis glomerata</i> | - | - | - | 0.5 | 1.0 | 3.0 |
| Ch. Molinio-Arrhenatheretea | | | | | | |
| <i>Poa trivialis</i> | 0.5 | 0.5 | 0.5 | 1.0 | 1.0 | 2.0 |
| <i>Alopecurus pratense</i> | - | - | 11.8 | 20.0 | 30.0 | 30.0 |
| <i>Holcus lanatus</i> | - | - | 10 | 15.0 | 12.0 | 15.0 |
| <i>Ranunculus acris</i> | - | - | - | 0.5 | 1.0 | 2.0 |
| <i>Poa pratensis</i> | - | - | - | 0.2 | 0.5 | 0.5 |
| Others | | | | | | |
| <i>Lemna minor</i> | 1.0 | 1.0 | - | - | - | - |
| <i>Mentha aquatica</i> | 4.0 | 3.0 | 0.1 | - | - | - |
| <i>Lycopus europaeus</i> | 2.0 | 2.0 | 3.0 | 1.0 | 1.0 | 1.0 |
| <i>Juncus inflexus</i> | 0.5 | 1.0 | 15.0 | 10.0 | 10.0 | 7.0 |
| <i>Bidens tripartitus</i> | - | 2.0 | 0.5 | - | - | - |
| <i>Cirsium arvense</i> | - | - | 4.0 | 1.0 | 3.0 | 5.0 |
| <i>Mentha arvensis</i> | - | - | 4.0 | 2.0 | 1.0 | 0.2 |
| <i>Ranunculus repens</i> | - | - | 0.5 | 1.0 | 2.0 | 4.0 |
| <i>Urtica dioica</i> | - | - | 2.0 | 1.0 | - | 0.5 |
| <i>Potentilla reptans</i> | - | - | 0.2 | 0.5 | 0.5 | - |
| <i>Poa annua</i> | - | - | 0.5 | 0.2 | - | - |
| <i>Rumex obtusifolius</i> | - | - | - | 0.5 | 2.0 | 3.0 |
| <i>Potentilla anserina</i> | - | - | - | 0.2 | - | 1.0 |
| <i>Galium aparine</i> | - | - | - | - | - | 2.0 |

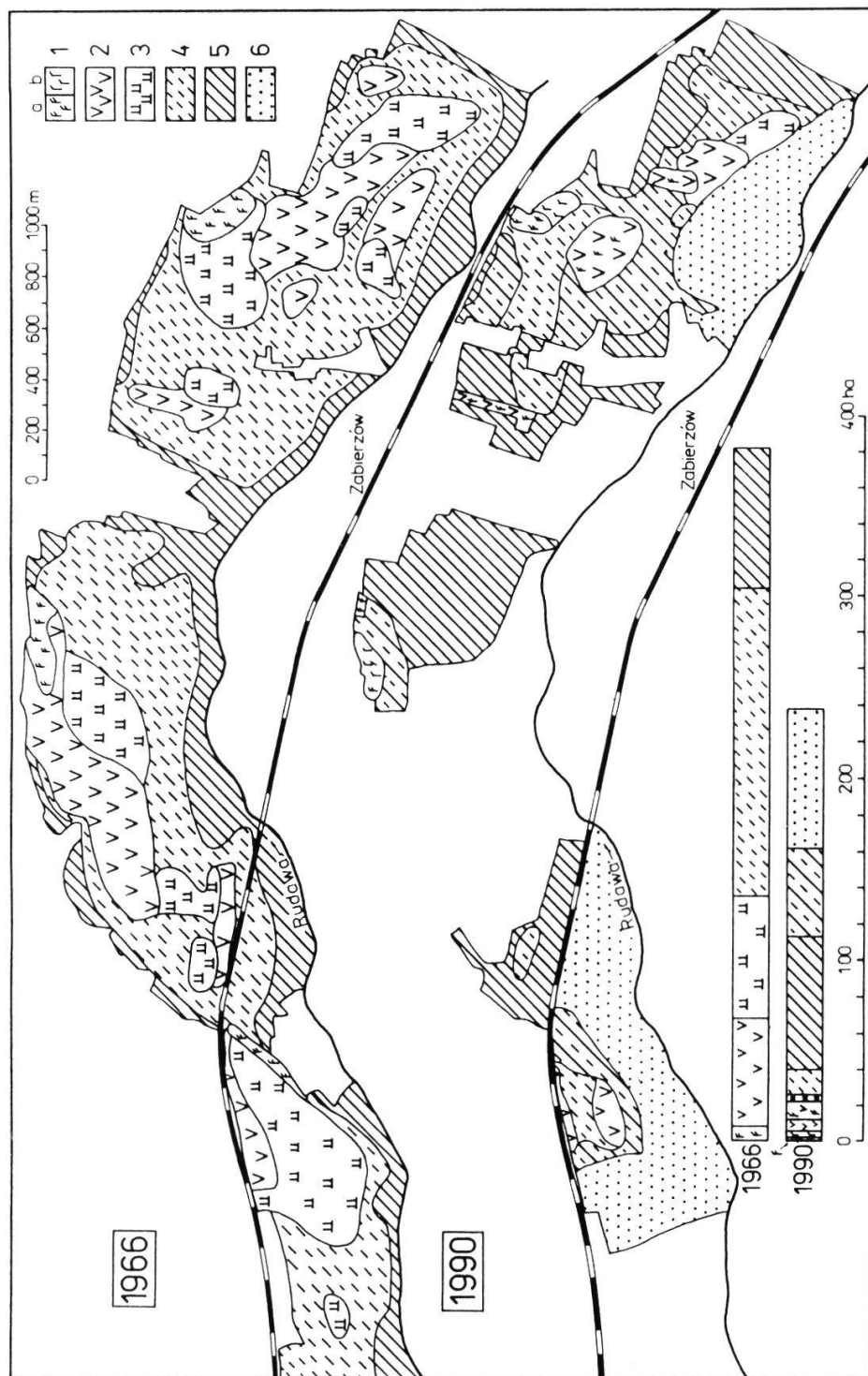


Fig 2. The state of the vegetation in the Rudawa river valley in 1966 and 1990.
 1 - swamp communities of the *Phragmites* alliance (a - typical, b - degradation stages), 2 - sedge communities (*Magnocaricion*), 3 - fen communities (*Scheuchzeria-Caricetea*), 4 - wet meadows (*Calthion*), 5 - fresh meadows and pastures (*Arrhenatheretalia*), 6 - artificial meadows which were created by ploughing the drained natural meadows and sowing fodder plants. The graph in the lower part of the figure shows the area (in ha) occupied by various plant communities.

Table 2. Succession of swamp communities (*Phragmitetalia*), as a result of ground water level lowering.

| Year | 1966 | 1970 | 1976 | 1980 | 1985 | 1990 |
|---|------|------|------|------|------|------|
| Cover of herb layer (%) | 95 | 97 | 100 | 100 | 100 | 100 |
| Ground-water level (cm) | +25 | +5 | -15 | -120 | -130 | -150 |
| Ch. Phragmition | | | | | | |
| <i>Oenanthe aquatica</i> | 1.0 | 0.2 | - | - | - | - |
| <i>Sagittaria sagittifolia</i> | 0.2 | 0.2 | - | - | - | - |
| <i>Acorus calamus</i> | 2.0 | 0.5 | 0.2 | - | - | - |
| <i>Butomus umbellatus</i> | 1.0 | 0.5 | 0.2 | - | - | - |
| <i>Sparganium erectum</i> | 0.5 | 0.2 | 0.2 | - | - | - |
| Ch. Magnocaricion | | | | | | |
| <i>Carex appriopinquata</i> | 2.0 | 0.5 | - | - | - | - |
| <i>Ranunculus lingua</i> | 2.0 | 0.2 | - | - | - | - |
| <i>Galium palustre</i> | 0.5 | 0.2 | - | - | - | - |
| <i>Scutellaria galericulata</i> | 0.2 | 0.2 | - | - | - | - |
| <i>Iris pseudacorus</i> | 3.0 | 0.5 | 0.1 | - | - | - |
| <i>Lysimachia thyrsoiflora</i> | 2.4 | 3.7 | 1.0 | 0.2 | - | - |
| <i>Carex vesicaria</i> | 2.0 | 5.0 | 2.0 | 0.5 | - | - |
| <i>Carex acuta</i> | 4.0 | 4.0 | 3.0 | 4.0 | 5.0 | 5.0 |
| <i>Phalaris arundinacea</i> | - | 2.0 | 8.0 | 10.0 | 5.0 | 2.0 |
| <i>Poa palustris</i> | - | 0.2 | 0.5 | - | - | - |
| Ch. Phragmitetea, Phragmitetalia | | | | | | |
| <i>Alisma plantago-aquatica</i> | 2.0 | 1.0 | - | - | - | - |
| <i>Equisetum fluviatile</i> | 7.0 | 7.0 | 0.5 | - | - | - |
| <i>Rumex hydrolapatum</i> | 1.0 | 0.5 | 0.5 | - | - | - |
| <i>Glyceria maxima</i> | 3.0 | 4.0 | 2.0 | 0.2 | - | - |
| <i>Eleocharis palustris</i> | 2.0 | 2.0 | 0.5 | 0.1 | - | - |
| <i>Phragmites australis</i> | 60.0 | 55.0 | 55.0 | 36.0 | 20.0 | 10.0 |
| Ch. Molinietalia | | | | | | |
| <i>Lythrum salicaria</i> | 0.2 | 0.2 | 0.2 | - | - | - |
| <i>Myosotis scorpioides</i> | 0.2 | 1.0 | 1.0 | 0.2 | - | - |
| <i>Caltha palustris</i> | 1.0 | 2.0 | 1.5 | 1.0 | 0.5 | - |
| <i>Filipendula ulmaria</i> | 0.5 | 3.0 | 5.0 | 12.0 | 10.0 | 10.0 |
| <i>Lychnis flos-cuculi</i> | 0.2 | 0.2 | 1.2 | 0.5 | 1.0 | 1.0 |
| <i>Juncus effusus</i> | - | - | 0.2 | 3.0 | 1.0 | - |
| <i>Sanquisorba officinalis</i> | - | - | - | 0.5 | 1.0 | - |
| <i>Cirsium rivulare</i> | - | - | - | 2.0 | 2.5 | 5.0 |
| Ch. Arrhenatheretalia | | | | | | |
| <i>Geranium pratense</i> | - | - | - | 6.0 | 12.0 | 14.0 |
| <i>Arrhenatherum elatius</i> | - | - | - | 0.5 | 2.0 | 10.0 |
| Ch. Molinio-Arrhenatheretea | | | | | | |
| <i>Poa trivialis</i> | - | 0.5 | 0.5 | 1.0 | 1.0 | 2.0 |
| <i>Symphythum officinale</i> | - | 0.2 | 1.0 | 1.0 | 1.0 | 2.0 |
| <i>Holcus lanatus</i> | - | - | 3.0 | 5.0 | 14 | 4.0 |
| <i>Angelica sylvestris</i> | - | - | 0.5 | 0.5 | 1.5 | 2.0 |
| <i>Avenula pubescens</i> | - | - | - | 0.5 | 0.5 | - |
| <i>Poa pratensis</i> | - | - | - | - | 2.0 | 3.0 |
| <i>Centaurea jacea</i> | - | - | - | - | 1.0 | 2.0 |
| <i>Achillea millefolium</i> | - | - | - | - | 0.2 | 0.3 |

Table 2 (continued)

| Year | 1966 | 1970 | 1976 | 1980 | 1985 | 1990 |
|------------------------------|------|------|------|------|------|------|
| <i>Lathyrus pratensis</i> | - | - | - | - | 2.0 | 3.0 |
| <i>Alopecurus pratense</i> | - | - | - | - | - | 3.0 |
| <i>Rumex acetosa</i> | - | - | - | - | - | 0.5 |
| Others | | | | | | |
| <i>Polygonum amphibium</i> | 1.5 | 0.2 | - | - | - | - |
| <i>Lycopus europaeus</i> | 0.5 | 1.0 | 1.5 | 0.2 | - | - |
| <i>Lysimachia nummularia</i> | 0.1 | 0.2 | 0.2 | 0.1 | - | - |
| <i>Ranunculus sceleratus</i> | - | 0.2 | 0.5 | - | - | - |
| <i>Carex rostrata</i> | - | 1.0 | 3.0 | 2.0 | 0.2 | - |
| <i>Carex nigra</i> | - | 2.0 | 2.0 | 5.0 | 9.0 | 10.0 |
| <i>Thalictrum lucidum</i> | - | 0.5 | 1.0 | 1.0 | 1.0 | 1.0 |
| <i>Carex hirta</i> | - | 0.2 | 3.0 | 3.0 | 2.0 | 2.0 |
| <i>Cardamine amara</i> | - | - | 0.5 | 0.5 | 0.2 | - |
| <i>Ranunculus repens</i> | - | - | 0.5 | 0.5 | 1.5 | 1.0 |
| <i>Mentha arvensis</i> | - | - | - | 2.6 | 0.2 | - |
| <i>Veronica chamaedrys</i> | - | - | - | 0.2 | - | 0.2 |
| <i>Heracleum sphondylium</i> | - | - | - | 0.2 | 3.3 | 5.0 |
| <i>Galium verum</i> | - | - | - | - | 0.2 | 1.0 |
| <i>Anthoxanthum odoratum</i> | - | - | - | - | 1.0 | 3.0 |



Fig 3. Wet meadows with *Polygonum bistorta* and *Cirsium rivulare* in the Rudawa river valley at Zabierzow, state in 1966. At present, a great part of this area has been drained and changed into arable land.

Table 3. Succession of the fen community with *Menyanthes trifoliata* (*Scheuchzerio-Caricetea*), as a result of ground water level lowering.

| Year | 1966 | 1970 | 1976 | 1980 | 1985 | 1990 |
|---|------|------|------|------|------|------|
| Cover of herb layer (%) | 90 | 95 | 100 | 100 | 100 | 100 |
| Ground-water level (cm) | +3 | -50 | -90 | -100 | -130 | -130 |
| <i>Ch. Caricetalia davallianae, Caricion davallianae</i> | | | | | | |
| <i>Scheuchzeria palustris</i> | 3.0 | - | - | - | - | - |
| <i>Viola palustris</i> | 0.2 | 0.1 | - | - | - | - |
| <i>Orchis laxiflora</i> subsp. <i>palustris</i> | 0.2 | 0.2 | - | - | - | - |
| <i>Epipactis palustris</i> | 0.5 | 0.5 | - | - | - | - |
| <i>Valeriana simplicifolia</i> | 5.0 | 1.0 | - | - | - | - |
| <i>Pedicularis palustris</i> | 0.5 | 0.5 | 0.1 | - | - | - |
| <i>Menyanthes trifoliata</i> | 35.0 | 5.0 | 0.5 | - | - | - |
| <i>Eriophorum angustifolium</i> | 10.0 | 2.0 | 0.5 | 0.2 | - | - |
| <i>Carex nigra</i> | 5.0 | 20.0 | 10.0 | 9.0 | 5.0 | 2.0 |
| <i>Ch. Molinietalia</i> | | | | | | |
| <i>Lathyrus palustris</i> | 0.5 | 0.2 | - | - | - | - |
| <i>Myosotis scorpioides</i> | 2.0 | 0.5 | - | - | - | - |
| <i>Lythrum salicaria</i> | 0.5 | 1.0 | 0.2 | - | - | - |
| <i>Caltha palustris</i> | 3.0 | 0.5 | 0.2 | - | - | 2.0 |
| <i>Lychnis flos-cuculi</i> | 1.0 | 1.0 | 1.0 | 1.5 | 2.0 | 3.0 |
| <i>Trifolium hybridum</i> ssp. <i>hybridum</i> | 2.0 | 3.0 | 1.5 | 0.5 | 1.0 | 2.0 |
| <i>Scirpus sylvaticus</i> | - | 2.0 | 5.0 | 3.0 | 0.5 | 0.5 |
| <i>Juncus effusus</i> | - | 1.0 | 3.0 | 4.0 | 3.0 | 3.0 |
| <i>Deschampsia caespitosa</i> | - | 1.0 | 1.0 | 2.0 | 4.0 | 5.0 |
| <i>Cirsium rivulare</i> | - | 0.5 | 5.0 | 5.0 | 4.0 | 4.4 |
| <i>Lotus uliginosus</i> | - | - | 0.5 | 0.5 | 0.2 | - |
| <i>Lysimachia vulgaris</i> | - | - | 4.0 | 3.0 | 0.5 | 1.0 |
| <i>Geranium palustre</i> | - | - | 0.5 | 0.5 | 0.5 | 0.5 |
| <i>Ch. Arrhenatheretalia</i> | | | | | | |
| <i>Taraxacum officinale</i> | - | 0.2 | 0.2 | 0.2 | 0.5 | 0.5 |
| <i>Dactylis glomerata</i> | - | - | 0.2 | 0.5 | 3.0 | 3.0 |
| <i>Trifolium repens</i> | - | - | - | 0.5 | 1.0 | 1.0 |
| <i>Knautia arvensis</i> | - | - | - | - | - | 0.5 |
| <i>Ch. Molinio-Arrhenatheretea</i> | | | | | | |
| <i>Poa trivialis</i> | 1.0 | 1.0 | 1.0 | 1.5 | 0.5 | 1.5 |
| <i>Lathyrus pratensis</i> | 0.1 | 1.0 | 1.0 | 3.0 | 5.0 | 5.0 |
| <i>Holcus lanatus</i> | - | 2.0 | 5.0 | 8.0 | 3.0 | 2.0 |
| <i>Alopecurus pratense</i> | - | 0.5 | 0.5 | 1.0 | 3.0 | 5.0 |
| <i>Cerastium holosteoides</i> | - | - | 0.2 | - | 0.5 | 0.5 |
| <i>Plantago lanceolata</i> | - | - | 0.2 | 0.5 | 0.5 | 1.0 |
| <i>Poa pratensis</i> | - | - | - | 0.2 | 2.0 | 3.0 |
| <i>Ranunculus acris</i> | - | - | - | 0.5 | 1.0 | 1.0 |
| <i>Centaurea jacea</i> | - | - | - | 0.5 | 1.2 | 1.5 |
| <i>Achillea millefolium</i> | - | - | - | - | 0.2 | 0.5 |
| <i>Rumex acetosa</i> | - | - | - | - | - | 0.5 |
| <i>Vicia cracca</i> | - | - | - | - | - | 1.0 |
| Others | | | | | | |
| <i>Carex vulpina</i> | 1.0 | - | - | - | - | - |
| <i>Equisetum fluviatile</i> | 2.0 | 0.1 | - | - | - | - |

Table 3 (continued)

| Year | 1966 | 1970 | 1976 | 1980 | 1985 | 1990 |
|------------------------------|------|------|------|------|------|------|
| <i>Equisetum variegatum</i> | 5.0 | 3.0 | 0.2 | - | - | - |
| <i>Eleocharis palustris</i> | 4.0 | 2.0 | 0.5 | 0.2 | - | - |
| <i>Medicago lupulina</i> | 0.2 | - | - | 0.5 | - | - |
| <i>Cardamine pratensis</i> | 1.0 | 3.0 | 2.0 | 1.0 | 0.2 | - |
| <i>Galium palustre</i> | 1.5 | - | - | - | - | 0.2 |
| <i>Carex vesicaria</i> | 0.5 | 2.0 | 0.5 | 0.2 | 0.5 | 0.5 |
| <i>Lysimachia nummularia</i> | 0.2 | 0.5 | 0.2 | 0.5 | 0.5 | 0.5 |
| <i>Phragmites australis</i> | 2.0 | 7.5 | 10.0 | 3.0 | 1.0 | 1.0 |
| <i>Mentha arvensis</i> | 0.1 | 1.0 | 0.5 | 0.5 | 1.0 | 2.0 |
| <i>Festuca rubra</i> | 0.5 | 1.0 | 1.0 | 1.0 | 2.0 | 3.0 |
| <i>Ranunculus repens</i> | 0.5 | 0.5 | 1.0 | 1.0 | 1.5 | 2.0 |
| <i>Ranunculus sceleratus</i> | - | 0.5 | 0.2 | - | - | - |
| <i>Potentilla reptans</i> | - | 0.5 | - | - | - | 0.5 |
| <i>Polygonum amphibium</i> | - | 0.2 | 0.2 | 0.5 | 0.5 | 0.5 |
| <i>Carex hirta</i> | - | 1.0 | 1.0 | 0.5 | 1.0 | 1.0 |
| <i>Cirsium arvense</i> | - | 2.0 | - | - | 1.0 | 1.0 |
| <i>Mentha longifolia</i> | - | 0.5 | 6.4 | 11.0 | 5.0 | 2.0 |
| <i>Potentilla anserina</i> | - | 0.5 | 1.0 | 0.5 | 2.0 | 2.0 |
| <i>Carex appropinquata</i> | - | 0.5 | 1.0 | 2.0 | 2.0 | 3.0 |
| <i>Juncus inflexus</i> | - | 4.0 | 15.0 | 20.0 | 26.0 | 24.8 |
| <i>Galium aparine</i> | - | - | 0.5 | - | 2.0 | 2.0 |
| <i>Briza media</i> | - | - | 0.5 | 0.2 | - | - |
| <i>Rumex conglomeratus</i> | - | - | - | 0.5 | 0.5 | 0.5 |
| <i>Carex spicata</i> | - | - | - | - | 0.5 | 1.0 |
| <i>Plantago major</i> | - | - | - | - | 0.5 | 1.0 |
| <i>Hypericum maculatum</i> | - | - | - | - | - | 0.5 |
| <i>Salix fragilis</i> | - | - | - | - | - | 0.1 |

3. RESULTS

The main reason for the changes in the meadow vegetation taking place in the Rudawa river valley was draining of terrain. The construction of the draining system consisting of building of a series of surface drainage ditches was already started in the twenties. From 1975 to 1987 a greater part of the meadow complex was completely drained. A large area of the meadows was ploughed (Fig. 1). The ground water level dropped by about 100 cm and lies now from 50 to 130 cm below the ground.

Around 1930 a greater part of the investigated area was occupied by the communities typical of marshy and wet habitats: swamps (mainly *Phragmites australis*, *Typha latifolia*, *Equisetum fluviatile*), communities of high sedges (*Carex vesicaria*, *C. acuta*, *C. rostrata*, *C. hudsoni*), fens with *Carex*

Table 4. Succession of the fen community with *Carex davalliana* (*Scheuchzerio-Caricetea*), as a result of ground water level lowering.

| Year | 1966 | 1970 | 1976 | 1980 | 1985 | 1990 |
|--|------|------|------|------|------|------|
| Cover of herb layer (%) | 100 | 100 | 100 | 100 | 100 | 100 |
| Ground-water level (cm) | -5 | -60 | -80 | -100 | -110 | -110 |
| <i>Ch. Caricetalia davalliana</i>, <i>Caricion davalliana</i> | | | | | | |
| <i>Eriophorum latifolium</i> | 10.0 | 8.0 | 0.5 | - | - | - |
| <i>Carex flava</i> | 8.0 | 7.0 | 1.0 | 0.5 | - | - |
| <i>Parnassia palustris</i> | 1.0 | 0.5 | 0.2 | 0.2 | - | - |
| <i>Carex davalliana</i> | 25.0 | 24.1 | 20.0 | 8.0 | 1.5 | 0.5 |
| <i>Valeriana simplicifolia</i> | 5.0 | 5.0 | 4.0 | 1.0 | 0.5 | 0.5 |
| <i>Dactylorhiza majalis</i> | 3.0 | 3.0 | 1.0 | 0.5 | 0.5 | 0.5 |
| <i>Ch. Scheuchzerio-Caricetea fuscae</i> | | | | | | |
| <i>Eriophorum angustifolium</i> | 2.0 | 0.5 | 0.1 | - | - | - |
| <i>Carex nigra</i> | 5.0 | 5.0 | 10.4 | 20.0 | 25.0 | 25.0 |
| <i>Ch. Molinion</i> | | | | | | |
| <i>Geranium palustre</i> | 3.0 | 2.0 | 0.5 | 0.2 | - | - |
| <i>Lythrum salicaria</i> | 2.0 | 1.0 | 1.0 | 0.2 | - | - |
| <i>Filipendula ulmaria</i> | 1.5 | 2.0 | 1.0 | 0.5 | - | - |
| <i>Succisa pratensis</i> | 1.0 | 0.5 | 0.2 | 0.2 | - | - |
| <i>Crepis paludosa</i> | 5.0 | 7.0 | 4.0 | 1.0 | 0.5 | 0.2 |
| <i>Myosotis scorpioides</i> | 2.0 | 2.0 | 1.0 | 0.5 | 0.2 | 0.2 |
| <i>Caltha palustris</i> | 2.0 | 2.0 | 2.0 | 1.0 | 0.2 | 0.2 |
| <i>Scirpus sylvaticus</i> | 1.0 | 1.0 | 1.0 | 0.5 | 0.2 | 0.1 |
| <i>Polygonum bistorta</i> | 1.5 | 2.0 | 8.0 | 14.0 | 10.5 | 5.0 |
| <i>Ch. Molinietales, Arrhenatheretalia</i> | | | | | | |
| <i>Equisetum palustre</i> | 3.0 | 3.0 | 2.0 | 1.0 | 1.0 | 1.0 |
| <i>Lychnis flos-cuculi</i> | 2.0 | 4.0 | 2.0 | 0.5 | 0.2 | 0.2 |
| <i>Angelica sylvestris</i> | 1.0 | 1.0 | 5.0 | 9.1 | 1.5 | 2.0 |
| <i>Deschampsia caespitosa</i> | 1.0 | 1.0 | 5.0 | 3.0 | 0.5 | 0.5 |
| <i>Cirsium rivulare</i> | 0.5 | 1.0 | 5.0 | 8.0 | 10.4 | 10.0 |
| <i>Lotus corniculatus</i> | 0.5 | 0.5 | 0.5 | 0.5 | 1.0 | 1.0 |
| <i>Daucus carota</i> | 0.5 | - | 0.5 | 0.5 | 1.0 | 1.0 |
| <i>Selinum carifolia</i> | - | - | 0.2 | 0.5 | 0.5 | 1.0 |
| <i>Bromus hordeaceus</i> | - | - | - | 0.2 | 0.5 | 0.5 |
| <i>Taraxacum officinale</i> | - | - | - | 0.2 | 0.5 | 1.0 |
| <i>Leucanthemum vulgare</i> | - | - | - | 0.2 | 1.0 | 1.0 |
| <i>Arrhenatherum elatius</i> | - | - | - | 0.2 | 1.0 | 1.2 |
| <i>Dactylis glomerata</i> | - | - | - | 0.2 | 1.5 | 2.0 |
| <i>Crepis biennis</i> | - | - | - | 1.0 | 3.0 | 4.0 |
| <i>Galium mollugo</i> var. <i>elatium</i> | - | - | - | - | 0.5 | 1.0 |
| <i>Geranium pratense</i> | - | - | - | - | - | 0.1 |
| <i>Carum carvi</i> | - | - | - | - | - | 0.2 |
| <i>Ch. Molinio-Arrhenatheretea</i> | | | | | | |
| <i>Cerastium holosteoides</i> | 0.2 | 0.2 | - | 0.2 | 0.1 | 0.1 |
| <i>Plantago lanceolata</i> | 0.2 | 0.2 | 0.5 | 0.5 | 1.5 | 1 |
| <i>Centaurea jacea</i> | 0.2 | 0.2 | 0.5 | 0.2 | 1.2 | 1.5 |
| <i>Ranunculus acris</i> | 1.0 | 1.0 | 1.5 | 2.0 | 3.0 | 3.0 |
| <i>Holcus lanatus</i> | 2.0 | 5.0 | 8.0 | 8.0 | 2.0 | 2.0 |
| <i>Poa trivialis</i> | - | 0.5 | 1.0 | 1.0 | 2.0 | 2.0 |

Table 4 (continued)

| Year | 1966 | 1970 | 1976 | 1980 | 1985 | 1990 |
|------------------------------|------|------|------|------|------|------|
| <i>Trifolium pratense</i> | - | - | - | 0.2 | 4.0 | 5.0 |
| <i>Lathyrus pratensis</i> | - | - | - | 0.5 | 1.0 | 1.0 |
| <i>Poa pratensis</i> | - | - | - | 0.5 | 4.0 | 4.0 |
| <i>Rumex acetosa</i> | - | - | - | - | 3.0 | 5.0 |
| Others | | | | | | |
| <i>Orchis coriophora</i> | 0.5 | 0.1 | - | - | - | - |
| <i>Equisetum variegatum</i> | 2.0 | 2.0 | 1.0 | 0.2 | - | - |
| <i>Briza media</i> | 1.0 | 0.5 | 1.0 | - | 0.2 | - |
| <i>Prunella vulgaris</i> | 0.2 | 0.2 | 0.2 | - | 0.2 | - |
| <i>Carex panicea</i> | 4.0 | 4.0 | 5.0 | 2.0 | 0.5 | 0.1 |
| <i>Mentha arvensis</i> | 1.0 | 1.0 | 0.5 | 1.0 | 0.2 | 0.1 |
| <i>Ranunculus repens</i> | 0.5 | 0.5 | 2.0 | 2.0 | 1.0 | 0.2 |
| <i>Potentilla erecta</i> | 0.5 | 0.5 | 0.5 | 1.0 | 1.0 | 0.5 |
| <i>Rhinanthus minor</i> | 0.2 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| <i>Poa annua</i> | - | 0.1 | - | 0.2 | 0.2 | 0.1 |
| <i>Festuca rubra</i> | - | 0.2 | 0.5 | 1.0 | 0.5 | 0.5 |
| <i>Agrostis tenuis</i> | - | 0.2 | 1.0 | 4.0 | 4.0 | 5.0 |
| <i>Avenula pubescens</i> | - | - | 0.2 | 0.2 | 0.2 | 0.5 |
| <i>Veronica chamaedrys</i> | - | - | - | 0.2 | 0.5 | 0.5 |
| <i>Galium verum</i> | - | - | - | 0.2 | 1.0 | 1.5 |
| <i>Equisetum pratense</i> | - | - | - | 0.5 | 2.0 | 3.0 |
| <i>Anthoxanthum odoratum</i> | - | - | - | 0.5 | 3.0 | 3.0 |

davalliana, *C. flava*, *C. nigra*, *Eriophorum latifolium*, *E. angustifolium*, *Valeriana simplicifolia*, *Menyanthes trifoliata*, and wet meadows composed of *Cirsium rivulare* and *Polygonum bistorta*. In 1966 these communities still occupied about 80% of the area, and in 1990 only 10% of the investigated meadow complex (Fig. 2 and 3).

As a result of the lowering of the ground water level, changes in the species composition and in the percentage of individual species in the plant biomass followed. Especially big changes, concerning 70-80% of the floristic composition, were observed in the water and swamp vegetation (Table 1 and 2), which turned into meadows of the *Molinio-Arrhenatheretea* class during the 24 years analysed. Only few species with the greatest toleration for the changing habitat condition (e.g. *Phragmites australis*, *Poa trivialis*, *Scirpus sylvaticus*, *Juncus inflexus*, *Carex acuta*, *Filipendula ulmaria*) survived during the whole period. A similar direction of succession was observed in the case of the vegetation of fens of the *Scheuchzerio-Caricetea* class (Table 3 and 4).

During the last 24 years the danger to the flora of the studied complex greatly

increased. The following vascular plant species probably died out (Ex): *Calla palustris*, *Ceratophyllum demersum*, *Epipactis palustris*, *Gentiana pneumonanthe*, *Hippuris vulgaris*, *Hottonia palustris*, *Orchis laxiflora* ssp. *palustris*, *Orchis coriophora*, *Pedicularis palustris*, *Scheuchzeria palustris*, *Scutellaria galericulata*. In the category of endangered plants (E) included were: *Comarum palustre*, *Equisetum fluviatile*, *E. variegatum*, *Lathyrus paluster*, *Lotus uliginosus*, *Menyanthes trifoliata*, *Oenanthe aquatica*, *Peucedanum palustre*, *Phyteuma orbiculare*, *Potamogeton natans*, *P. crispus*, *Ranunculus lingua*, *Rumex hydrolapatum*, *Sagittaria sagittifolia* and many others. About 40-60 species are now in the category of vulnerable plants (V) and most of them will probably become extinct in the coming decades. These are for example: *Alisma plantago-aquatica*, *Berula erecta*, *Carex vesicaria*, *C. acuta*, *C. elongata*, *C. echinata*, *C. curta*, *Crepis paludosa*, *Dactylorhiza maialis*, *Eriophorum latifolium*, *E. angustifolium*, *Eleocharis palustris*, *Geum rivale*, *Galium palustre*, *Iris pseudoacorus*, *Lysimachia thyrsiflora*, *Lythrum salicaria*, *Parnassia palustris*, *Ranunculus flammula*, *Stellaria uliginosa*, *Solanum dulcamara*, *Valeriana simplicifolia*, *V. dioica*, and others.

4. DISCUSSION

The trends of changes in the meadow, swamp and fen vegetation presented in this paper are mainly similar to the results of earlier studies in the Rudawa river valley (PAWLOWSKI 1928, WITKOWSKI 1975) and in the Vistula river valley near Cracow (ZARZYCKI 1958a,b, 1992) TUMIDAJOWICZ and ZUBEL 1978). As the ground water level lowers, the swamp vegetation (*Phragmition*) turns into sedge communities (*Magnocaricion*). When the ground water level lies about the ground level (+10 to -15 cm) on the poorer localities fen communities (*Caricion fuscae*, *Caricion davallianae*) occur, and on the fertile localities wet meadows (*Calthion*, *Molinion*) appear. The end stadium of the succession are the fresh meadow communities (*Arrhenatherion*), which are usually changed into arable land.

On every study plot (see Table 1-4) the greatest species diversity was observed in the middle succession stages. Earlier WITKOWSKI (1975) had the same results. During the early succession stages the process of species immigration dominated over the process of elimination. The result of this is an increase in the number of species and their relative abundance becomes more equal. During the further stages of succession, the elimination process of

species typical for the initial and transitional community gains in strength, and causes a decrease in diversity (LOUCKS 1970, WHITTAKER 1965).

SUMMARY

The fen and meadow vegetation in the Rudawa river valley, located 15 km from Cracow, has changed greatly during the last decades as a result of human economy (PAWLOWSKI 1928, MICHALIK 1980). The wet valley bottom was drained and a large part of the meadows was ploughed (Fig 1). Associations of swamp (*Phragmitetalia*), fen (*Scheuchzerio-Caricetea*) and wet meadow (*Molinietalia*) occupied 80% of the meadow complex in 1966 and only 10% in 1990 (Fig. 2). The changes in the plant species composition took place very quickly and were dependent on the speed and range of the ground water level lowering (Tables 1-4).

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