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PRODUCTIVITY AND CHEM VEGETATION IN POSTGLA SC	ACIAL A CAPE *	ALORI	ZATION (ULTURAL	OF MIRE LAND-

ABSTRACT: The studies examined mire vegetation overgrowing wetlands located on the bottom of hollows without surface run-off in the Masurian Lakeland. Two directions of succession in wetland overgrowing were analyzed: a dystrophic sequence (on bogs) - from transition bogs through bog moss pine forest up to a bog pinewood, and a mesotrophic sequence (on fens) - from reeds and *Carex* fens through willow shrubberies up to alder wood fen. In both sequences of plant communities there were observed similar regularities in the succession course yet different manners of matter managing (accumulation of nutrients, efficiency of primary production, matter retention, transmitting elements to matter cycling). Mire vegetation in agricultural landscape was valorized in an attempt to determine whether it might have an anti-eutrophication effect.

KEY WORDS: Hollows without run-off, wetlands, bogs, fens, mire vegetation, minerotrophism, ombrotrophism, succession, dystrophic and mesotrophic sequence, nu-trients, matter managing.

1. INTRODUCTION

Cardinal significance of hydrochemical factor in ecology of wetlands and peatlands in particular, has been stressed for a long time. It was regarded in terms of determining the distribution of plant communities, their structure and floristic species composition, as well as habitat richness (K u l c z y ń s k i 1939/1940, G o r h a m 1956a, 1956b, N e w b o u l d and G o r h a m 1956, M a k s im o w 1965, I n g r a m 1967, H e i n s e l m a n 1970, S u m m e r f i e l d 1974, O ś w i t 1977, P o l a k o w s k i et al. 1980, W a r n c k e 1980,

* This study was financially supported under project MR II/15.

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A ACTIVE ALLERING

Okruszko 1981, Botch and Masing 1983, Gore 1983, Sjörs 1983, Oświt 1984).

With respect to supply source, the following types of peatlands may be distinguished: ombrogenic – being supplied almost exclusively with precipitation water, topogenic – whose moisture comes from ground water most frequently stagnating in form of an underground water basin, soligenic – supplied with inflowing current ground water, and limnogenic (or fluviogenic) – supplied with current surface water inflowing with water courses (O k r u s z k o 1981, S j ö r s 1983).

In case of limnogenic, topogenic and soligenic wetlands, water contains dissolved ions coming mainly from mineral soils, hence these mires are regarded in terms of minerotrophism. In case of ombrogenic wetlands, ions contained in mire water come exclusively from precipitation, an occurrence defined as ombrotrophism (B o t c h and M a s i n g 1983, G o r e 1983, S j ö r s 1983). Chemical composition of mire water determines the development of a definite vegetation type. Minerotrophic type of nutrient supply brings about development of fen vegetation, while ombrotrophic type — that of bogs.

There are only a few empiric works comparing the two types of habitats (Largin 1976, Pietsch 1976, Tolonen and Seppänen 1976,

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W a u g h a m 1980). Analyses of water, peat or vegetation in the bog and fen gradient is difficult due to a great changeability in time and space of concentration of particular elements. Besides a complicated character of intraecosystemic structures and interrelations determining transition of certain forms of elements into others (e.g. reduction of Fe^{3+} to Fe^{2+} or Mn^{4+} to Mn^{2+} etc.) as well as antagonism or synergism occurring between particular elements (F r i e d and B r o e s h a r t 1967, C l y m o 1983), there are, moreover, extraecosystemic factors, much blurring the actual picture. The phenomena in question are also under a strong effect of meteorological conditions (G o r h a m 1956, S u m m e r f i e l d 1974), proximity of ocean causing a greater amount of Cl, B, Na, Cu in rain water (T o ł p a and G o r h a m 1961, T o l o n e n and S e p p ä n e n 1976), general air pollution in a given region (T o l o n e n and S e p p ä n e n 1976), season of the year, which determines element dynamics (L a r g i n 1976, W a r n c k e 1980).

It is difficult to define precisely the actual effect of biotic component, i.e. vegetation, on the studied phenomena. The only fact which has been stated so far is that chemical properties of water sampled less than 10 cm off the plant roots notably differed from those of water sampled farther off (S u m m e r f i e l d 1974, I n g r a m 1983). Most likely vegetation secretes through its roots various substances; for instance, while flooded, willow (*Salix* sp.) diffuses ethanol directly into water (C r a w f o r d 1983). On one hand a plant is influenced by a whole set of habitat factors (water, oxygen deficiency, peat soil, temperature, light, etc.), while on the other hand these factors are opposed by the plant's individual requirements and metabolic mechanisms. Peaty plants absorb directly from mire water only Na⁺ and

Cl^- ions, the other	nutrients being absorbed	I by them from the surface of peat
particles by way of	ion exchange processes	(Tolonen and Seppänen

1976). This, in turn, is connected with very complicated mechanisms of active absorption of ions, conditioned by a number of factors (e.g. mineral status of the environment, ion interaction, temperature, etc.). Therefore it is only natural that at such a complex character of the problem, accurate estimates of interdependence between the habitat and a mire plants failed (G o r e 1961a, 1961b, L i w s k i 1961, H o l m e n 1964, K l o p a t e k 1975, S z c z e p a ń s k i 1979, G ob a t 1984). Attempts were also undertaken to identify indicatory peaty plants, which would signalize certain chemical properties of water (H e i n s e l m a n 1970), or to estimate bioindicative value of whole plant communities (K l o s o w-s k i 1983). None the less the issue of wetland ecology and of their chemical traits has not been fully investigated yet.

Although interest has always focused on peat deposits occupying large areas, yet peatlands of small hollows with no surface run-off have been hardly ever examined, despite the fact that they rank among characteristic elements of young glacial landscape. Contrary to vast peat deposits, the latter are much more dependant on their catchment area and hence they may serve as an example of ecosystems which reflect processes occurring in their neighbourhood. A specific character of peatlands located on morraine areas and especially a direct dependence of chemical properties of their water on the mires' catchment areas, was stressed by Heinselman (1970) and Kruk (1988b). A no-outflow hollow is characteristic for the lack of surface run-off. It is this feature alone that advances development of wetland on its bottom overgrown with mire vegetation. This vegetation was examined in the present studies. Hardly any works provided relevant floristic information (Solińska 1963, Podbielkowski and Tomaszewicz 1979); also productivity and chemical valorization of mire vegetation growing in hollows with no surface run-off were very poorly examined. The aim of the present studies analyzing the bog - fen gradient was: (1) - phytosociological examination of wetland vegetation in hollows without run-off, (2) – chemical valorization of wetland water, (3) – chemical valorization of mire vegetation of hollows without run-off, (4) – estimate of standing crop and primary production of chosen plant communities, (5) – estimate of nutrient accumulation by certain mire vegetation communities, (6) – an attempt to define the function of mire vegetation in young glacial agricultural landscape.

2. GENERAL CHARACTERISTIC OF THE STUDY SITE

The study site encompassed a plot of the Masurian Lakeland, 3147 ha in area, spreading on the border of the Great Masurian Lakes Region and the Mragowo

Lake District. The site was delimited with the watershed of the Jorzec lake catchment
area (excluding the catchment area of the Majcz Wielki Lake and that of Struga
Baranowska), the watershed of the Krujanka lake catchment area (belonging to the

Krutynia river basin) and the nooutflow area located between the tunnel-valley of the Głębokie and Jorzec lakes and that of the Tałty lake.

With respect to geomorphology, the prevailing was young glacial landscape, termed by K o n d r a c k i (1972) as a hilly lakeland landscape.

The areas without run-off spreading on the studied site accounted for about 69.7% (K l o s s et al. 1987).

Among the examined 285 hollows there were distinguished unmired hollows without run-off, hollows without run-off containing drained mires and hollows without run-off containing natural mires. Natural mires with no run-off occupied 201.2 ha, which accounted for 6.4% of the whole study site area, and for 50.8% of the area of all the mire types. It should be emphasized, however, that, although occupying merely about 7% of the site area, the mires in question affected hydrologically by means of their catchment basins, at least 34% of the site area (K 1 o s s et al. 1987).

The climate of the studied site was influenced by marine as well as continental climate (Polakowski 1963, Panfil 1968), which was designated by K o n d r a c k i (1972) as a relative continentalism with a notable contribution of subboreal zone features. Consequently, the characteristic trait of this climate was a great changeability in time and space of thermic conditions and humidity, additionally augmented by varying, hilly lakeland landscape (R a d o m s k i 1971, Radomski and Hutorowicz 1971). The climate of the Masurian Lakeland has been generally considered to be less advantageous to agriculture than in other parts of Poland. The vegetation period is relatively short there and comes with about a fortnight delay (R a d o m s k i 1969, R a d o m s k i and H utorowicz 1969). The study site considerably overlapped the Jorka river basin, the latter being marked for (Bajkiewicz-Grabowska 1985): (1) - high annual amplitudes of mean temperatures $(22.1^{\circ}C)$ and of mean extremal temperatures $(31.1^{\circ}C)$, (2) - mean annual precipitation of 580 mm, with prevalence of summer precipitation, (3) – occurrence of squall rain ≥ 10 mm (mostly in summer), (4) – the length of vegetative season amounting to 206 days (since April 10 till November 1), (5) - the length of occurrence of snow cover amounting to 77 days on the average.

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Soil diversity of the site was poor: 80% of the area was occupied by brown soils formed of boulder clay, 15% – by black earths and peat soils and 5% – by podzolic and pseudopodzolic soils (B a j k i e w i c z - G r a b o w s k a 1985). Hollows without run-off containing natural mires usually comprised in their bottom part peat deposits, while their unpeated parts were made of hardly permeable formations i.e. loams and loamy sands. On the contrary, the catchment areas of unmired hollows without run-off were mostly composed (in about 70%) of well-permeable sands (K r u k 1988a).

About 74% of the study site was occupied by plowlands and grasslands (Kloss



3. METHODS OF STUDIES 3.1. METHODS OF PHYTOSOCIOLOGICAL STUDIES

In analyses of mire vegetation of hollows with no run-off the B r a u n - B l a nq u e t (1964) method was used, commonly employed in phytosociology. 70 phytosociological records were made in 1979 - 1981.

3.2. ESTIMATES OF ABOVE-GROUND TOTAL BIOMASS AND PRIMARY PRODUCTION OF PLANT COMMUNITIES

Estimates of standing crop were made in mid-August in 1980 and 1981 vegetative seasons. For most studied plants it was the time of their development peak in the climate of the Masurian Lakeland. The estimates were made by the method worked out by T r a c z y k (1967a), i.e. calculating the product of density of specimens or shoots of particular plant species and their average individual growth.

In order to determine plant density in particular plant communities, there were performed random tossings of 0.1 m² ring or random measurements by means of wooden fork of 0.25 m² surface. The number of tossings depended on the area of the studied vegetation plot and ranged 25 - 50. Percentage cover with herbaceous plants (including the water plants) and bryophytes as well as the number of individuals or shoots were counted in every tossing. The method was modified in case of two plant communities. In case of Caricetum elatae W. Koch 1926, in three different plant plots, the number of hummocks on a given area (25 m²) was counted, and, subsequently, species composition and biomass (from this and former years) was analysed of five hummocks chosen at random. In plots of Salicetum pentandro-cinerae (Almq. 1929) Pass 1961, on areas of 60, 50 and 100 m², there was counted the number of boughs of Salix cinerea, falling into definite thickness classes, established on the basis of measurements of bough diameter taken by tree caliper directly at the soil surface. Then 10 individuals (boughs) were filed off, representing particular thickness classes (the most abundant, i.e. the medium thickness classes including several individuals), whose wood in fresh weight and leaves (after plucking and drying) were weighed. From each of the examined willow individual two disks were filed off at the bough base so as to define age and water content in wood (fresh wt) (in attempt to calculate the obtained wood weight results in terms of dry wt). In order to estimate the standing crop of duckweed (Lemna sp.) the use was made of a nylon-netted 0.1 m² ring. Sampling of duckweed by the ring (at 100% coverage) was made in 10 replications and in two variants, i.e. from well insolated water surface (willows in lagg) and from shaded water surface (under willows).

Standing crop of bog mosses (Sphagnum sp.) was estimated on the basis of

samples taken with 0.1 m² ring in 5 replications at 100% coverage. Biomass of bryophytes in bog pinewood was calculated from samples taken in 5 replications

from 10×10 cm square area. Primary production of dwarf shrubs was counted separating current year's shoots from perennial ones (M o s z y ń s k a 1973). Plant material was dried to constant weight at $65-70^{\circ}$ C.

Stand volume of tree stands was determined with the help of tables of standing tree volumes (C z u r a j et al. 1960). For this reason DBH * of all the trees on the sample area was measured with tree caliper as well as their height with Matusz heightmeter. Average age of the studied stands was estimated by calculating arithmetic mean of the age of more than 10 representative trees. The age of these trees was defined on the basis of annual increment rings using Pressler's increment borer.

3.3. CHEMICAL ANALYSES

Plant material for chemical denotations was sampled once (mid-August). One sample of a definite species included 30 - 200 specimens (5 in case of macrophytes), collected at random from homogenous plots. The plants were subsequently dried to constant weight at $65 - 70^{\circ}$ C and homogenized (the above-ground parts having been formerly separated). In order to determine the content of mineral components in dry wt of wood, random bore samples were taken by means of Pressler's increment borer in the studied stands (one sample included more than 10 bore samples). Having been burnt to ashes at 530°C, plant samples were dissolved in 20% hydrochloric acid and after the obtained solution was quantitatively dripped into measuring flasks and the following elements were denoted: P - by colorimetric method, Ca, K and Na - by flame photometrical method, Mg – by atomic absorption method, $S-SO_4$ – by nephelometric method. N_{tot.} content was denoted by Kjeldahl's method in separate samples. Water samples from the examined mires in hollows with no run-off were taken once (in June). The water having been preserved by toluene in the site and dripped through mineral filter paper of GF/F Whatman type, the content of the following elements was denoted: Na, K, Mg, Ca, Fe, Mn, Zn – by atomic absorption method, Cl - by means of ionoselective electrode, $S - SO_4 - by$ nephelometrical method and PO₄, N-NH₄, N-NO₃ - by autoanalyzer.

3.4. METHODICAL ASSUMPTIONS

The question of productivity of plant communities in mires poses a number of methodical difficulties (C l y m o 1970b, S o l o n e v i č 1971, F a b i s z e w-s k i 1981). Therefore certain assumptions and simplifications must be admitted. Dry mass of tree stands was estimated by multiplying its volume and specific weight of wood of particular tree species. The values of specific weights were taken

after K a m i n s k i and L a u r o w (1966), as they had supplied data	on the
ytes in bog pinewood was calculated from samples taken in 5 replications	bryopl
*DBH diameter of stem at breast height (1.3 m).	

three tree species which were dealt with in the present studies and, moreover, their data were relevant for Poland. Thus the specific weight of wood (G/m^3) was 0.49 for *Pinus silvestris*; 0.51 for *Alnus glutinosa*; 0.59 for *Betula pubescens*.

Another fix was calculation of biomass of leaves (needles) of pine, birch and alder. Accurate counts of actual biomass of leaves is extremely toilsome. However, the output of needles and leaves, although fairly diversified (B i a ł o b o k and Ż e l a w s k i 1967, A s s m a n 1968, M a d g w i c k 1970, D i x o n 1976, L e m k e 1983), yet is not unrestricted and the values it assumes in similar climatic zones are much alike (S a t o o 1970). A possible error caused by leaf consumption by phytophages is slight, as they consume less than 3% of overground net production (W h i t t a k e r and M a r k s 1975).

There are two methods of estimates of leaf biomass: a direct and an undirect one based on the leaf fall. It is assumed in the latter that the fall equals leaf production (M a d g w i c k 1970, V y s k o t 1976), which corresponds to biomass value in case of leafy species. Therefore leaf biomass counts made in the present studies considered the data concerning leaf fall. The following parameters were taken into account: the age of the examined stands, their site quality class and total stand volume (alder -55 years old, III site quality class, birch -50 years old, III site quality class, pine -55 years old, V site quality class) as well as the habitat type (i.e. peat soil). Having found the data most appropriated to the examined situation (O v i n g t o n and M a d g w i c k 1959b, H o l m e n 1964, T r a c z y k 1967b, M o l č a n o v 1974, U s o l' c e v 1974, M ä l k ö n e n 1975, S t a c h u r s k i and Z i m k a 1976, U s o l' c e v and K r i č u n 1982), the mean value was calculated and applied in further counts (Table 1).

Table 1. Literature data and assumed values of biomass of birch, alder and pine leaves

Tree species	Leaf (needle) biomass g dry wt/m ²	Author	Assumed mean value g dry wt/m ²
Betula pubescens	350 230 400 267	Usol'cev and Kričun 1982 Ovington and Madgwick 1959b Molčanov 1974 Usol'cev 1974	312 0891 401 00
Alnus glutinosa	412 373.4	Stachurski and Zimka 1976 Traczyk 1967b	393
Pinus silvestris	443 350	Mälkönen 1975 Holmen 1964	400

peal moors, manaition bogs, bogrites withings, forests and shrubberies on peals)

In case of plant communities made up entirely of herbaceous plants, it is commonly assumed that standing crop is tantamount to their primary production.

During field investigations of two plant communities it was found out that in plots of Caricetum elatae primary production accounted for 94.2% and for 85.3% of biomass in plots of Typhetum latifoliae. Thus the pertinent assumption may be regarded as hardly bias at all (especially in case of sedge communities) and was adhered to in estimates for the other communities in which only herbaceous plants occurred.

In counts of production of dwarf shrubs, current increments may be fairly easily distinguished from biomass of former years, yet it is much more difficult to estimate current thickness increment in perennial shoots, which is feasible only on the basis of microscopic measurements (M o s z y \acute{n} s k a 1973). Present calculations took into account current increment only.

Values of bryophytes production was taken after other authors, who had evidenced that about 1/3 bryophyte biomass should be regarded in terms of current production (H. T r a c z y k and T. T r a c z y k 1967, M o s z y ń s k a 1970, M ä l k ö n e n 1975). However for phytocoenoses of Caricetum limosae and Ledo-Sphagnetum magellanici, where bog mosses (*Sphagnum* sp.) highly contributed to biomass of the whole community the values obtained in detailed studies were applied, according to which 54% of Sphagnales standing crop came from current's year production (R e j m e n t - G r o c h o w s k a et al. 1975).

Production of stands of bog moss pine forest, bog pinewood, alder wood fen and willow shrubberies, was estimated on the basis of so-termed average increment (A s s m a n 1968), i.e. by dividing present tree stand volume by their age. When tree leaf production was added to this value, which in case of leafy trees was tantamount with their biomass values, then the total primary production of stand was calculated. These counts were more complicated with respect to pine (*Pinus silvestris*), whose needles fell into different age classes. It was assumed after data from literature (M \ddot{a} 1 k \ddot{o} n e n 1975, L e m k e 1979, O r 1 o v 1980) that mean mass of current needles accounted for 32% of total biomass of pine needles (Table 2).

Table 2. Mean share of annual needles in total biomass of pine needles (Pinus silvestris)

	(analome). The wal	Mean share of annual needles in % dry	wt or in % fresh wt
	Author	literature data	assumed mean value
	Mälkönen 1975 Lemke 1979 Orlov 1980	$\begin{array}{r} 31.5-31.9 \ (dry \ wt) \\ 31-40 \ (fresh \ wt) \\ 32.67 \ (dry \ wt) \ - \ value \ estimated \\ from \ fall \end{array}$	32 (dry wt)
	393.	31.67 (dry wt) – direct measurement on model trees	Alfras giatinosa
		4. RESULTS	
	4.1. MIRE	VEGETATION OF HOLLOWS WITH NO	O RUN-OFF
(over	On the bottom of grown with vegeta	the examined no-outflow hollows the tion of natural and semi-natural characteristics of the semi-natur	here occurred wetland aracter. On the basis

fied (Kloss and Wilpiszewska 1983, 1985). The names of the following syntaxones were supplied after Matuszkiewicz (1981).

4.1.1. Taxonomy of the identified plant associations

Class – Phragmitetea R. Tx. et Preisg. 1942 Order – Phragmitetalia W. Koch 1926 Alliance – Phragmition W. Koch 1926 Association – Phragmitetum communis (Gams 1927) Schmale 1939 - Equisetum limosi Steffen 1931 - Typhetum latifoliae Soó 1927 - Acoretum calami Kobendza 1948 Order - Magnocaricetalia Pign. 1953 Alliance – Magnocaricion W. Koch 1926 Association – Phalaridetum arundinaceae Libb. 1931 - Caricetum acutiformis Sauer 1937 - Caricetum elatae W. Koch 1926 - Caricetum vesicariae Br.-Bl. et Denis 1926 Class – Scheuchzerio-Caricetea fusci R. Tx. 1937 Order – Scheuchzerietalia palustris Nordh. 1936 Alliance – Rhynchosporion albae W. Koch 1926 Association – Caricetum limosae Br.-Bl. 1921 Alliance – Caricion lasiocarpae Van den Berghen 1949 Association - Caricetum lasiocarpae W. Koch 1926 Class - Oxycocco-Sphagnetea Br.-Bl. et R. Tx. 1943 Order – Sphagnetalia magellanici (Pawł. 1928) Moore (1964) 1968 Alliance – Sphagnion magellanici Kästner et Flössner 1933 em. Dierss. 1975 Association - Sphagnetum magellanici (Malc. 1929) Kästner et Flössner 1933 - Ledo-Sphagnetum magellanici Sukopp 1959 em. Nauhäusl 1969 Class – Alnetea glutinosae Br.-Bl. et R. Tx. 1943 Order – Alnetalia glutinosae R. Tx. 1937 Alliance – Alnion glutinosae (Malc. 1929) Meijer Drees 1936 Association - Carici elongatae-Alnetum W. Koch 1926 - Salicetum pentandro-cinerae (Almq. 1929) Pass 1961 Class – Vaccinio-Piceetea Br.-Bl. 1939 Order - Vaccinio-Piceetalia Br.-Bl. 1939 Alliance – Dicrano-Pinion Libb. 1933 Association – Vaccinio uliginosi-Pinetum (Kleist 1929) Kobendza 1933

4.1.2. Two succession sequences (series)

The present state of vegetation in mires is the resultant of its development since the origin of hollows with no run-off. A considerable floristic diversity (reeds, sedge peat moors, transition bogs, bogmoss swamps, forests and shrubberies on peats) reflects various stages of mire overgrowing, which, at the same time, overlap with various stages of terrestrialization of water basins and lakes (K l o s s et al. 1987).



transition bog -Caricetum lasiocarpae adhered to m estudiately for Caricetum limosae in counts namy tendents in algobald me in ant destants toman stances mi distinguished from momass of fr bog moss swamp carrent that mess in crement in Sphagnetum magellanici o s z y n s k a (020 1926 deal y n mile Association - Integnitolum communis (Cams 1927) Schmale most that about Ledo-Sphagnetum magellanici - monthelp pinewood bog Vaccinio uliginosi-Pinetum applied, according to, Fig. 1. Succession scheme in dystrophic sequence reeds alliance Phragmition 2/11 4 C 5 1 1 1 1 Acoretum calami



Two succession series were distinguished, namely, (1) a dystrophic serie (of bogs) - from transition bogs through bogmoss swamps to bog pinewood (Fig. 1) and (2) a mesotrophic one (of fens) - from reeds and *Carex* fens through willow shrubberies to alder wood fen (Fig. 2). A similar course of succession in raised bogs and fens was stated also by other authors (e.g. K o b e n d z a 1930, P o d b i e l k o w s k i

, 1	1960	, So	botka	a 1967, P	aw	vło	wski	and 2	Larzy	ycki 19	977).	
	I	nstead	of succe	ession series	s the	e ter	m succes	ssion se	equence	was used	further of	on.
]	The	latter	notion,	according	to	the	author,	much	better	captured	changes	of

vegetation in time, their historic and dynamic aspect, and, primarily, structural and functional interrelations between particular links (stages) with respect to a good deal of analyzed parameters. Hence the terms dystrophic and mesotrophic sequences were consequently used therinafter. As to the qualifiers, they were introduced so as emphasize the specific character of the examined habitats, and thus, dystrophic denotes extremely nutrient-deficient habitats where humus acids accumulate, while mesotrophic characterizes habitats richer than the former yet poorer than fluviogenically supplied eutrophic fens.

4.2. PRELIMINARY CHEMICAL VALORIZATION OF WATER AND VEGETATION WITHIN PLANT COMMUNITIES OF THE TWO SUCCESSION SEQUENCES

Chemical valorization (water and plant analyses) was made in 19 hollows with no run-off (Fig. 3) under various stages of mire overgrowing. As some of them could be attributed to mixed systems, therefore 26 vegetation plots (Table 3) representing 13 plant associations were asigned for examinations.



Num- ber	Plant species	Number of vegetation plots in which a given species was analyzed	n 1 1a C. -S 1a	Plan repr nun pl – 3 sioc lim Spha nici	nt a rese ities nic carp osa agno , 7 inos	ntin s in sequ Ca bae, e, 6 etun	ciat g c dy uend arico 4- n n Val inet	ions om- stro ce: etur - 5 Led nage ccin um	s - n 	P s 14 c la Ca	lan equ alar atifo	t a enc C. ni, olia i e	ssoc ce: 8 acu 17 le, 2 long	ciati 3 — 9 tifo — F 20 — gata	ons 	rep Can , 1: gmi – S net - 26	ores tice 5 – itetu alic um:	enti tum Eq um etun 23 Ri	ng ela uise cor m p bo	cor atae etetu nmu bent Sp nig	nmu , 1(um unis adr ohag ri-A	unit) — 1 lim , 18 o-ci gno lne	ies 13 - osi, 3 - ner squ tum	in 1 - C 16 19 - eae, 1arr	mes ve - T 23 osi-	otro sica Acc yph -2 Alr	ophi ariae oretu etu 6 -	ic e, um m m,
		5	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
1	Alnus glutinosa*	4		1				Ya	1						10	3			-	120				1212	+	+	+	+
2	Betula pubescens	2	2		1			tan	+	E			100	1	~	- Line	1			KIX	8			10	+	10		(B)
3	Pinus silvestris	1				20	8	+					1		1	1				2	-			10			0	(TO)
4	Salix cinerea	3													2 IS	200				1		+	20	2	+	+	2	10
5	S. pentandra	1				20	3	R I						1.3	1	1 and	1.44			18	8	+	161	prid	21	CIE		11
6	S. vinimalis	1					1								10.11	Alle	(W			- Will			+	B	3	17R		- more
7	Frangula alnus	2		19					+						1	15			1	3			101	1.Sec	10	+	1 H	1
8	Acorus calamus	1														. 2		+		13			8	13		3		12
9	Andromeda polifolia	1			-			+							8	- Inte	1		1	- AN			COS	ETTS .	N.	200	- 3	CU12
10	Bidens cernuus	19														18	100			1 AL	+		6.6	10	200	26		100
11	Calamagrostis canescens	1												20	5	1.12			-	NE				- Inter	+	12	100	-5
12	Calla palustris	2													10	NH I	1		2	1			IIIs	01	8	+	gu	+
13	Carex acutiformis	2													117	+	1						100	0530	No.	90	+	215

Table 3. List of plant species subject to chemical analyses Numbers: 1-7 - tress and shrubs, 8-49 - herbaceous plants, 50-56 - mosses



14	C. elata	9	220	+		013			110	+	+	+	38	opi	+	iq.		+		+		Ì				+		+
15	C. elongata	4	-54	ter.	1 11		SCS De	00	epe	boa	100	0	ba	1101	anara.	ere:	E C	112	Da	525	115	+	1 10		+	+		+
16	C. lasiocarpa	5	+	+	+		+			+																		
17	C. limosa	1				+	+	+																1	÷			
18	C. pseudocyperus	1							+																			+
19	C. rostrata	2							-					+	+													
20	C. vesicaria	6										+	+	+	+			+			+				+	+		
21	Comarum palustre	9		+	+				+		+	+			+	+	+		+									+
22	Deschampsia caespitosa	1									+							-								+		
23	Dryopteris thelypteris	1					+																			+		
24	Epilobium palustre	4									+					+			+		+					+		
25	Equisetum limosum	4					+		+					+			+		+									
26	Eriophorum vaginatum	1						+																				
27	Galium palustre	3									+		+							+	+							+
28	Hottonia palustris	2															+											+
29	Iris pseudoacorus	6								+			+			+	+	+	+			+				+	t	+
30	Juncus effusus	1					+																			+		
31	Ledum palustre	2		+				+	+										+							+		
32	Lemna sp.	3					4																+	+		+		+
33	Lycopodium annotinum	1				÷	+	+	+																			
34	Lycopus europaeus	5			+						+										+					+		+
35	Lysimachia thyrsiflora	4				+	+				+			+	+				Ŧ						÷	+		
36	L. vulgaris	5	1	+					16	HT.	10	13	1	12	18	143	18	1à	30	3.5	32	+	54	25	70	+	+	+
37	Lythrum salicaria	11	DOG	+	+		9	1	1	+	+			P.	+	+	8	1	-	N.	+	+	-	101	10	+	+	+

Productivity and chemical valorization of mire < vegetation 15

1	2	3	4	5	6	7	8
38	Menyanthes trifoliata	4		spe	250	+	+
39	Oenanthe aquatica	1		1	F	- 30	0
40	Oxycoccus quadripetalus	3		-3	-	+	+
41	Peucedanum palustre	2					+
42	Phragmites communis	3	-	+		tim	
43	Rhynchospora alba	and 1 ed					+
44	Solanum dulcamara	7		5		-	-
45	Trientalis europaea	1		5		7	-
46	Typha latifolia	2					
47	Vaccinium myrtillus	1					
48	V. uliginosum	1					
49	Viola palustris	1	-				
50	Aulacomnium palustre	1					+
51	Caliergon cuspidatum	1					
52	Dicranum undulatum	1		Ŧ	Ŧ		
53	Drepanocladus aduncus	2					
54	Entodon Schroeberii	1					
55	Hylocomnium splendens	1					
56	Sphagnum sp.	5				+	+
10	C. Instocarpa	$\Sigma = 152$	-	-	-		

*All the trees and shrubs were subject to separate analyses on the content of particular elements and ash in their leaves (needles) and branches. Moreover, additional bore samples were taken with Pressler's increment borer of the first 4 species, the samples being subsequently subject to chemical analyses. Hence a total of 170 samples was obtained.

cd. tab. 3





Table 4. pH and concentration of elements in water (mg/l) sampled from mires of both sequences and statistical analysis of the samples with Student test (n = 22)

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						A. Results of	of chemical an	nalyses of wat	ter						
						Eleme	ent concentrat	ion in water	(mg/l)					Tatal	
Name of plant associations in phytocoenoses overgrowing mires	pH	N-NO ₃	N-NH4	PO ₄	K	Ca	Mg	Na	SO4	Cl	Fe	Mn	Zn	rali- zation (mg/l)	
Caricetum lasiocarpae C. lasiocarpae C. limosae C. limosae Ledo-Sphagnetum magellanici Ledo-Sphagnetum magellanici Vaccinio uliginosi-Pinetum	6.9 7.1 6.7 6.0 5.4 4.4 5.9	0.04 0.02 0.03 0.01 0.01 0.02 0.06	0.05 0.08 0.20 0.06 0.02 0.07 0.04	0.017 0.038 0.026 0.058 0.149 0.486 0.104	2.2 1.5 2.5 5.7 2.2 3.0 2.5	1 1 1 1 1 1 1	1.3 1.0 1.0 0.4 0.4 0.4 0.4 0.6	8.4 9.7 10.8 12.2 7.0 6.7 13.3	4.5 6.0 7.0 5.0 3.0 4.0 4.0	7.8 2.5 5.0 7.7 2.5 2.5 2.5	0.57 0.52 0.51 0.31 0.22 0.16 0.31	0.36 0.28 0.19 0.04 0.06 0.01 0.12	$ \begin{array}{r} 1.03 \\ 1.36 \\ 1.62 \\ 1.50 \\ 0.76 \\ 0.67 \\ 1.87 \\ \end{array} $	27.3 24.0 29.9 34.0 17.3 19.0 26.4	
Caricetum elatae C. elatae C. vesicariae C. vesicariae C. acutiformis Equisetetum limosi Acoretum calami Phragmitetum communis Typhetum latifoliae Salicetum pentandro-cinereae Salicetum pentandro-cinereae Ribo nigri-Alnetum Ribo nigri-Alnetum Ribo nigri-Alnetum Sphagno-squarossi-Alnetum	7.4 7.6 7.4 7.6 7.7 7.4 7.5 7.7 7.1 7.5 7.7 7.2 6.8 6.8 6.8	0.04 0.01 0.03 0.01 0.04 0.01 0.02 0.01 0.02 0.01 0.02 0.01 0.03 0.04 0.02 0.04 0.02 0.04	0.02 0.02 0.02 0.01 0.01 0.01 0.02 0.02 0.02 0.02 0.07 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.02 0.02 0.02 0.01 0.15 0.11	0.012 0.011 0.009 0.008 0.010 0.032 0.015 0.011 0.012 0.239 0.013 0.020 0.013 0.020	6.9 0.9 2.4 1.6 2.5 1.2 2.4 2.8 1.2 4.0 2.5 2.4 2.5 2.4 2.5 2.4 2.1 1.6 0.9	24 96 42 63 73 76 66 78 91 13 88 91 13 88 88 88 94 36 25	4.6 12.6 5.8 8.8 10.6 13.3 7.9 10.2 15.0 2.8 11.1 15.3 9.4 6.4 5.4	6.4 6.0 6.7 7.2 8.5 9.0 5.2 10.6 7.6 7.2 10.8 8.1 8.1 8.1 8.1 8.1 8.1 8.1 8.1 8.1 8	5.5 6.5 6.0 1.5 1.5 1.5 2.0 1.5 2.0 1.5 6.0 2.5 1.5 4.5 5.5 6.5	$ \begin{array}{r} 11.5 \\ 5.3 \\ 13.8 \\ 9.6 \\ 15.7 \\ 17.4 \\ 9.4 \\ 16.7 \\ 6.8 \\ 12.5 \\ 20.0 \\ 6.8 \\ 15.8 \\ 9.0 \\ 14.2 \\ \end{array} $	0.18 0.03 0.15 0.03 0.10 0.13 0.03 0.10 0.15 0.07 0.12 0.12 0.13 0.22 0.51	0.01 0.04 0.03 0.01 0.15	0.24 0.13 0.24 0.19 0.28 0.24 0.16 0.18 0.16 0.24 0.21 0.21 0.19 0.27 0.27 0.27 0.43	59.4 127.5 77.2 92.0 112.3 119.0 92.8 120.6 123.4 46.0 135.4 122.5 134.4 66.1 61.8	
						B. Statist	ical analysis ((Student test)							
$\bar{x} \pm SD$ D seq.	6.1±0.95	0.030 ± 0.018	0.074 ± 0.059	0.125 ± 0.166	2.80 ± 1.36	1 ± 0	0.73 ± 0.37	9.73±2.53	4.79±1.35	4.36±2.49	0.37 ± 0.16	0.151 ± 0.131	1.26 ± 0.45	25.41±5.88	
$\bar{x} \pm SD$ M seq.	7.4±0.3	0.023 ± 0.013	0.035 ± 0.042	0.029 ± 0.058	2.36±1.51	63.53 ± 28.31	9.28±3.81	7.79±1.56	3.60 ± 2.18	12.30 ± 4.40	0.14 ± 0.12	0.035 ± 0.050	0.229 ± 0.072	99.36±30.46	
t_{x_1,x_2}	4.737	0.636	1.685	1.907	0.628	5.730	5.645	2.103	1.263	4.247	3.588	2.868	8.214	6.070	
p	0.001	> 0.05	> 0.05	> 0.05	> 0.05	0.001	0.001	0.05	> 0.05	0.001	0.01	0.01	0.001	0.001	

1.81

Type of Ca/Mg sequence 0.77 1.00 1.00 2.50 2.50 2.50 1.70 dystrophic 5.22 7.62 7.24 7.16 6.89 5.71 meso-8.35 7.65 trophic 6.07 4.64 7.93 5.75 10.00 5.63 4.63

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			57				X			
					13 04 04 04 04 04 04 04		22 22 22 22 22 22 22 22 22 22 22 22 22			
	59.4 127.2 127.2 92.0 119.0 120.6 122.4 135.4 136.1 136.1		0.13 0.03 0.10 0.10 0.13 0.13 0.13 0.13		• • • • • • • • • • • • • • • • • • •	· 88 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4				
			3.588					> 0.05		



4.2.1. Element concentration in water Water sampled from mires representing various stages of overgrowing (Table 4) was analyzed as to the content of (mg/l): Na, K, Mg, Ca, Fe, Mn, Zn, PO₄, N-NO₃, N-NH₄, SO₄, Cl and pH. Statistical analysis of the data (Student test) indicated significance of differences in mean content of a majority of the elements in water of dystrophic and mesotrophic sequence (Table 4), namely, at 0.001 significance level for Mg, Ca, Zn, Cl and pH, at 0.01 significance level for Fe and Mn, and at 0.05 significance level for Na. For the remaining ones, i.e. K, PO₄, N-NO₃, N-NH₄, SO₄, differences in mean values were insignificant.

Water from plant communities of dystrophic sequence was noted for significantly higher mean content of Zn, Fe, Mn and Na, as compared to corresponding values in mesotrophic sequence. Also mean content of K, SO_4 , PO_4 , $N-NO_3$, $N-NH_4$ was higher, yet the differences were not statistically significant. On the other hand water sampled from mires of mesotrophic sequence had a significantly greater mean content of Ca, Mg, Cl and pH.

A good indicator of element content in water is a so-termed general mineralization, i.e. total concentration of all the ions contained in water (mg/l). It was estimated that for dystrophic sequence the values of this parameter ranged from $x_{min} =$ = 19.0 mg/l to x_{max} = 34.0 mg/l, while for mesotrophic sequence the interval was 46.0 and 135.4 mg/l (Table 4). Those were notable differences as the intervals of the values did not even overlap. Therefore it may be stated that water coming from plant communities of dystrophic sequence was considerably poorer in nutrients than that from mesotrophic sequence. This is quite understandable as the main source of nutrient supply in the former sequence was precipitation and wind-drifted dust (ombrogenic type), while in the latter – ground water (soligenic type). According to Kivinen (1933) the content of Ca in water determines development of a specific type of vegetation. When Ca content does not exceed 1 mg/l, vegetation of raised bogs develops, whereas when the value is greater - vegetation of fens appears, as proven by the present results (Table 4). Bellam y (1966, 1968) defined ombrotrophic water as that of low pH values, little content of alkalis and Ca/Mg ratio < 1. Analyses of water sampled in dystrophic sequence revealed that the ratio in question was higher, its values ranging 0.77 - 2.5 (Table 4). Similar results in which the values of the studied parameter exceeded 1.0, i.e. the value formerely regarded as the limit one, had been arrived at also by other authors (Sjörs 1961, Heinselman 1970, Sonneson 1970, Waughman Similar results concertifie ash, N. K. Ca and Michaele obtained by other a .(0801

4.2.2. Concentrations of elements in plants Chemical valorization of vegetation in the gradient of dystrophic and mesotrophic sequences was made on the basis of samples of 56 plant species (Table 3). The sampled species constituted structural elements of particular plant communities growing on mires. The set of analyzed plants included a majority of species found in mired hollows without run-off and consisted primarily of species dominating in particular communities as well as of certain accompanying species. Due to a considerable floristic diversity, plots of several plant associations were subject to repeated examinations. For instance, phytocoenoses of alder swamp Carici elongatae-Alnetum (sensu lato) were analyzed four times, namely, phytocoenosis with the herb layer dominated by *Carex vesicaria*, the one with the herb layer dominated by *Carex vesicaria*, the one with the herb layer dominated by *Carex acutiformis*, a flooded one with a considerable contribution of *Lemna* sp., and the phytocoenosis of alder swamp representing the association Sphagno squarrosi-Alnetum (Table 3).

The obtained results of chemical analyses pointed to heterogenousness of the sampled material. Ranges of changeability in concentrations of particular elements and ashes (in dry weight) for all plants (herbs, dwarf shrubs and bryophytes) were fairly wide (Table 5). On the average the share of ash in dry mass of the analyzed plants amounted to about 8.0%, while the elements it contained could be ordered from the greatest to the smallest content in the following way: $K \ge N > Ca > Mg > P = S > Na$.

The greatest changeability (as well as ash) in the analyzed plant material was betrayed by potassium, while the smallest - by sodium. Investigations of chemical nature of plants from swampy and waterlogged habitats (Table 5) did not take into account shrubs and trees as their chemical composition is very specific (especially of ligneous substance referred to as wood, along with bark). Concentrations of particular elements in dry weight of trees were much lower than the ones estimated for herbaceous plants, dwarf shrubs and bryophytes. In all the examined trees the smallest nutrient content was recorded in ligneous substance, somewhat greater - in branches and the greatest - in leaves (needles). These relations were presented in Table 6, which supplies exemplary data on the chemical composition of alder. In order to compare chemical composition of vegetation in the two succession sequences, statistical analysis (Student test) was conducted, aimed at capturing significance of differences in mean concentrations of nutrients and ash in dry weight of plants from dystrophic and mesotrophic sequences (Table 7). The obtained result was positive for all the examined parameters. At 0.01 significance level mean concentrations of ash, N, P, K, Ca, Mg and Na were significantly different. Only significance of differences in mean concentrations of $S - SO_4$ was slightly less distinct, as it was recorded at p = 0.05 level (Table 7). Statistical analysis showed that vegetation composing plant communities of mesotrophic sequence had a higher mean content of all the examined elements and ash than that of dystrophic sequence. Similar results concerning ash, N, K, Ca and Mg were obtained by other authors (Maciak 1963, Waughman 1980, Gobat 1984). The present findings revealed, in addition, that as compared to vegetation of dystrophic sequence that of mesotrophic sequence had significantly greater content of sodium and phosphorus. Only in case of sulphur $(S - SO_4)$ the obtained data on differences in its content in vegetation of the two mire types were hardly significant, which, most likely, resulted



Table 5. Ranges and mean content values for particular elements and ash (in % of dry wt) for all the analyzed plants except for trees and shrubs (n = 138)

Values	Ash	N _{tot} .	P _{tot} .	K	Ca	Mg	Na	S-SO ₄
Range of values $x_{min.} - x_{max.}$	1.79 - 19.91	0.68-4.12	0.034-0.841	0.343 - 4.94	0.065 - 2.92	0.057 - 2.69	0.009-0.782	0.024-1.46
Mean content x	7.99	1.67	0.231	1.71	0.767	0.291	0.127	0.231

Table 6. Chemical composition of alder (Alnus glutinosa) (in % of dry wt)

Analyzed sample	Ash	N _{tot} ,	P _{tot} .	K	Ca	Mg	Na	S-SO ₄
Ligneous substance Branches	0.55 2.33	0.16 0.96	0.008 0.106	0.045 0.330	0.130 0.418	0.030 0.080	0.030 0.019	0.026 0.040
Leaves	5.30	2.40	0.173	0.642	1.020	0.321	0.034	0.120



Parameters	Number N*	Ash	N _{tot.}	P _{tot} .	K	Ca	Mg	Na	S-SO4
$\bar{x} \pm SD$ of M sequence	101	9.092 ± 3.405	1.951 ± 0.716	0.273 ± 0.114	1.961 ± 0.910	0.887 ± 0.584	0.325 ± 0.274	0.153 ± 0.173	0.254 ± 0.2
$\bar{x} \pm SD$ of D sequence	37	4.972 ± 2.558	1.157 ± 0.410	0.116 ± 0.048	1.008 ± 0.581	0.438 ± 0.371	0.197 ± 0.161	0.057 ± 0.081	0.168 ± 0.1
t_{x_1}, x_2	-	6.651	5.426	8.023	5.895	4.340	2.657	3.204	2.282
p		0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.05

*In case of nitrogen the number amounted to n = 53 for mesotrophic and n = 29 for dystrophic sequence.

Table 7. Comparison of mean concentrations of nutrients and ash (% dry wt) in plants of mesotrophic (M) and dystrophic (D) sequence (Student test)



4.3. ECOLOGICAL CONDITIONS OF DISTINCTIVITY OF THE TWO SUCCESSION SEQUENCES

There occurs a distinct correlation between the type of mire water supply (ombrogenic and soligenic) and, consequently, the manner of nutrient supply (ombrotrophism and minerotrophism) and development of definite plant communities. This correlation was captured in regularities of distribution of mire plant communities with respect to hydrography of the studied site. Conditions prevailing on areas drained by watercourses favoured development of peatlands of mesotrophic sequence. On the other hand, peatbogs of dystrophic sequence developed on the area situated on morainic plateau, which was characteristic for the lack of distinct hydraulic gradients of groundwater horizon I, i.e. lacking any run-off (K l o s s et al. 1987). Peatbogs of dystrophic sequence accounted merely for 7% of the total number of 285 examined wetlands on the studied site.

Also other regularities were revealed in the course of the present studies, which attested to a distinct character of the two sequences (Table 8). Mean area of peatbogs of dystrophic sequence ($\bar{x} = 3.53$ ha) as well as of no-outflow hollows where they occurred ($\bar{x} = 10.34$ ha) was several times greater than the values recorded for corresponding parameters in mesotrophic sequence (0.55 and 3.04 ha respectively).

Table 8. The effect of catchment area on mires in two succession sequences

Sequence type	Type of plant community overgrowing mires	Number of mires*	% of total mire number*	Mean mire area (ha)*	Mean hollow area (ha)*	Number of ha of catchment area fal- ling to 1 ha of mire
spread on	reeds and Carex fens	42	14.7	0.73	3.45	3.73
Mesotrophic	willow shrub- beries	135	47.4	0.44	2.66	5.05
Greater nu	alder wood fens	39	13.7	0.73	3.90	4.34
Ca. C-C	total	216	75.8	0.55	3.04	4.53
Dystrophic	transition and raised bogs, bog pinewoods	20	7	3.53	10.34	1.93
Eight p	Bra Somminice	making u	5 - 82 8**	12140.200	1. S. 7 100	TOSUES WUSE

*Data in four columns marked with an asterisk were taken from the paper by Kloss et al.

(1987).

** The lacking 17.2% of total mire number (n = 285) was made up by ponds. They were disregarded

here as irrelevant to the subject of the paper.

Table 9. Comparison of element pool yearly inflowing to 1 hectare of mire in catchment area of dystrophic and mesotrophic sequence

Sequence type	Number of ha of	Type of	Type of mire water supply Sources of element inflow	3.90	Amounts of inflowing elements in kg·ha ⁻¹ ·yr ⁻¹											
	area affecting 1 ha of mire	of mire water supply		N _{tot} .	P _{tot} .	K	Ca	Mg	Na	S-SO ₄	Cl	Fe	Mn	Zn	Cu	C-CO
Dys- trophic	1.93	ombro- genic	atmos- phere* Σ_1	17.70 17.70	0.28 0.28	3.60 3.60	7.68 7.68	1.17 1.17	7.41 7.41	8.38 8.38	13.61 13.61	0.64 0.64	0.086 0.086	1.80 1.80	0.056 0.056	2.85 2.85
Meso- trophic	4.53	soli- genic	atmos- phere* ground waters Σ_2	17.70 31.35** 49.05	0.28 1.13* 1.41	3.60 4.08** 7.68	7.68 622.47** 630.15	1.17 69.17** 70.34	7.41 63.92** 71.33	8.38 117.60** 125.98	13.61 171.69** 185.30	0.64 7.29* 7.93	0.086 0.680* 0.766	1.80 0.50* 2.30	0.056 0.034* 0.090	2.85 333.86* 336.71
A lator	ise of nig	ogen the	Σ_2/Σ_1	2.8	5.0	2.1	82.1	60.1	9.6	15.0	13.6	12.4	8.9	1.3	1.6	118.1

*Estimates were made on the basis of balance data for catchment area of a coniferous forest located near Mikołajki (Bobrówko) in the Masurian Lakeland in the season of 1982/1983, taken from the work by Z i m k a (in press). **Estimates were made on the basis of balance data for 3 agricultural catchment areas near Mikołajki in the Masurian Lakeland, in the season of 1982/1983 and 1983/1984, taken from the paper by K r u k (1990).



Hence it may be concluded that the effect of catchment area on mires was greater in case of mesotrophic sequence. It may be easily evidenced by estimating how many hectares of catchment area fell to one hectare of the mire it comprised. For mesotrophic sequence the value averaged 4.53, while for dystrophic sequence it came merely to 1.93 (Table 8). Considering the fact that the main source of nutrient supply in dystrophic sequence was precipitation and that mires of this sequence had hardly any contact with water-bearing layer, it should be stated that the effect of catchment area on mires was even stronger in mesotrophic sequence as it might have been concluded from the comparison of the above-mentioned values only (4.53 to 1.93; hence it would be more exact to compare 4.53 to 0).

An attemptive estimate of nutrient pool supplying one hectare of mire in dystrophic and mesotrophic sequence was presented in Table 9. Due calculations were made on the basis of the work by Z i m k a (in press) and K r u k (1990). It follows from the tabulated data that as compared to dystrophic sequence, habitats of mesotrophic sequence were supplied with a several times greater amount of nutrients (kg \cdot ha⁻¹ \cdot yr⁻¹), which concerned all the examined elements, i.e. N_{tot.}, P_{tot.}, K, Ca, Mg, Na, S-SO₄, Cl, Fe, Mn, Zn, Cu, C-CO₃. The smallest differences in nutrient watershed loadings in the two sequences, i.e. 1.3- and 1.6-fold, were calculated for Zn

and Cu (Table 9), whereas several dozen-fold differences were recorded for: Mg - 60.1-fold, Ca - 82.1-, and C $-CO_3 - 118.1$ -fold (Table 9). It should be noted that initial balance data supplied by K r u k (1990) concerned three catchment areas of typically agricultural character. The data having been averaged and the amount of elements outflowing from 1 ha of plowland yearly having been calculated, the effect of 4.53 ha of this type of catchment area on 1 ha of mire was estimated. The work quoted above supplies watershed balance for N, K, Ca, Mg, Na, $S-SO_4$, Cl. In case of the remaining elements, i.e. P, Fe, Mn, Zn, Cu, C $-CO_3$, estimates were made on the basis of data taken from the work by Z i m k a (in press). As the matter of fact these data concerned catchment area grown with coniferous forest, yet this area spread on the same site and occupied analogous soils and, moreover, both studies overlapped in time.

Hence it may be concluded that habitat distinctiveness of mires of the two sequences was unquestionably manifested in the course of reported examinations. Greater nutrient aboundance in mires of mesotrophic sequence was recorded in case of all the studied elements, i.e. $N_{tot.}$, $P_{tot.}$, K, Ca, Mg, Na, S-SO₄, Cl, Fe, Mn, Zn, Cu, C-CO₃ (Table 9).

man latifoliae.

4.4. PRODUCTIVITY OF PLANT COMMUNITIES IN MIRES

Eight plant communities making up links of the two succession sequences were assigned for detailed examinations. In dystrophic sequence these were the following phytocoenoses: Caricetum lasiocarpae, Caricetum limosae, Ledo-Sphagnetum



structural elements of the examined plant communities were subject to further studies, i.e. the herb, bryophyte, shrub and tree layers. The results obtained for the initial links of succession were ordered according to increasing values of standing crop, primary production, etc. (in dystrophic sequence Caricetum lasiocarpae preceeded Caricetum limosae, in mesotrophic sequence Caricetum elatae preceeded Typhetum latifoliae). General trends and conclusions were formulated on the basis of arithmetical means of values of particular parameters for 4 plant communities of each sequence. Thus succession schemes served mostly the purpose of a representative selection of 4 phytocoenoses in each sequence, which would consider a substantial floristic diversity and yet allow for comparison of results, notwithstanding great differences in biomass. This method of assigning sample sites made it possible to choose in each of the sequences 2 communities made up almost exclusively of herbaceous plants and 2 comprising tree stands *. 4.4.1. Standing crop

The outcome of elaboration of the author's results and data from literature (see chapter 3.4) was presented in Tables 10 and 11. On general, biomass of plant communities of mesotrophic sequence attained greater values than the ones estimated for dystrophic sequence (Fig. 4). In both sequences a tendency was observed to an increase in total aboveground biomass coupled with succession course. An amazingly high biomass was recorded in the community of willow shrubberies Salicetum pentandro-cinereae, which, however, was intelligible when density of willows in osiery was compared to density of trees and shrubs in other communities. Density of willows in Salicetum was 35 times greater than density of trees and shrubs in alder wood fen, by 27 times greater than in bog pinewood and by about 20 times greater than in bog moss pine forest (Table 12). Moreover, attention should be paid to the fact that bryophytes had a greater contribution to communities of dystrophic sequence. They included mainly bog mosses (Sphagnum sp.). Their abundance in those habitats would point to the fact that they are very well adapted to assimilating elements from precipitation (ombrotrophism). Their numerous properties predisposing them to development under extreme conditions had been frequently stressed (Clymo 1970a, Heinselman 1970, Damman 1978, Gobat 1984). It follows from comparison of standing crop of herbaceous plants in both sequences that it attained the greatest value in the community Typhetum latifoliae. The value estimated for this community was by several times higher than in other plant communities. Standing crop in Typhetum latifoliae amounted to 18 114 kg dry wt/ha, while in the other communities it ranged from merely 654 to 4240 kg dry wt/ha (Tables 10, 11). It also should be noted that in Caricetum lasiocarpae and in Typhetum latifoliae the layer of herbaceous plants was the only structural element of



Table 10. Standing crop and primary production in plant contractifies making succession stages in dystrophic sequence

accinio ulini-				1			Examined ai productions
dry	30	D		3	М		
biomass (kg/ha)		21042	1 1507	039 100		May Br	and rates Albertum
200 000 -		1361	15117	- %		physics to year	oca N 196
190 000 -		4 000	2689	_91.p. [8	1141 4 200		Standinges E
180 000 -		07130	257	- 801	- (eads		Cop - B
170 000 -		52.090					within (and in the
160 000 -		N-2 Ve					1 13 689
150 000 -	in ser	olunika) o					
140 000 -		1233.00	1628	101	2		STATE STATE
130 000 -		0.00			5		



D - dystrophic sequence, M - mesotrophic sequence, 1 - herbaceous plants (and dwarf shrubs), 2 - bryophytes, 3 - tree leaves (needles), 4 - ligneous substance

Table 10. Standing crop and primary production in plant communities making succession stages in dystrophic sequence

Examined producti-	Structural elements of plant		Caric lasioc	etum arpae	Caricetum limosae		Ledo-Sphagne- tum magellanici		Vaccinio uligi i nosi-Pinetum	
rameter	ptifoli	communities	N	%	N	%	N	%	N	%
ach sequer	Herb	layer	3939	100	1507	17.5	2 042	2.0	4 240	3.1
ive selection	Bryop	ohyte layer			7117	82.5	7 361	7.4	1 548	1.2
Standing crop = B (kg dry	Tree	leaves (needles) slash (branches) large timber	T-se				4 000 24 150	rple si made	3 120 23 480	der in Obrest
wt/ha)	layer	(trunks) Σ		nding	crop	-	90 240	90.6	102 750	95.7
The out	Total standi	community ing crop Σ	3939	100	8624	100	99 643	100	135 138	100
ommunutre minnatari fi	Herb	layer	3939	100	1156	23.1	880	11.4	2 064	25.1
bearved to	Bryop	ohyte layer	al=ov	giepo	3843	76.9	3 975	51.6	516	6.3
Primary pro- duction = P	Teres	leaves (needles) slash (branches)					1 280 440	d shri	3 120 470	alen.
wt/ha)	layer	(trunks)	-			-	1 130	er tha	2 060	io v
bout 20 tip	ies g	Σ	n n ass	pi - bi	-		2 850	37	5 650	68.6
f dystroph bundance i	Total prima	community ry production Σ	3939	100	4999	100	7 705	100	8 230	100
o assimilar	% of	standing crop	100	abida	58		7.	7	6.1	Pous
B/P	tress		97001	.00	1	.73	12.	93	16.4	42

biomass of the whole community. The respective biomass values came barely to 3939 in the former and as much as 18 114 kg dry wt/ha in the latter (Tables 10, 11).

Analyses of leaf biomass and its share in total community biomass revealed that tree stands of mesotrophic sequence produced greater amounts of leaves than those of dystrophic sequence. The largest quantities of leaves were yielded by willows in phytocoenoses of Salicetum pentandro-cinereae, which seemed to result from a considerable density of *Salix* specimens in these phytocoenoses (Table 12).

In both sequences tree stands accounted for a notable percentage of total aboveground biomass, namely, 90.6% in bog moss pine forest, 95.7% in bog

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Table 11. Standing crop and primary production in plant communities making succession stages in mesotrophic sequence

Examined producti- vity pa-	Sti	ructural elements of plant	Cario ela	cetum tae	Typh latife	etum oliae	Salicetur tandro-c	n* pen∙ inereae	Carici gatae-A	elon- Inetum
rameter	gest i	communities	N	%	N	%	N	%	N	%
Herbaccor	Herb	layer	2689	91.3	18 114	100	654	0.5	3 297	1.7
Produc	Bryop	hyte layer	257	8.7	-		Para bi	_		
Standing crop = B (kg dry wt/ha)	Tree layer	leaves slash (branches) large timber (trunks)	The second				8 470 55 200 67 100		3 930 13 680 171 200	came ne fac e ove
substance) Typhetum	Tree layer	Σ				exam test a	130 770	99.5	188 810	98.3
matter. In communit	Total standi	community ng crop Σ	2946	100	18 114	100	131 424	100	192 107	100
dystrophic	Herb	layer	2239	96.9	15 446	100	654	3.9	3 297	31.1
-Sphagnet	Bryop	hyte layer	86	3.1			Contra		ecites)	0710
Primary pro- duction = P (kg dry wt/ha)	Tree layer	leaves slash (branches) large timber (trunks)	-			a set or set of the se	8 470 1 570 6 150		3 930 250 3 110	trees e her in th
communit stands of The m	Tree layer	Σ	-	-			16 190	96.1	7 290	68.9
biomass a studied co	Total prima	community ry production Σ	2325	100	15 446	100	16 844	100	10 587	100
at final st	% of	% of standing crop		.2	85.3		12.8		5.5	
B/P	B/P		1.06		1.17		7.80		18.15	

*See chapter 3.2 – data on this community are the mean from 3 variants of the herb layer, i.e. the herb layer made up of herbaceous plants, and the layer composed mainly of *Lemna* sp. (on insolated water surface and in shadow beneath willows).

Structural	P	lant communit sequ	ties of dystrophic tience	c	Plant communities of mesotrophic sequence					
elements of plant communities	Caricetum lasiocarpae	Caricetum limosae	Ledo-Spha- gnetum ma- gellanici	Vaccinio uliginosi- -Pinetum	Caricetum elatae	Typhetum latifoliae	Salicetum pentandro- -cinereae	Carici elongatae- -Alnetum		
Herb layer	c* = 82%	c = 55%	c = 34%	c = 63%	d = 29 500 hummocks/ /ha	c = 77% + c Lemna = 42%	c = 36% + c Lemna = 100%	c = 76%		
Bryophyte layer		c = 100%	c = 100%	c = 38%	-	-	-			
Tree layer	annul 2	- 3	d** = 1808 (ind./ha)	d = 1328 (ind./ha)		-	d = 32 200 (ind./ha)	d = 1017 (ind./ha)		
*c – Coverage. **d	- Density of s	specimens or h	ummocks.	nsr atob Mah	a dina di di		ALL	R S		
Hands in the second sec										
	aly to 3939		August 201	NIG 6.3						

100				

Table 12. Parameters of density structure in plant communities making succession stages in dystrophic and mesotrophic sequence



pinewood, 99.5% in willow shrubberies and 98.3% in alder wood fen (Tables 10, 11). Again mesotrophic sequence was marked for higher absolute values and percentage contribution as well (Fig. 4).

4.4.2. Primary production

The formerely outlined tendency of greater biomass values recorded for plant communities of mesotrophic sequence as compared to dystrophic one became even more distinct when production was analyzed (Fig. 5). Production of the herb layer was the largest in communities of Caricetum lasiocarpae and Typhetum latifoliae, i.e. it amounted to 3939 and 15446 kg dry wt/ha respectively (Tables 10, 11). Herbaceous plants made up the only component of these communities.

Production in plots of Typhetum latifoliae was incomparably high. It exceeded production even of such plant communities as bog moss pine forest, bog pinewood and alder wood fen (Tables 10, 11). Only production of willow shrubberies came close to its values (15 446 and 16 844 kg dry wt/ha). However, considering the fact that in Salicetum only estimated 9124 kg dry wt/ha was subject to matter cycle over a year (the remaining part of annual production falling in increment of ligneous substance), it should be stated that among the examined communities it was Typhetum latifoliae which produced yearly the greatest amount of turnover-subject matter. In this respect Salicetum pentandro-cinereae was the second most productive community.

The contribution of bryophyte layer to production was significant only in dystrophic sequence (especially in the plots of Caricetum limosae and Ledo--Sphagnetum magellanici).

It may be broadly assumed that the contribution of tree leaves (needles) to tree stand production amounted to $\pm 50\%$, i.e. production of leaves approximated production of ligneous substance (i.e. the thickness and length increment of trees). Production of leaves (needles) usually exceeded production of plants from the herb layer (except for bog moss pine forest, where peatmosses had the greatest share in the community production). Leaf production and increment of ligneous substance in tree stands of mesotrophic sequence were higher than in dystrophic sequence.

The ratio of total aboveground biomass to production (in dry wt) is defined as biomass accumulation index (W h i t t a k e r and W o o d w e 11 1968). In the studied communities the values assumed by the ratio ranged from 1 to 1.73 at initial stages of succession, 7.80 for willow shrubberies, 12.93 for bog moss pine forest, and, at final succession stages -16.42 for bog pinewood in dystrophic sequence and 18.15 for alder wood fen of mesotrophic sequence (Tables 10, 11). According to W h i t t a k e r and W o o d w e 11 (1968) the value of the ratio should approximate 1.0 for herbaceous plants, from 7.0 to 10.0 for larger arborescent shrubs and well over 10.0 for trees. The present results corroborated these data.

Summing up it may be stated that primary production of plant communities in

mesotrophic sequence was greater than in dystrophic sequence and, furthermore, phytocoenoses of Typhetum latifoliae and Salicetum pentandro-cinereae produced yearly the biggest amount of phytomass subject to matter turnover.



4 M dry V Dires recorded biomass (kg/ha) more distinct when production was a Erdepiction of the was the largest in communities of Carlestinn Islocar fae, and 3 ypherum lat 20000 it amounted to 3939 nb gx [Table respectively SILTY 19000 2512 10 Herbaceous plants made up the on communitie Production in plots of Typhetum latitoli 18000 production even of such 17000s-bog moss bi comm in fores

Allow shrubbe roducti DD PDF V 16000 Egidry wt/hall However, considerin sgidry wit/ha was subject to matter 7 15000 1.1 14000ybotq" Examined communities it 13000

and alder wood fen (close to its values (15 that in Salicetum only a year (the remaining substance), it should



Fig. 5. Structure of primary production in particular plant communities D - dystrophic sequence, M - mesotrophic sequence, 1 - herbaceous plants (and dwarf shrubs), 2 - bryophytes, 3 - tree leaves (needles), 4 - increment of ligneous substance

4.5. METHODS OF MATTER MANAGING IN PLANT COMMUNITIES OF THE TWO SUCCESSION SEQUENCES

4.5.1. Accumulation of nutrients in plant communities of the two sequences

Accumulation of nutrients in plants is usually calculated in terms of quantity and area units, i.e. in kilograms of nutrients contained in dry wt of plants growing over the area of 1 hectare. Accumulation of nutrients and ash in biomass of plant communities of the two sequences increased, on the whole, along with succession course (Fig. 6). Hence the greatest accumulation values were recorded in communities of bog pinewod and alder wood fen. It was noted, at the same time, that a mean content of nutrients in plant communities of mesotrophic sequence was respectively higher (Table 13).

Table 13. Accumulation of mineral components (kg dry wt/ha) in standing crop of the examined plant communities

Sequence type	Name of plant community	Biomass	N _{tot} .	P _{tot} .	K	Ca	Mg	Na	S-SO ₄
	Caricetum lasiocarpae	3 939.0	34.6	2.0	40.9	7.7	3.3	0.8	6.8
	Caricetum limosae	8 624.1	65.2	4.5	55.3	14.8	7.8	6.3	27.3
Dystrophic	Ledo-Sphagnetum magellanici	99 643.0	369.8	35.6	215.8	148.8	60.3	25.7	30.6
	Vaccinio uliginosi- -Pinetum	135 138.0	441.6	40.7	201.9	394.7	105.4	41.6	74.6
	x	61 836.0	227.8	20.7	128.5	141.5	44.2	18.6	34.8
	Caricetum elatae	2 945.6	38.0	5.2	52.9	14.5	4.1	0.9	1.3
	Typhetum latifoliae	18 114.0	166.4	23.9	267.9	219.6	64.3	43.8	15.3
Mesotrophic	Salicetum pentandro- -cinereae*	131 423.8	375.7	55.1	289.3	379.4	85.8	26.4	65.1
	Carici elongatae- Alnetum	192 107.0	563.9	42.1	197.5	331.4	82.0	56.4	58.3
annihim	x	86 147.6	286.0	31.6	201.9	236.2	59.1	31.9	35.0

*Values are a mean from 3 variants of this community.

It follows from analysis of data in Figure 4 and Figure 6 that the value of accumulation depended on the amount of biomass. However a closer scrutiny of the data revealed a noteworthy exception, namely, in case of Typhetum latifoliae nutrient accumulation was so very high that hardly comparable to the amount of community biomass. Hence it may be concluded that the community in question



1 2//// 4.5. METHODS OF MATTER MANAL 2 *****

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Accumulation of nutrients in plantscients nully calculated in terms of quantity and area units, i.e. in kilo rams d'autrients contained n dry vicht plants er- 0002 the area of I hectare. Accumulation of matrients and ash in piomass of plant communities of the two sequences mercased on the whole, along with succession course (Fig. 6. Hence the areatest accumulation values were recorded in confficinities of bog pid even a la side wood fem it was not d, at the same time, if another i and the same time of a sectively

1500



Fig. 6. Accumulation of ash and nutrients in standing crop of plant communities D - dystrophic sequence, M - mesotrophic sequence, - 1 ash, 2 - total amount of nutrients (N_{tot.} + $+ P_{tot.} + K + Ca + Mg + S - SO_4$

Na in particular) than treed communities (Table 13), notwithstanding the fact that its biomass was 5-10-fold smaller than that of the latter communities (Tables 10, 11). Analyses of accumulation of mineral components in annually produced biomass



higher (Table)



communities of the two sequences were 2-5-fold, at 1.8-fold difference in mean values of primary production of communities of the two sequences (Table 14). The highest accumulation values were recorded in community of Typhetum latifoliae

(Fig. 7), though its primary production was not the greatest (Fig. 5).
Two plant communities were noted for their excessive nutritional requirements,
namely, Typhetum latifoliae and Salicetum pentandro-cinereae. These plant commu-

Table 14. Accumulation of mineral components (kg dry wt/ha) in primary production of the examined plant communities

Sequence type	Name of plant community	Primary production	N _{tot.}	P _{tot.}	K	Ca	Mg	Na	S-SO ₄
Dystrophic	Caricetum lasiocarpae	3 939.0	34.6	2.0	40.9	7.7	3.3	0.8	6.8
	Caricetum limosae	4 999.0	38.9	2.9	35.2	8.5	5.0	3.6	15.7
	Ledo-Sphagnetum magellanici	7 705.0	57.8	6.7	35.0	12.2	8.2	3.2	3.5
	Vaccinio uliginosi- -Pinetum	8 230.0	115.1	9.4	54.8	44.5	19.5	2.3	9.3
	x	6 218.3	61.6	5.3	41.5	18.2	9.0	2.5	8.8
Mesotrophic	Caricetum elatae	2 325.0	29.3	. 3.9	42.7	8.4	3.1	0.7	0.8
	Typhetum latifoliae	15 446.0	142.9	20.6	229.5	186.9	55.0	37.3	13.2
	Salicetum pentandro- -cinereae*	16 844.0	232.5	36.0	193.1	121.4	29.3	6.7	30.5
	Carici elongatae- Alnetum	10 587.0	166.0	14.2	77.5	56.8	20.8	3.5	9.3
	x	11 283.0	142.7	18.7	135.7	93.4	27.1	12.1	13.5

*Values are a mean from 3 variants of this community.

Table 15. Nutrient consumption to a unit of produced dry wt (kg/t dry wt) in standing crop of plant communities

Sequence type	Name of plant community	N _{tot.}	P _{tot} .	K	Ca	Mg	Na	S-SO ₄
Dystrophic	Caricetum lasiocarpae	8.78	0.51	10.38	1.95	0.84	0.20	1.73
	Caricetum limosae	7.56	0.52	6.41	1.72	0.90	0.73	3.17
	Ledo-Sphagnetum magellanici	3.71	0.36	2.17	1.49	0.61	0.26	0.31
	Vaccinio uliginosi- -Pinetum	3.27	0.30	1.49	2.92	0.78	0.31	0.55
	\bar{x}	5.83	0.42	5.11	2.02	0.78	0.38	1.44
Mesotrophic	Caricetum elatae	12.92	1.77	17.95	4.92	1.39	0.31	0.44
	Typhetum latifoliae	9.19	1.32	14.79	12.12	3.55	2.42	0.84
	Salicetum pentandro- -cinereae*	2.86	0.42	2.20	2.89	0.65	0.20	0.50
	Carici elongatae- Alnetum	2.94	0.22	1.03	1.73	0.43	0.29	0.30
an outstyn		6.00	0.00	0.00	5.40	1.51	0.01	0.52



nities may be therefore regarded as very expansive in transformation of their habitats. They produced annually a huge amount of biomass (Fig. 5), rich in mineral components (Fig. 7), which, most likely, accelerated matter turnover.

Accumulation of nutrients and ash in primary production of communities of dystrophic sequence assumed more balanced values as compared to those estimated for mesotrophic sequence (Fig. 7). It may be stated that the amount of particular elements and ash increased along with growing values of primary production in both





succession sequences. This regularity was most evident in case of nitrogen, phosphorus and potassium. The elements notably deviating from this rule were sodium and sulphur (Table 14), which would suggest that mire vegetation absorbed them in a most selective manner.

Accumulation of mineral components in plants may also be expressed in terms of an amount of absorbed elements required for production of a certain mass unit (e.g. kg of nutrients/1 t dry wt). Also in this respect a mean content of elements and ash in 1 ton of biomass of plant communities was pronouncedly higher in mesotrophic

					94 54.8 44.3					
		6 2183	KXXXXXX							
	Caricettum cintar Typhotam D	2 325.0	29.3		М					
(kg/t)	-cincreac*	16 8440	232.5		193.4					
800 -	Almetum	19.3870	166.0		77					
		Site man	2375	Ø	1-2-1					




sequence, especially in case of calcium, phosphorus and sodium (Table 15). Only in case of sulphur an inverse tendency was observed, i.e. its mean content in 1 ton of biomass of plant communities was greater in dystrophic sequence, which would suggest that absorption of this element by mire vegetation was more intense at lower pH values. In case of treed plant communities, differences in accumulation of elements in 1 ton dry wt were very slight. It seemed to result from a levelling effect of a huge amount of tree phytomass (Fig. 8).

In dystrophic sequence accumulation of elements in 1 ton of plant community biomass was little diversified, especially in case of phosphorus and magnesium (Table 15). A noteworthy fact were slight differences in sulphur concentration in 1 ton of biomass of plant communities in mesotrophic sequence (Table 15). An extremely nutrient-abundant was 1 ton of biomass of Caricetum elatae and Typhetum latifoliae (Table 15, Fig. 8). In both sequences there were observed selective preference of particular plant communities towards certain elements, e.g. towards sodium and sulphur by Caricetum limosae and Typhetum latifoliae, towards nitrogen — by Caricetum elatae (Table 15), etc.

Subsequent analyses concerned element accumulations in 1 ton dry wt of primary production of the studied plant communities. Also in this respect the values estimated for plant communities of mesotrophic sequence were greater than those for dystrophic one. The only exception was the content of sulphur, which was already commented upon (Table 16). The content of nutrients in 1 ton dry wt of production was less diversified than their content in standing crop (Figs. 8, 9). It resulted from the fact that binding of mineral components in primary production occurs mainly in the herb layer and in tree leaves, and is not affected by tree stand (with exception for

Table 16. Nutrient consumption to a unit produced dry wt (kg/t dry wt) in primary production of plant communities

Sequence type	Name of plant community	N _{tot} .	P _{tot} .	K	Ca	Mg	Na	S-SO4
	Caricetum lasiocarpae	8.78	0.51	10.38	1.95	0.84	0.20	1.73
18.4 45.5	Caricetum limosae	7.78	0.58	7.04	1.70	1.00	0.72	3.14
Dystrophic	Ledo-Sphagnetum magellanici	7.50	0.87	4.54	1.58	1.06	0.42	0.45
	Vaccinio uliginosi- -Pinetum	13.99	1.14	6.66	5.41	2.37	0.28	1.13
0.0	\overline{x}	9.51	0.78	7.16	2.66	1.32	0.41	1.61
16.3 26.2	Caricetum elatae	12.60	1.68	18.37	3.61	* 1.33	0.30	0.34
N.2.1. 2.2.5	Typhetum latifoliae	9.25	1.33	14.86	12.10	3.56	2.41	0.85
Mesotrophic	Salicetum pentandro- -cinereae*	13.86	2.15	11.51	7.24	1.75	0.40	1.82
12,02 112,84	Carici elongatae- -Alnetum	15.68	1.34	7.32	5.37	1.96	0.33	0.88



*Values are a mean from 3 variants of this community.

the so-termed increment of ligneous substance). The amounts of elements in production dry wt unit were very similar in succession terminal communities, i.e. in alder wood fen and bog pinewood (Table 16). Particular plant communities were observed to differ in their selective absorbability of certain elements, e.g. of Caricetum limosae towards sodium, of Salicetum pentandro-cinereae towards sulphur (Table 16).

4.5.2. Indices of primary production efficiency

Index of production efficiency denotes the amount of kilograms of dry weight produced by a given plant community at absorption of 1 kilogram of a given nutrient.

It was noted that as compared to mesotrophic sequence, an average efficiency of production of plant communities in dystrophic sequence was greater, e.g. almost 3-times in case of calcium and over 2-times in case of phosphorus. Mesotrophic sequence was marked for a higher value of mean production efficiency only with respect to sulphur (Table 17). The communities of bog pinewood and alder wood fen, forming the last succession stages in respective sequences, had very similar values of production efficiency indices. In case of calcium, magnesium and sulphur production efficiency of bog pinewood was slightly smaller, whereas in case of the remaining elements - it was greater than that of alder wood fen.

The studies evidenced that as compared to mesotrophic sequence, plant

Table 17. Primary production efficiency of plant communities (kg dry wt/kg of nutrients)

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Sequence type	Name of plant community	N _{tot} .	P _{tot} .	K	Ca	Mg	Na	S-SO ₄	Nu- trients in total
2-304	Caricetum lasio- carpae	113.8	1969.5	96.3	511.6	1193.6	4923.8	579.3	41.0
	Caricetum limosae	128.5	1723.8	142.0	588.1	999.8	1388.6	318.4	45.5
Dystro- phic	Ledo-Sphagnetum magellanici	133.3	1150.0	220.1	631.6	939.6	2407.8	2201.4	60.9
1.13	Vaccinio uliginosi- -Pinetum	71.5	875.5	150.2	184.9	422.1	3578.3	884.9	32.3
10.1	x	111.8	1429.7	152.2	479.1	888.8	3074.6	996.0	44.9
100	Caricetum elatae	79.4	596.2	54.4	276.8	750.0	3321.4	2906.3	26.2
200	Typhetum latifoliae	108.1	749.8	67.3	82.6	280.8	414.1	1170.2	22.5
Mesotro- phic	Salicetum pentandro- -cinereae*	72.1	465.9	86.9	138.2	572.5	2503.6	550.0	25.8
88.0	Carici elongatae- Alnetum	63.8	745.6	136.6	186.4	509.0	3024.9	1138.4	30.4



communities of dystrophic sequence, poorly supplied in nutrients as they were, were able to produce more dry matter to a unit of absorbed nutrients. H e i n s e 1 m a n (1970) obtained analogical results for bryophytes.

4.5.3. Matter retention

The content of elements in 1 ton dry wt of ligneous substance (with bark) was examined in bog moss pine forest, bog pinewood, willow shrubberies and alder wood fen. The investigated parameter depicts matter retentability, i.e. abilities to build in elements in plant tissues for over a longer period of time.

There was observed a distinct tendency to a stronger matter retention in tree stands of dystrophic sequence, where mean content of almost all the examined nutrients in 1 ton dry wt of ligneous substance was greater. It primarily concerned ash, nitrogen and potassium and in the smallest degree – sodium (Table 18).

Table 18. Retention of mineral components in ligneous substance of certain plant communities (kg of elements/t dry wt of wood)

Analogical succes-	A	sh	N _{tot} .		P _{tot} .		K		Ca		Mg		Na		S-SO ₄	
sion stages in both sequences	D*	M**	D	M	D	M	D	M	D	M	D	M	D	M	D	M
III bog moss pine forest → willow shrubberies	9.3	5.2	3.0	1.3	0.3	0.2	1.8	0.9	1.4	2.4	0.5	0.5	0.2	0.2	0.3	0.3
IV bog pinewood \rightarrow alder wood fen	7.8	6.7	2.3	2.2	0.2	0.2	1.1	0.7	2.7	1.5	0.7	0.3	0.3	0.3	0.5	0.3
x	8.6	6.0	2.7	1.8	0.25	0.20	1.5	0.8	2.1	2.0	0.6	0.4	0.25	0.25	0.4	0.3

*D - Values for dystrophic sequence. **M - Values for mesotrophic sequence.

4.5.4. Models of nutrient transmission to matter turnover

It was presumed that the nutrient pool bound in primary production returned yearly to matter turnover. Exception to it were treed plant communities, where yearly production included herb layer production, tree leaves and increment of ligneous substance. In this case it was conjectured that matter subject to turnover comprised primary production of the whole community reduced by ligneous substance increment, as elements bound in this substance each year joined retained matter.

Quality and quantity of the pool of matter subject to turnover was different in the two sequences. A comparison was drawn of percentage contribution of turnover-subject elements with respect to their total amount bound in biomass of particular

plant	communitie	es. It wa	s noted	that a	mean	percentage	e contribution	1 of elements
yearly	entering	matter	cycling	was	always	larger i	in mesotroph	nic sequence
(Table	19). Both	the amo	ount of	yearly	turnov	er matter	$(\bar{x} = 8.53 t d$	ry wt/ha) as

Table 19. Comparison of element transfer to matter turnover in plant communities of the two succession sequences

		See and	% of a		% of	Amount					
Se- quence type	Name of plant community	Ash	N _{tot} .	P _{tot} .	K	Ca	Mg	Na	S-SO4	biomass yearly entering matter turnover	of matter yearly entering turnover (t dry wt/ha
	Caricetum lasiocarpae*	100	100	100	100	100	100	100	100	100	3.94
	Caricetum limosae	59.8	59.7	65.0	63.7	57.5	64.0	57.6	57.6	58.0	5.00
D	Ledo-Sphagnetum magellanici	13.3	14.4	17.7	14.9	6.7	12.3	10.9	10.1	6.2	6.14
	Vaccinio uliginosi- -Pinetum	21.3	24.8	21.9	25.8	9.5	16.9	3.9	10.7	4.2	5.70
and a	x	48.6	49.7	51.2	54.8	43.4	48.3	43.1	44.6	42.1	5.20
- 03 54	Caricetum elatae	74.1	77.0	75.0	80.8	58.0	76.2	73.8	62.5	78.9	233
Call of	Typhetum latifoliae	85.6	85.9	86.3	85.7	85.1	85.5	85.1	86.5	85.3	15.45
М	Salicetum pentandro- -cinereae	56.5	56.3	58.6	61.4	24.3	29.0	19.7	42.7	6.9	9.12
	Carici elongatae- -Alnetum	24.9	28.1	32.6	38.1	15.6	24.0	4.4	14.4	3.8	7.23
	x	60.3	61.8	63.1	66.5	45.8	53.7	45.8	51.5	43.7	8.53

*In case of this community all biomass was assumed to enter matter turnover.



well as its greater element content (as evidenced by percentage contribution of turnover elements as well as the content of elements in primary production discussed above) would suggest that matter management in mesotrophic sequence was more "wasteful". In dystrophic sequence matter management was more economic, aimed at matter retention and its smaller participation in cycling (the amount of mean yearly turnover matter amounted to $\bar{x} = 5.20$ t dry wt/ha and correspondingly smaller were the amounts of turnover elements; Table 19).

4.5.5. Models of functioning of plant communities in the two sequences

Summing up all the above-mentioned aspects of matter management in plant communities of the two sequences it may be concluded that ecological distinctiveness of the two sequences was definitely documented. Similar results were arrived at while employing to analyses a nonparametric statistical test, i.e. the so-termed sign test (Siegel 1956). The test showed that for most examined parameters there occurred significant differences in their mean values for dystrophic and mesotrophic sequence (Table 20). A negative value was reckoned only for nutrient consumption calculated to a produced dry matter unit in regard to standing crop of plant communities. The values estimated for the two sequences were similar in this respect, due to a levelling effect of treed communities (two in each sequence). Ligneous substance constituting a greater part of phytomass in these communities was hardly variable in its chemical composition, while possible differences were likely to have been additionally levelled out by differences in amounts of produced biomass. In general the test confirmed distinct character of the studied succession sequences with respect to a majority of their examined features, and, moreover, it proved that vegetation of mesotrophic sequence was trophically more abundant and its matter management was more "wasteful", as mean values of particular parameters were higher in this sequence (Table 20).

Table 20. Distinctiveness of the two succession sequences revealed by nonparametric statistical test, i.e. the sign test

Analyzed features	Sign number	Test value Z	p
Accumulation of mineral components in standing crop of the examined plant communities (kg/ha)	$+ \rightarrow 7$ $- \rightarrow 29$	- 3.500	≤0.00023
Accumulation of mineral components in primary production of the examined plant communities (kg/ha)	$+ \rightarrow 7$ $- \rightarrow 28$	- 3.381	< 0.0004
Nutrient consumption to a unit of produced dry matter (kg/t dry wt) in standing crop of plant communities	$\begin{array}{c} + \rightarrow 13 \\ - \rightarrow 19 \end{array}$	-0.884	>0.189*
Nutrient consumption to a unit of produced dry matter (kg/t dry wt) in primary production of plant communities)	$+ \rightarrow 4$ $- \rightarrow 25$	-3.714	< 0.00011
	10		





Regularities discussed above resulted in utterly different models of functioning of plant communities in the two succession sequences (Fig. 10). Mesotrophic sequence turned out to be trophically more abundant. Both plant productivity as well as accumulation of elements in phytocoenoses was greater there. However, this sequence was noted for a smaller primary production efficiency and smaller matter retention. In effect matter management in mesotrophic sequence was less economic and more wasteful. Not only the amount of turnover matter was greater but also it was qualitatively richer. On the other hand, in dystrophic sequence all the discussed trends took an inverse course (Fig. 10). The consequence of such a functioning of plant communities in the two sequences, was a different rate of matter cycling: more rapid in mesotrophic sequence.

It was observed, moreover, that dystrophic sequence had a smaller amplitude of changes, i.e. the intervals of the value range of the studied parameters were smaller. Differences in mean values of the examined parameters for particular succession stages were smaller in this sequence than in mesotrophic one, due to very specific and extremely severe habitat conditions (a very low pH value in particular), considerably restricting variability of particular features. Such circumstances entirely excluded occurrence of plants which could not sustain habitat pressure and, consequently, resulted in smaller species diversity. Furthermore, the smaller amplitude of changes was primarily the result of ombrotrophism. In mesotrophic sequence, where element management was minerotrophic the discussed trends took an inverse course (Fig. 10).

4.6. REGULARITIES ISSUING FROM SUCCESSION COURSE IN THE TWO PLANT SEQUENCES

The course of succession in the two sequences was much alike. There was observed, only, a likely antiphase, i.e. mesotrophic sequence was trophically more abundant as compared to dystrophic one (Fig. 11). Regularities, however, were analogical in both.

According to O d u m (1977), ecosystems subject to succession-due development undergo numerous changes, both in their structural and functional features. The author stated as many as 24 parameters modified in the course of succession. Some of them were analyzed below.

The measure of advancing succession may be the percentage contribution of primary production of plant communities in their standing crop, or the ratio of standing crop to respective primary production (B/P). In the examined sequences there was recorded a decrease in percentage contribution of production to total standing crop occurring in advancing succession, namely, from 100% in initial stages down to barely 6.1% in dystrophic sequence and to 5.5% in mesotrophic sequence. On the other hand, B/P index rose from ± 1.0 in initial stages up to more than 10 in final stages, i.e. to 16.42 in dystrophic sequence and to 18.15 in mesotrophic sequence

(Tables 10, 11). The data evidenced supervention within succession sequences from
poorly organized phases to mature final stages. The two parameters in question
reflected the rate of capturing, i.e. retention of matter in biocoenoses, and thus



indicated a gradual closing of mineral cycles and slowing down of the rate of nutrient exchange between plants and the habitat.

Further consequence of the process was alternation of nutrient status from extrabiotic to intrabiotic one (for prolongedly built-in in plant tissues), which resulted, in turn, in the fact that retention of nutrients – poor at initial stages – became stronger in the final ones. An outcome of these modifications was a greater stability and total homeostasis coupled with progressing succession.

Biocoenosis structure was also subject to evolutions, as manifested, among others, by a small amount of total organic matter at initial stages mightily increasing in the final ones. An index of this feature assumed in the present studies was the amount of biomass increasing with advancing succession (Fig. 4, Fig. 11). Obviously the values for mesotrophic sequence were higher than in dystrophic one (Tables 10, 11).

Another parameter subject to changes was the layer structure and spatial heterogeneity, proceeding from poorly to highly organized. It was best marked in the present studies, as initial stages of succession sequences were made up of one layer only, i.e. of herbaceous plants (with admixture of bryophytes in places), while final stages had a complex, multilayer structure (the layer of herbs, bryophytes, shrubs, trees).

There was recorded a decreasing percentage contribution of herbaceous plants in standing crop of plant communities paralelling succession, namely, from 100% at initial stages down do 3.1% in dystrophic and 1.7% in mesotrophic sequence at their final stages (Tables 10, 11). It was a logical consequence of all the regularities stated above, and, primarily, of a tendency of ecosystems to increase matter accumulation (Fig. 11), i.e. its retention in perennial tissues.

Moreover, along with the proceeding succession there was recorded an increase in the output of primary production of plant communities, on the understanding that in dystrophic sequence the course of changes was rising, while in mesotrophic sequence the top values fell in the initial and intermediate stages, with a drop in the final one. An alike productivity course following succession was observed by other authors as well (Sharpe 1975). It would seem that standing crop was likely to increase along with the proceeding succession (Fig. 11), whereas in case of primary production this tendency was not so very distinct. In habitats of small amplitude of changing parameters, the tendency would be upward, whereas in habitats of wide amplitude the above situation would be likely to occur, i.e. the value of primary production may be lower in final phase than in certain preceeding stages (Fig. 11). While analyzing a hypothetical matter turnover in both sequences, i.e. disregarding increment of ligneous substance, it turned out that the tendency in question took the following course: after it proceeded upwardly in initial succession stages then it distinctly dropped down in communities forming the final succession stage. The decline was most abrupt (following a step course) in mesotrophic sequence, while in dystrophic sequence it was even and moderate (Fig. 5). Accumulation of mineral components, expressed in quantity-to-area units, i.e. kg/ha, increased according to succession course. The growth was particularly

clear-cut in standing crop of plant communities of dystrophic sequence (Fig. 6, Fig. 11). However, with respect to primary production values of the examined parameter varied in both sequences. In dystrophic sequence these variances were slight, while in mesotrophic sequence — notably greater. In bog pinewood and alder wood fen i.e. at final succession stages, the values were fairly levelled out (Fig. 7). Furthermore, advancing succession was also accompanied by a decrease in the content of mineral components in 1 ton dry weight plant communities in the two sequences. It was a logical consequence of growing complexity and heterogeneity of biocoenoses (layer structure, a larger number of species). It was best seen while analyzing standing crop of the two sequences (Fig. 11) and primary production in mesotrophic sequence; it was less distinctly shown by primary production of phytocoenoses of dystrophic sequence (Fig. 11). The content of ash and nutrients yearly joining matter turnover decreased gradually along with advancing succession, namely, from 100% at initial stages down to less than 10% at the final ones (Table 19).

A noteworthy fact is that the two examined plant sequences, although differing in their trophic abundance, reached functionally most alike final stages, as evidenced, e.g. by a percentage contribution of primary production to total standing crop, namely 6.1% in bog pinewood and 5.5% in alder wood fen. In general, along with proceeding succession most of the examined parameters assumed approximate values in bog pinewood and alder wood fen (e.g. accumulation of mineral components in biomass and primary production expressed both in kg/ha and kg/l t dry wt, percentage contribution of ash and nutrient yearly joining matter turnover, production efficiency index, etc.). It seems that a mechanism responsible for that was a different functioning of plant communities in the two sequences, and, primarily, diverse primary production efficiency (Fig. 10). The observed convergence was an effect of similar environment pressure in the form of analogical climate and habitat factors (peat bedding). Bog pinewood and alder wood fen may be interpreted as a functionally convergent edaphic climax of the two succession sequences. It should be noted, moreover, that general regularities in the course of succession were more distinct with respect to biomass of the studied plant communities (Fig. 11). It is well justified as both the produced biomass and succession are additional effects of long-lasting processes (especially in case of intermediate and final succession stages). In case of primary production spanning a year period, general trends were disturbed by fluctuations of features at particular succession stages, which was caused by an annual resultant of varying environment parameters.

4.7. MIRE VEGETATION IN AGRICULTURAL LANDSCAPE

A majority (95%) of the examined 285 hollows without run-off was located on areas under agricultural use (K l o s s et al. 1987). The mires occurring in these

White multiving a hypothesical matter turnover in both sequences, i.e. disregarding

hollows, along with overgrowing vegetation, are generally classified as wasteland. For a long time there has been a tendency to cultivate and transform this type of habitats. In Masurian Lakeland over 80% of total peatland area has been drained

(O 1 k o w s k i 1972). In case of hollows without run-off only 4.6% area of all the mires occurring on their bottom were drained effectively enough to function as grasslands nowadays. As to the rest, drainage was neglected or, being too costly, was not even undertaken. The reason of this state of affairs was the fact that 87.7% of all the examined mires on the study site, had a very tiny area of less than 1.0 ha (K 1 o s s et al. 1987). Besides plowland and grassland, mires constituted as integral part of local agricultural landscape. All the elements made up a mosaic spatial structure of the region.

Biomass and chemical composition of these diverse, co-occurring phytocoenoses were compared. Vegetation was divided into two basic groups: I. crop plants of economic use, i.e. cereals, root and industrial crops, meadows and pastures (data from the works by C z e r w i n s k i et al. 1985a, 1985b, T r a c z y k 1985), and II. mire vegetation of hollows with no run-off, i.e. reeds, *Carex* fens, transition bogs and forests, shrubberies on peat, i.e. alder wood fens, willow shrubberies, bog moss pine forests, bog pinewoods (Table 21). The data in Table 21 were, on the whole, means for particular agrophytocoenoses or mire phytocoenoses. The order of standing crop communities in diminishing gradient was as follows:

forests and shrubberies on peat \rightarrow meadows and pastures \rightarrow reeds \rightarrow root and industrial crops \rightarrow cereals \rightarrow transition bogs \rightarrow Carex fens

Comparison of total nutrient accumulation in the distinguished vegetation types produced the same order, hence nutrient accumulation was closely related to biomass of the examined plant communities (Table 21). Analyses of particular nutrient binding revealed that the investigated process was selective in its nature and quantitatively differentiated depending on phytocoenosis (Table 21).

The parameter which even better reflected selective properties of particular communities was the content of elements expressed in % dry weight (Table 21). It turned out that forests and shrubberies on peat, although producing a huge amount of phytomass, yet did not rank among the most elements-abundant communities. The order of communities according to a diminishing total nutrient content was as follows:

root crops = meadows and pastures \rightarrow reeds \rightarrow *Carex* fens \rightarrow transition bogs \rightarrow cereals \rightarrow forests and shrubberies on peat

After a close analysis of element content (in % dry wt) in plant communities it was ascertained that the following elements were absorbed most selectively by the distinguished communities: nitrogen – by meadows and pastures, *Carex* fens, root and industrial plants; phosphorus – by meadows and pastures, root and industrial plants, *Carex* fens and reeds; potassium – by *Carex* fens, root and industrial plants and reeds; calcium and magnesium – by reeds, meadows and pastures; sodium – by reeds, root and industrial plants; sulphur – by transition bogs (Table 21).

Actual binding of elements by trees was best reflected by the nutrient content in leaves (Table 21). It appeared that also forests and shrubberies on peat had their significant share in depleting of habitat nutritive resources. It was most evident in case of nitrogen, calcium and magnesium. Trees were also noted to betray selective species properties. Large amounts of nutrients were contained in leaves of willow

	Biomass	inter i	Nutrie	ent acc	umulati	on in	on in biomass (kg/ha)				Nutrient content in plant dry wt (%)							
Vegetation type	kg dry wt/ha	N _{tot.}	P _{tot.}	K	Ca	Mg	Na	S-SO ₄	Total nutrients	N _{tot.}	P _{tot} .	K	Ca	Mg	Na	S-SO4	Total nutrien	
言言語なる	3 9 9	- Hard			I. (Crop p	lants o	of econ	omic use*		0.0						E d	
Cereals	11 569.0	87.0	10.0	102.0	16.0	7.0	3.0	7.0	235.0	0.75	0.09	0.88	0.14	0.06	0.03	0.06	2.03	
Root and industrial plants	13 386.0	157.0	31.0	240.0	77.0	26.0	26.0	25.0	627.0	1.17	0.23	1.79	0.58	0.19	0.19	0.19	4.68	
Meadows and pastures	21 336.0	360.0	63.0	236.0	217.0	49.0	17.0	40.0	983.0	1.69	0.30	1.11	1.02	0.23	0.08	0.19	4.61	
	- BOS	Value a	pa	I	I. Mire	veget	ation of	of no-o	utflow hol	lows		100		a lo	-		E.F	
Transition bogs	6281.6	49.9	3.3	48.1	11.3	5.6	3.6	17.1	138.9	0.79	0.05	0.77	0.18	0.09	0.06	0.27	2.21	
Carex fens = sedge marshes	2945.6	38.0	5.2	52.9	14.5	4.1	0.9	1.3	116.9	1.29	0.18	1.80	0.49	0.14	0.03	0.04	3.97	
Reeds	18114.0	166.4	23.9	267.9	219.9	64.3	43.8	15.3	801.2	0.92	0.13	1.48	1.21	0.35	0.24	0.08	4.42	
Forests and shrubberies on peat	139 578.0	437.8	43.4	226.1	313.6	83.4	37.5	57.2	1199.0	0.31	0.03	0.16	0.22	0.06	0.03	0.04	0.86	
Mean for pine, birch and alder leaves	3 6 8 3 . 3	66.4	5.5	24.5	26.4	10.4	1.3	3.7	138.2	1.84	0.15	0.37	0.72	0.29	0.03	0.10	3.50	
Willow leaves	8470.0	196.5	29.5	158.2	87.4	21.8	4.3	25.4	523.1	2.32	0.35	1.87	1.03	0.26	0.05	0.30	6.18	

*Data on nutrient accumulation in crop plants were taken from the paper by Traczyk 1985 and Czerwiński et al. 1985a, 1985b.

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Table 21. Valorization of mire vegetation in hollows with no run-off in agricultural landscape



(Table 21). As compared to all the examined vegetation groups, willow accumulated (in leaves) the greatest amount of: nitrogen, phosphorus, potassium, sulphur and nutrients in total. Hence it turned out that willow was a "voracious" species.

On the basis of the conducted analysis it may be concluded that vegetation of hollows with no run-off, and especially willow shrubberies on peat, reeds, and, to a smaller extent, also *Carex* fens, could sometimes accumulate larger quantities of elements than man-aided (in the form of fertilizers, pesticides, etc.) crop plants. This is an indirect outcome of man's activity, as his various agrotechnical treatments eventually diminish the so-termed environmental capacity of agroecosystems with respect to the introduced chemical substances (R y s z k o w s k i 1979).

Nutrients which are not captured by agrophytocoenoses and sorptive complex of soil are likely to "feed" natural vegetation. In case of vegetation of hollows without run-off this is of upmost importance. The vegetation in question overgrows mires occurring on the hollows' bottom, which lack any surface outflow. Therefore the mires occurring amidst plowlands must be under an immense eutrophic pressure of their agricultural catchment areas. With this in mind, an analysis was conducted aimed at ordering of various types of mires overgrowing communities from the most to the least eutrophication-exposed, with respect mire area characteristics and mean percentage contribution of the mire area to the area of the no-out-flow hollow where

it was located. The established order was as follows: ponds \rightarrow reeds and *Carex* fens = willow shrubberies \rightarrow alder wood fens \rightarrow transition and raised bogs with bog pinewoods (K l o s s et al. 1987).

The presented order of types of mire overgrowing and data on their chemical valorization were noted to be related. As it was already mentioned above, willow shrubberies and reeds (and also Carex fens in regard to some elements) were recorded to accumulate the greatest amounts of nutrients, considerably surpassing, in this respect, most field crops and grasslands. The observed effect was totally free of any cost on the part of man, as mire vegetation simply made use of surplus nutrients inflowing from adjacent mineral lands. Quite interesting was the comparison of the amount of elements thus reaching the mires to the quantity of nutrients accumulated in mire vegetation. For this reason the amount of elements yearly inflowing to 1 hectare of mire was compared to the nutrient content in primary production of mire plant communities. Furthermore it was estimated in percentage contribution how much of the pool of mire-inflowing nutrients could have been potentially accumulated by plants in their primary production (Tables 22, 23). As it was stated above, there were multiple differences in the quantities of nutrients inflowing to mires of dystrophic and mesotrophic sequence (Table 9). Also multiple differences were recorded in the amounts of nutrients accumulated in production of mire plant communities of the two sequences (Table 14).

In dystrophic sequence the pool of inflowing nutrients was smaller than the amount of nutrients accumulated in primary production of plants. Nutritive requirements of mire vegetation were by far greater. If the input of elements from

catchment area was assumed as 100%, then vegetation of dystrophic sequence

accumulated over 3.5 times more of nitrogen, 18.8 times more of phosphorus 11.5

Table 22. Potential capabilities of plant communities of dystrophic sequence to accumulate elements inflowing to the mire $(kg \cdot ha^{-1} \cdot yr^{-1})$

Analyzed parameter	N _{tot} .	P _{tot} .	K	Ca	Mg	Na	S-SO ₄
Pool of elements inflowing to 1 ha of mire	17.70	0.28	3.60	7.68	1.17	7.41	8.38
Mean accumulation of elements in primary production of plant communities in dystrophic sequence	61.60	5.25	41.48	18.23	9.00	2.48	8.83
Mean % of inflowing element pool contained in primary production of plant communities	348	1875	1152	237	769	34	105
Range of values of % inflowing element pool in primary production of plant communities	196÷650	714÷3357	972÷1522	100÷579	282÷1667	11÷49	42÷187

50

The medented order of types of mire overgrowing and dath on their chemical

Table 23. Potential capabilities of plant communities of mesotrophic sequence to accumulate elements inflowing to the mire $(kg \cdot ha^{-1} \cdot yr^{-1})$

Analyzed parameter	N _{tot} .	P _{tot} .	K	Ca	Mg	Na	S-SO ₄
Pool of elements inflowing to 1 ha of mire	49.05	1.41	7.68	630.15	70.34	71.33	125.98
Mean accumulation of elements in primary production of plant communites in meso- trophic sequence	142.68	18.68	135.70	93.38	27.05	12.05	13.45
Mean % of inflowing element pool contained in primary production of plant communities	291	1325	1767	15	38	17	above, avb lo b-11ber mmos
Range of values of % inflowing element pool	100 . 112	1012 . 2229	1022 . 22/0	0 10	21 50	6 22	7.00



times more of potassium, 2.4 times more of calcium, 7.7 times more of magnesium (Table 22). Only sodium was supplied in excess, as plants could use up merely 1/3 (34%) of the load inflowing from catchment area. The percentage amount of nutrients accumulated in annual production in relation to the pool of watershed load varied depending on the type of plant community (different biomasses and nutrient accumulation abilities). The values of the examined parameter ranged within a wide interval. It was also noted that the amount of sulphur inflowing from catchment area might sometimes surpass actual needs of certain plant communities of dystrophic sequence (Table 22). The upper limit values of the examined parameter were frequently recorded for bog pinewood and bog moss pine forest. These communities were potentially most capable of capturing the inflowing elements.

In general it may be ascertained that in dystrophic sequence watershed load only partly met nutritional requirements of vegetation (except for sodium and, sometimes, sulphur). It should be emphasized that on the landscape scale, both the amount of element input from catchment area as well as nutritive requirements of vegetation were rather small in case of dystrophic sequence, due to ombrogenic type of mire supply.

Plant communities of mesotrophic sequence received from their catchment areas about 2.9 times less of nitrogen, 13.3 times less of phosphorus and 17.7 times less of potassium with respect to their requirements (Table 23). The other elements under studies were provided in excess. Out of the received watersheed load pool, helophytes could potentially bind only 38% of magnesium, 17% of sodium, 15% of calcium and 11% of sulphur. Also in this case potential nutrient interception abilities of plants, expressed in terms of a percentage ratio of elements accumulated in primary production to the inflowing element watershed load, differed depending on the type of plant community and intensity of catchment area pressure (Table 8), which restricted the quantity of the examined pool (soligenic type of mire supply). Willow shrubberies were recorded to assume the highest values of the parameter under studies for nitrogen, phosphorus, potassium and sulphur, while reeds and Carex fens - for magnesium, sodium, and, close to the highest - for potassium. Hence it was observed that mire vegetation of mesotrophic sequence might potentially have any significance in binding of the pool of inflowing phosphorus, potassium and nitrogen. Vegetation demand for nitrogen, phosphorus and potassium, both in dystrophic and mesotrophic sequence, was catered for by catchment area in alike proportions. In both cases watershed load did not satisfy nutritive requirements of plants, as they accumulated many times greater amounts of these elements in their primary production, namely, from 2.9 to 3.5 times more of nitrogen, from 13.3 to 18.8 times more of phosphorus, and from 11.5 to 17.7 times more of potassium (Tables 22, 23). Even considering the fact that initial balance data (see chapter 4.3) may have been underrated (in case of phosphorus in particular) it could not be possibly questioned that the pool P, increased by the amount of elements reaching the mires in effect of fertilization, etc., may be potentially captured by mire vegetation.



recorded in their studies that release of nutrients from decayed plant residues took

Table 24. Potential capabilities of treed plant communities to ligneous

Diant communities	N _{tot} .		P _{tot} .		K		Ca		Mg		Na		S-SO ₄	
Plant communities	R	%	R	%	R	%	R	%	R	%	R	%	R	%
Ledo-Sphagnetum magellanici	0.90	5.1	0.02	7.1	0.45	12.5	1.13	14.7	0.34	29.1	0.28	3.8	0.31	3.7
Vaccinio uliginosi-Pinetum	1.65	9.3	0.10	35.7	1.05	29.2	5.46	71.1	1.18	100.9	0.70	9.5	1.15	13.7
Salicetum pendandro-cinereae	7.38	14.0	0.96	62.3	4.92	60.4	13.53	1.9	3.01	3.8	1.05	1.3	1.85	1.3
Carici elongatae-Alnetum	4.98	10.4	0.25	18.3	1.40	18.6	4.04	0.7	0.93	1.4	0.93	1.3	0.81	0.7

R - the amount of elements annually retained in ligneous substance. % - Percentage contribution of the amount of "immobilized" elements in retained matter in relation to the pool of nutrients inflowing to 1 ha of a given mire in annual balance.

)	retain	elements	(in	$kg \cdot ha^{-1}$	$\cdot yr^{-1}$)	inflowing	to	a	given	mire	in
S	substa	ance									



sometimes place after a period shorter than a year. Under these circumstances attention should be paid to treed plant communities, in which a part of nutrients is yearly deposited in wood. Table 24 presents capabilities of the analyzed plant communities in this aspect. The greatest amount of nutrients was noted to be retained by willow. Out of the pool of nutrients inflowing to mires, willow retained in its wood 14.0% of nitrogen, 62.3% of phosphorus, 60.4% of potassium (Table 24). Retention of the other mineral components was slight, ranging from 1.3 to 3.8% (Table 24). Willow shrubberies accounted for almost a half of the examined mire plant communities on the studied area (Table 8). Salix cinerea, the species predominantly making up these communities, possesses a number of physiological properties predisposing it to enormous dynamism and expansion in occupying more and more new stands (J e n i k 1983, R u s a 1 e n k o 1983).

Summing up it should be stated that mire vegetation of the two sequences was potentially capable of accumulating catchment area load of NPK (as well as of Ca, Mg, $S-SO_4$ – in case of plant communities of dystrophic sequence). The issue, however, should be further investigated. The data presented in the work do not give grounds for drawing any ultimate conclusions as to the function of mire vegetation in agricultural landscape.

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5. DISCUSSION

Chemical properties of mire vegetation has not been examined thoroughly enough; in particular there are hardly any empirical studies which would compare chemical composition of bog and fen plants. According to I n g r a m (1967) vegetation of ombrogenically supplied peatbogs must be of oligotrophic nature, as accumulation of mineral components from rain water is by far slower than in case of other sources of water supply to mires. W a u g h m a n (1980) recorded greater contents of K, Ca, Mg and N in fen vegetation, yet concentration of heavy elements, i.e. Mn_{tot.}, Fe_{tot.}, Pb, Cd and Al_{tot.} was the highest in plants growing on raised bogs. G o b a t (1984) juxtaposed acidophilous plants growing in nutrient-poor sites and of relatively low nutrient content to nutrient-abundant vegetation of fens.

Comparative studies of this type have not been conducted in Poland. There are only works dealing with chemical composition of mostly fen vegetation, mainly concerning microelement content (L i w s k i 1961, W a l c z y n a, K u c z y ńs k a and S a p e k 1976, O ś w i t and S a p e k 1982, O ś w i t and S a p e k 1983). Only M a c i a k (1963) compared the content of mineral nitrogen in vegetation of raised bogs and fens — to the advantage of the latter.

The data produced in the present work corroborated the results arrived at by the authors quoted above, namely, a higher content of ash, $N_{tot.}$, K, Ca, Mg, but also additionally of Na and $P_{tot.}$ and $S - SO_4$ at significance limit, in plant communities of mesotrophic sequence (fens). Although empirical studies on chemical composition of fen and bog vegetation

are very scarce, nonetheless all of them were unequivocal in noting an unquestion-

ably greater nutrient-abundance of biomass of fen vegetation. However the content of elements in fen and bog water is a highly controversial issue.

The least questioned index of trophic status of fen and bog water is total mineralization of water. According to L a r g i n (1976) total mineralization of water in ombrogenically supplied peatlands may range from 8 to 45 mg/l, while water pH - from 3.5 to 5.9. The results of the present studies were analogical in regard to the first parameter, namely, from 17.3 to 34 mg/l, and higher in case of water pH, i.e. from 4.4 to 7.1 (but including also transition bogs). According to the quoted author, total mineralization of water of eutrophic peatlands, i.e. of fens, in European part of the Soviet Union varied from 60 to 500 mg/l, while water pH - from 5.3 to 7.1. Similar values were estimated for the studied mires of mesotrophic sequence, with the maximal value amounting to 135.4 mg/l, i.e. approximating the lower limit of the quoted value interval, which was the consequence of mesotrophism of the examined habitats (Table 4).

Distinctiveness of chemical composition of fen and bog water is very well indicated by the content of Ca in water (K i v i n e n 1933), which also became apparent in the results of the present studies. G o r h a m and P e a r s a 11 (1956) observed that in case of water sampled from raised bogs, pH was very low (pH = 4.0-4.4) and Ca content usually did not exceed 2 mg/l, while in water

sampled from fens the calcium content was greater, i.e. over 5 mg/l. The authors, however, doubted if Ca concentration could be regarded as the sole criterion of development of raised bogs and hinted that water content in peat was equally important. It seems that the amount of Ca may not be the only factor conducing the division of peatlands into two categories, yet a very significant one. This point of view was discreetly shared by other authors, who noted that fen water contained greater amounts of calcium salts (Maksimow 1965), or that peatmosses (Sphagnum sp.) avoided the presence of Ca (Strasburger 1967), while being an ever-present structural element of raised bogs. Also meticulous studies by Pietsch (1976), which were carried out on 490 peatlands in northern Czechoslovakia, Poland and western part of the Soviet Union, revealed that water of raised and transition bogs was poor in Ca and CO₃, and rich in SO₄ ions, whereas water of fens abounded in Ca and CO₃ ions and was poor in SO₄. Present results cooroborated these records, for, besides the limiting Ca content discussed above, also a greater content of SO₄ was noted in mire water of dystrophic sequence (raised bogs), though the differences were not statistically significant.

Quite disputable are interpretations concerning the content of other elements in water of raised bogs and fens. The issue beyond all controversy is that both pH and the content of Ca and Mg in water as well as in peat, is higher in fens and lower in raised bogs (e.g. H e i n s e 1 m a n 1970, W a u g h m a n 1980), which also was recorded during the present studies. As to the other elements, the authors not only are discordant but also their findings are frequently contradictory. It cannot be

precluded that water (or peat) of raised bogs may sometimes have a greater con	itent
of such elements as: N _{tot} , N-NH ₄ , P-PO ₄ , SO ₄ , Mn, Pb and B (L i w s k i 1	961,
Maciak 1963, Pietsch 1976, Tolonen and Seppänen 1	976,

V i r r i 1976, W a u g h m a n 1980, O ś w i t 1984). In the present work there were recorded higher concentrations of Zn, Fe, Na, Mn, and, less significant, of K, SO_4 , PO_4 , $N-NH_4$, $N-NO_3$ in water of mires of dystrophic sequence. A likely reason of an increased content of Na, Zn and $N-NH_4$ in mire water of dystrophic sequence may be a greater than elsewhere in Poland inflow of these elements from atmosphere in this part of the Masurian Lakeland (S t a c h u r s k i and Z i m-k a 1984, 1985).

The results obtained in the present studies confirmed distinctiveness of chemical composition of water in mires of dystrophic and mesotrophic sequence, as well as recorded such values of total mineralization, Ca and Mg content and pH, which allowed for regarding these parameters as determining development of a definite type of vegetation. As to the remaining elements, only detailed balance examinations with respect to catchment areas may elucidate this issue sufficiently enough. Estimates of the pool of nutrients yearly inflowing to mires of dystrophic and mesotrophic sequence pointed to a greater nutrient-abundance of habitats in mesotrophic sequence with respect to all the examined elements. However this was confirmed by analyses of surface water and results obtained by other authors, only in case of Ca, Mg, pH and total mineralization. Higher concentrations of other nutrients, sometimes recorded in water of raised bogs are likely to be brought about by seasonal dynamics, i.e. a more rapid or slower rate of absorption of nutrients by vegetation, microflora, etc., by seasonal changes in solubility of certain compounds as well as by the fact that in these mires stagnating water occurs, while in mires of mesotrophic sequence – flowing ground water, etc. The present data on biomass and primary production of helophytes corresponded to those estimated by other authors (Table 25), and, especially, to the ones obtained in the same climatic zone. It may be broadly stated that the amounts of produced biomass and primary production were recorded to differ notably. It may have been brought about be a whole complex of factors, such as: climatic zone, species composition of phytocoenoses and density of particular specimens, mineral and water status of the habitat, photosynthetic efficiency of plants, etc. Computer--aided productivity models were worked out (Lieth 1975, Sharpe 1975), which considered data concerning biomass, production as well as such climatic factors as annual precipitation, mean annual temperature, evapotranspiration, the length of vegetative season. The present studies assumed that matter entering turnover was mostly made up of the current year's production (except for treed communities, where it was diminished by the increment of ligneous substance). Analogical supposition was put forward by Bazilewicz and Rodin (1976), who, in order to assess geochemical activity of live matter in dynamic aspect, coined a notion of "efficiency of biological cycle", i.e. the amount (in kg/ha) of elements yearly absorbed by plant formations. This way of reasoning may be questioned, especially in regard to dead



Plant association or species	Productivity (kg/ha)		9 Gollewolli 9	Opposite and participate to	
	Standing crop	Primary production	Study site	Author	
egard to the first	t paramete	I. Dystrop	hic sequence	34 mg/l, and REEON PREFSS	
Carex lasiocarpa	5100		England	Pearsall and Gorham 1956	
Scheuchzerio- -Caricetum limosae	7560	4860	north-western Poland	Rieley 1981	
Sphagnum spp.	istering inter	500÷16600	Great Britain	According to numerous authors; quoted after Bradbury and Grace 1983	
S. spp.	2300÷9600	oli autorioi	England	Pearsall and Gorham 1956	
S. spp.	isther an	3000÷4000	Great Britain	Clymo 1970b	
S. magellanicum	Bringuene v	1045 ± 228	Sweden	Damman 1978	
S. fuscum	loganos finis	933 ± 174	Sweden	Damman 1978	
S. fuscum	ns that the	2690	England	Bellamy and Rieley 1967	
Vaccinio uliginosi- -Pinetum → herb layer		911.1÷1424.1	Poland	Klimsa 1980	
Vaccinio uliginosi- -Pinetum → herb layer	1692.7	1037.5	Poland	Moszyńska 1970	
Vaccinio uliginosi- -Pinetum → herb layer	3015÷8615	2505÷4360	north-western Poland	Rieley 1981	
in and chieven bound	nevdillerman	II. Mesotro	phic sequence	The present studies deliver	
Carex elata	litantanida 185 hadgistas	3370÷5480	southern Sweden	Mörnsjo 1969 (after Bradbury and Grace 1983)	
Typha latifolia	on Swhoel as	24 560	U.S.A.	Klopatek 1975	
T. latifolia	10 700	mshi20 (ad	England	Pearsall and Gorham 1956	
100 - 10 - 10 - 10 - 10 - 21	C. C	- denterrowith a	ALL FROM SHIP	CARRIER CO. C.	



cd. tab. 25

Plant association or species	Productivity (kg/ha)		in the state state	indiana and a second
	Standing crop	Primary production	Study site	Author
T. latifolia	2150÷9540	3300÷4180	U.S.A.	McNaughton 1966
T. angustifolia	10 000÷25 000	ales estoral-	Czechoslovakia	Dykyjova and Kvet 1982
Salici-Franguletum → herb layer	2496.7	idan SSE nan	north-eastern Poland	Polakowski and Endler 1985
Carici elongatae- -Alnetum → herb layer	1050.0	ent m the	Poland	H. Traczyk and T. Traczyk 1967
Carici elongatae- -Alnetum → herb layer	557.0		Poland	Traczyk 1967b
Carici elongatae- -Alnetum → herb layer	3328.6		Poland	Polakowski and Endler 1985

Table 26. The share of dead trunks and withered branches in the canopy layer of live trees (literature data)

Tree species	% share of dead matter in the canopy		Author		
Pinus silvestris	22 33 40 44 45 55	$11.5 \\ 6.48 \\ 4.0 - 4.43 \\ 4.2 \\ 4.35 \\ 5.82 - 5.97$	Utkin et al. 1980 Ovington and Madgwick 1959a Utkin and Ermolova 1979 Holmen 1964 Mälkönen 1975 Utkin et al. 1981		
Betula pubescens	40 55	0.42 1.04	Mälkönen 1977 Ovington and Madgwick 1959b		

up 1-6% of treestand aboveground phytomass (Table 26). Obviously, with respect to immense biomass of treestands, their quantity was not small (Tables 10, 11). However, when chemical composition of dead and live branches was compared it turned out that actual input of nutrients thus entering the pool of cycling matter was by far smaller (Table 27 on the basis of data after M ä l k ö n e n 1975, 1977). It should be moreover remembered that all the decayed part of treestand does not enter biogeochemical cycles in the very same year, but the process may continue for over



Table 27. Comparison of chemical composition of live and withered tree branches, after literature data (M ä l k ö n e n 1975, 1977)

Tree species H	Kind of	Nutrient content in kg dry wt/ha				
	branches	N	Poor	K	Ca	
Birch	withered live	0.67 33.72	0.04 4.38	0.09 13.73	0.73 36.55	
Pine	withered live	3.70 29.22	0.20 3.22	0.44 12.00	1.98 15.93	

When dynamic aspects of the examined phytocoenoses had been taken into account, distinctiveness of matter management in the two sequences would be even more distinct, which may be concluded on the basis of findings by Stachurski and Zimka (1975a, 1975b, 1976). The authors evidenced that the more rapid was the rate of matter decomposition, the greater was leaf fall in treestands, and, in consequence, the more rapid was the rate of nutrient release and the greater was trophic abundance of habitat. 3 groups of plant species were distinguished by the quoted authors, namely, (1) – species of a high rate of nutrient withdrawal from falling leaves and poorly responding to the habitat trophic status (e.g. birch, pine), (2) - plastic species of diversified rate of nutrient withdrawal due to trophic status of the habitat, (3) – species of a low rate of nutrient withdrawal and yet poorly responding to trophic conditions of the environment (e.g. alder). The plant communities of the examined dystrophic sequence constituting the intermediate and final stage of succession (bog moss pine forest and bog pinewood) were dominated by pine and birch. They were accompanied in the herb layer by Vaccinium myrtillus, which, according to Moszyńska (1983), may be considered a plastic species. In mesotrophic sequence analogical stages of succession were mostly made up of willow and alder. Thus it should be expected that according to the regularities mentioned above, the processes of nutrient withdrawal were by far more effective in dystrophic sequence. Hence a more economic matter management in dystrophic sequence was once again distinctly contrasted with a more "wasteful" one in mesotrophic sequence. In case of the latter the observed regularity was additionally underlined by greater biomass of produced (and, consequently, shed) leaves. Also other authors noted that plant species of raised bogs reabsorbed much larger amounts of nitrogen from leaves before their shedding than plants of other habitats (Bradbury and Grace 1983). Stuart Chapin III (1980) asserted that plants from poor habitats were dominated by species tolerating nutritional stress owing to specific types of compensating mechanisms and strategies. The plants in question are marked for a natural slow rate of growth, a slackened rate of photosynthesis and nutrient



phosphatases). Their roots and leaves are long-lived, which may be a likely cause of their low absorbility and slackened rate of nutrient cycling in them. The plants react with only slight growth to a greater nutrient inflow and under conditions of luxury consumption they store nutrients in their tissues to be subsequently used up in periods of strong nutrient deficiency. Their annual nutritional requirements are low due to a slow rate of their tissue production and relatively little nutrient loss in effect of leaf aging (very intensive autumn withdrawal or ever-green leaves) or leaching (lignified or well-cuticled leaves etc.). According to Stuart Chapin III (1980) all these mechanisms make slow-growing species successfully develop in poor habitats and make them tolerant to nutritive stress, on the understanding that their normal metabolic effectiveness is upheld under such extreme conditions. Vegetation of dystrophic sequence was marked in the present studies for a slower growth and nutrient absorption rate, which was a metabolic adaptation to poor habitat. Hence the recorded lower nutrient content in vegetation of this sequence as well as lower values of its biomass and production as compared to the amounts estimated for vegetation of mesotrophic sequence, were ecophysiologically justified.

Another author (Dickinson 1983) stressed the problem of mycorrhizal associations. He noted in conclusions that peatland plants developed under a regular effect of various types of mycorrhizal fungi. Among the plant species which, according to the quoted author, entered this form of symbiotic association there was found a majority of components of phytocoenoses in dystrophic sequence, namely, Pinus spp., Betula pubescens, many representatives of the family Ericaceae (Empetrum nigrum, Andromeda polifolia, Calluna vulgaris, Erica spp., Vaccinium myrtillus, Vaccinium oxycoccus, Vaccinium vitis-idaea). On the other hand, numerous representatives of the families Cyperaceae and Juncaceae, which were major components of phytocoenoses in mesotrophic sequence (fens), were not recorded to enter into mycorrhizal relations. It is not unlikely that mycorrhiza was the main reason of a greater production efficiency of plant communities in dystrophic sequence. Another feature differentiating vegetation of the two sequences was its root system. Plants growing on bogs (dystrophic sequence) either did not have roots (peatmosses) or their root system developed shallow in surface soil layers (K a rney and Pawłowicz 1952, Holmen 1964, Vakurov 1973, Gob a t 1984). An exception was Eriophorum vaginatum, whose roots may reach even 1 m down (Dickinson 1983). Plants growing on fens (mesotrophic sequence) were more deeply enrooted (Holmen 1964, Gobat 1984). It was a further consequence of various systems of water supply and trophic status of the examined plant communities. Plants of dystrophic sequence absorb nutrients and water mainly from precipitation. The surface of these mires is not flooded. Hence the root system is actually needless for plants or is developed only in surface soil layers, where the rain-and dust-confined elements are most intensively absorbed. This is not so on fens (mesotrophic sequence). Plants growing here derive mineral components mainly from ground water and, moreover, they must resist frequent waterlogging or floods. Under such conditions shallowly enrooted plants have no chance of survival. All the discussed aspects of distinctiveness of the two succession sequences

affected also other biotic components of these systems. Their fauna was noted to differ in abundance, density or even specimen body size (M a s o n and S t a n-d e n 1983).

Thus diverse models of functioning of plant communities in the two succession sequences presented in this work were ecologically corroborated and firmly justified. With this in mind, the result-predicted various rate of matter cycling: more rapid in mesotrophic sequence and slower - in dystrophic sequence (Fig. 10), seems to be well-grounded.

According to M a k s i m o w (1965) decomposition of fen vegetation is more intensive, which most likely, results from a greater cellulose content in their tissues. In a neutral or alkaline habitat decomposition processes are much quicker than in an acid one, moreover, lowmoor peat is more abundant in microorganisms (M a k s im o w 1965). Decay of residues in raised bogs proceeds at a very slow pace, the residues retaining their biological structure for over a long period of time. Matter cycling is not fully closed. Annual biomass production is small, only in a minimal degree being subject to mineralization. Peat is noted for the presence of so-termed antiseptics, i.e. substances restricting activity of microorganisms (M a k s i m o w 1965, P e r e l m a n 1971).

The present results frequently indicated that as compared to field crops, mire vegetation accumulated greater amounts of nutrients, which was most distinct in case of willow shrubberies, reeds and, sometimes, Carex fens. When mean element content in primary production of mire plant communities of the two sequences was compared to the element content in so-called watershed load it turned out that vegetation of the two sequences was potentially capable of fixing the entire inflowing amounts of NPK, and also of Ca, Mg and $S-SO_4$ in dystrophic sequence. A question arises, however, whether mire vegetation can possibly function as anti-eutrophication filters or barriers in agricultural landscape. First of all it should be admitted that from the comparison mentioned above there cannot be drawn any firm conclusions whether these were only potential capabilities of helophytes to accumulate nutrients inflowing from catchment area or if it was an empirical fact indeed. It was uncertain what share in the pool of nutrients fixed by plants had the nutrients coming from mineral grounds and what share was held by nutrients released during mobilization of peat-stored nutritive resources, and, finally, how much was contributed by mineral components in effect of decomposition of organic residues. All these processes advanced very intensively in the studied habitats, as evidenced by the fact that the amounts of NPK accumulated in primary production of plant communities were greater than those inflowing from catchment area. Traczyk (1985) ascertained that on the studied site most crop fields were overfertilized with phosphorus and, to smaller extent, with potassium, while root crops - with NPK. In the opinion of the quoted author, meadows and pastures were drastically underfertilized with NPK. If watershed load was assumed as natural



cultivation. On the other hand, mire vegetation received from catchment area excessive amounts of Na in case of dystrophic sequence and of Ca, Na, Mg, $S - SO_4$ in case of mesotrophic sequence. Should it be regarded as anthropogenic factor (Na in particular) impending over wetlands?

Another puzzling question was whether the recorded high concentrations of nutrients in phytomass of willow and reed species were a sign of specific species properties or of luxury consumption and if so, at what point the toxicity threshold was crossed. The issue requires further studies, the more so as on the studied site analogical high contents of mineral components were recorded in other reed associations, namely, Acoretum calami, Phragmitetum and Glycerietum maximae (Traczyk 1985). Similar results were obtained by Oświt (1980) for mire vegetation of the Narew river valley.

In agroecosystems most of the produced biomass is taken away as harvest, whereas mire vegetation remains in its site after it withers. Hence, by way of counter-reasoning, it may been alleged to function as an eutrophic factor. Obviously, this tentative supposition may easily be ruled out, as it is a well-known fact that matter decomposition in peatlands is much impeded, contrary to its rapid decay rate in mineral soils (Maksimow 1965, Okruszko 1969, Perelman 1971).

Decomposition of mire plants under natural conditions proceeds in various time depending on plant species (K o z l o v s k a j a et al. 1978), viz., at Sphagnum fuscum initial mass loss accounted for merely 30% after 3 years; at Sphagnum balticum 85% of initial mass was still not decomposed after 2 years; at Eriophorum vaginatum only 14% of initial mass was recorded after 3 years; at Scheuchzeria palustris decomposition lasted from 2.5 to 3 years; at Ledum palustre, decomposition of its leaves was completed after 2 years; in case of needles of Pinus silvestris, still 57% of initial mass was found after 2 years; at Drepanocladus sp. - complete decomposition took place over 3 years; at Equisetum limosum – about 3 years; Carex lasiocarpa – almost 3 years; in case of leaves of Betula pubescens – after 2 years the loss of only half of the initial mass occurred; leaves of Salix caprea were decomposed after about 2 years; leaves of Alnus incana - from 1.5 to 2 years, Comarum palustre – about 1 year.

Potassium and phosphorus were recorded to be most quickly released from decomposing matter (K o z l o v s k a j a et al. 1978). It would explain, among others, greater amounts of NPK in primary production of mire plant communities as compared to the quantities of these elements inflowing from catchment area. It may be concluded that the process of decomposition is likely to be much slacked in peatlands than, e.g., on a mineral meadow. Even if considerable amounts of nutrients may eventually reach ground water, still it should be pondered on whether the function of antieutrophication "valves" modifying the rate of matter turnover in agricultural landscape, could not be possibly attributed to mire vegetation of hollows

Matter decomposition in dystrophic sequence is sustained and little effective. Peatbogs have a much obstructed contact with ground water. Hence deferring of half

with no run-off.

decomposed organic matter in the form of peat is a method of defense against "self-poisoning" and, at the same time, of storing nutritional resources for hard times. In this aspect mire vegetation has a highly anti-eutrophication effect. In the landscape, however, this is not of any greater significance (nowadays) due to meager quantities of fixated elements (ombrogenic type of supply).

In mesotrophic sequence the greatest amounts of nutrients are bound by willow shrubberies, reeds and *Carex* fens. Matter decomposition is quicker there than in mires of dystrophic sequence, yet slow enough, on the landscape scale, to make them function as anti-eutrophication "valves". Most effective in this respect are willow shrubberies, as they retend a considerable part of nutrients in wood, thereby excluding them, for a longer time, from matter turnover.

It is difficult to state whether the above suppositions hold water O s w i t (1980) added to the discussed issues a very interesting aspect of a great importance of reed vegetation in the process of water self-purification. According to this author, these plants would not only accumulate large quantities of nutrients, but, by their metabolism, they would also inactivate and neutralize various substances and pollutants, e.g. phenols, cyanides, thiocyanates, etc. (in his latter assumptions the author referred to Seidel's studies from the area of West Germany). According to Skalski (after Obmiński 1975) also willows considerably advance water self-purification, even by as much as 33 - 40%. Under the effect of these shrubs oxygen saturation of water occurred in time by about 86-95% shorter than in places lacking vegetation. The quoted author noted in his studies an immense accumulation of mineral salts in phytomass of certain aquatic plants and reeds (Carex elata and Scirpus lacustris) as well as their ability to remove toxic compounds from water, e.g., phenols. On the basis of the observations noted in the present work it may be concluded that mire vegetation of hollows without run-off (mainly in mesotrophic sequence) performs in agricultural landscape a much more significant function than it has been generally assumed.

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6. CONCLUSIONS

 The type of water supply determines trophic status of wetland habitats: water in ombrogenically supplied mires (of dystrophic sequence) is usually poorer in nutrients than that in the soligenically supplied ones (of mesotrophic sequence).
 The parameter decisive of ecological distinctiveness of the both mires types is

watershed nutrient load.

3. Habitat distinctiveness of mires in dystrophic and mesotrophic sequence determines analogical distinctiveness of average chemical composition and productivity (standing crop and primary production) of mire vegetation in the two sequences.



primary production) of plant communities in mesotrophic sequence is greater than in

dystrophic sequence.

5. Mean production efficiency of plant communities in dystrophic sequence is larger than in mesotrophic sequence.

6. Matter retention in treestands of plant communities in dystrophic sequence is greater.

7. Plant communities perform different functions in the two sequences: in mesotrophic sequence matter management is wasteful, while in dystrophic sequence - more economic.

8. Notwithstanding various trophic abundance, regularities of succession course in the two sequence of plant communities are analogical.

9. Mire vegetation of no-outflow hollows of mesotrophic sequence (willow shrubberies and reeds in particular) functions in agricultural landscape as antieutrophication "valves" against NPK.

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7. SUMMARY

The subject of the present studies was mire vegetation growing on wetlands located on the bottom of hollows with no run-off in the Masurian Lakeland. On the basis of phytosociological examinations phytocoenoses of 15 plant associations were identified. Two succession series were distinguished, namely, dystrophic (of bogs) – from transition bogs through bogmoss swamp to bog pinewood (Fig. 1), and mesotrophic (of fens) – from reeds and *Carex* fens through willow shrubberies to alder wood fen (Fig. 2).

Chemical valorization (analyses of water and 56 plant species) was made in 19 no-outflow hollows (Fig. 3) under various stages of wetland overgrowing with mire vegetation. Since several of them ranked among mixed systems, studies were eventually conducted on 26 plant plots, representing 13 plant associations (Table 3). Mire water in dystrophic sequence was, on the average, poorer in nutrients (ombrogenic type) than water in mires of mesotrophic sequence (soligenic type), which was most evident in case of Ca and Mg content, pH and total mineralization (Table 4). The obtained results of chemical analyses allowed for assessing average chemical composition of mire vegetation, i.e. of herbs, dwarf shrubs and bryophytes, in total (Table 5) and for stating its considerable distinctiveness as compared to chemical properties of trees in these habitats (Table 6). It was shown (by means of Student test) in the gradient of dystrophic and mesotrophic sequence that plants making up plant communities of mesotrophic sequence were marked for a higher mean content in dry wt of ash, N_{tot.}, P_{tot.}, K, Ca, Mg, Na and, at the limit of significance level, also of $S - SO_4$ (Table 7). The studies recorded diverse area and watershed characteristics as well as different effects of catchment areas (i.e. hollows) on mires occurring on them (Table 8) in the two succession sequences. It was evidenced on the basis of watershed balance that the type of water supply was decisive of trophic status of mire habitats in regard to all the analyzed elements (Table 9).

Eight plant communities constituting links in the two succession sequences were assigned for close studies. It dystrophic sequence these were: Caricetum lasiocarpae, Caricetum limosae, Ledo-Sphagnetum magellanici and Vaccinio uliginosi-Pinetum, while in mesotrophic sequence – Typhetum latifoliae, Caricetum elatae, Salicetum pentandro-cinereae and Carici elongatae-Alnetum. Both biomass and primary production of plant communities in mesotrophic sequence were higher, on the average, than

analogical values estimated for dystrophic sequence (Table 10, 11, Figs. 4, 5). Among the examined plant communities, Typhetum latifoliae and Salicetum pentandro-cinereae produced yearly the greatest amount of phytomass entering matter turnover and, moreover, specimen density was the highest in willow shrubberies (Table 12).

Mean content of mineral components ($N_{tot.}$, $P_{tot.}$, K, Ca, Mg and Na) bound in biomass of plant communities in mesotrophic sequence was higher than in dystrophic sequence. In case of primary production of the examined plant communities, this regularity concerned all the analyzed elements and, moreover, also $S-SO_4$ (Tables 13, 14, Figs. 6, 7). The highest nutritional requirements were noted in Typhetum latifoliae and Salicetum pentandro-cinereae, which, considering the largest amounts of phytomass they produced, would indicate that the plant communities in question were very expansive in transforming their habitats. Nutrient consumption estimated to a unit of produced dry mass (kg/t dry wt) was, on the average, higher in plant communities of mesotrophic sequence, both, with respect to standing crop as well as to primary production (Tables 15, 16, Figs. 8, 9). Sulphur ($S-SO_4$) was sometimes noted to deviate from the outlined regularities, which attested to selectivity of mire plant communities in absorption of this element. It was noted that mean production efficiency of plant communities in dystrophic sequence was higher (Table 17), and matter retention in treestands of this sequence was stronger (Table 18) than in mesotrophic sequence.

Mean percentage contribution of elements entering matter turnover - in relation to their total resources bound in biomass of plant communities - was always greater in mesotrophic sequence (Table 19). An outcome of the observed regularities was a different functioning of plant communities in the two sequences: in mesotrophic sequence matter management was less economic, while in dystrophic one - more sparing and frugal (Fig. 10). Ranges of all the studied features were smaller in dystrophic sequence; in mesotrophic sequence the amplitude of changes of all the analyzed parameters was fairly wide. Also statistical analysis (non-parametric sign test) confirmed ecological distinctiveness of plant communities in the two sequences (Table 20). A further consequence of the above mentioned regularities seemed to be different rate of matter cycling and decomposition: more rapid in mesotrophic sequencce and slower - in dystrophic one. The course of succession in the two sequences of plant communities was alike (Table 11). In both cases regularities were analogical, viz. advancing succession was noted to be paralelled by a decrease in percentage contribution of production to total standing crop, an increase in B/P ratio (biomass to production ratio), greater heterogeneity of plant communities, diminishing percentage contribution of herbaceous plants to standing crop of plant communities, increasing accumulation of mineral components in phytomass, a decrease in percentage quantity of ash and nutrients yearly entering matter turnover, etc. Notwithstanding the fact that plant communities of both succession sequences were at various levels of trophic abundance, yet eventually they were observed to reach functionally alike final stages (bog pinewood and alder wood fen), which may be interpreted as functionally alike edaphic climax of the two succession sequences. The mechanisms primarily responsible for such a succession course was production efficiency. Mire vegetation in agricultural landscape was subject to valorization. Comparative analysis of the obtained chemical data and corresponding values estimated for nearby agrophytocoenoses revealed a greater content of certain nutrients in mire vegetation (Table 21), which was most evident in case of willow shrubberies, reeds and, to a smaller extent, also Carex fens. The amount of nutrients yearly inflowing to 1 ha of mire was compared to the nutrient content in primary production of mire plant communities in dystrophic (Table 22) and mesotrophic sequence (Table 23). It turned out that mire vegetation was potentially capable of entirely accumulating the amounts of NPK inflowing from catchment area in its primary production, and in case of plant communities of dystrophic sequence - also of Ca, Mg, $S - SO_4$. In this aspect fairly significant were plant communities in which the elements were retained in perennial tissues, i.e. in wood (Table 24). Most effective in this respect were willow shrubberies. The findings of the present studies were confronted with

literature data (Tables 25, 26, 27).

8. POLISH SUMMARY

Przedmiotem badań była roślinność bagienna zarastająca mokradła położone w dnie zagłębień bezodpływowych na Pojezierzu Mazurskim. W wyniku rozpoznania fitosocjologicznego zidentyfikowano fitocenozy 15 zespołów roślinnych. Wyodrębniono 2 szeregi sukcesyjne, mianowicie: dystroficzny (torfowisk wysokich) – of torfowisk przejściowych poprzez mszary wysokie do boru bagiennego (rys. 1) oraz mezotroficzny (torfowisk niskich) – od szuwarów wodnych i błotnych poprzez zarośla łozowe do olsu (rys. 2).

Waloryzację chemiczną (analizy wody i 56 gatunków roślin) wykonano w 19 zagłębieniach bezodpływowych (rys. 3) wykazujących różnorodne fazy zarastania mokradeł. Niektóre z nich stanowiły układy mieszane, ostatecznie więc do badań wybrano 26 płatów roślinnych, reprezentujących 13 zespołów roślinnych (tab. 3). Woda z torfowisk ciągu dystroficznego była przeciętnie uboższa w związki biofilne (typ ombrogeniczny) w porównaniu z wodą z torfowisk ciągu mezotroficznego (typ soligeniczny). Szczególnie jednoznacznie dowiedziono tego na przykładzie zawartości Ca, Mg, pH oraz ogólnej mineralizacji (tab. 4). Uzyskane wyniki analiz chemicznych pozwoliły ustalić przeciętny skład chemiczny roślinności bagiennej, tzn. roślin zielnych, krzewinek i mszaków – łącznie (tab. 5) i stwierdzić jego znaczną odmienność w porównaniu z chemizmem drzew z tych siedlisk (tab. 6). Wykazano (test Studenta) w gradiencie: ciąg dystroficzny a mezotroficzny, że rośliny budujące zbiorowiska roślinne ciągu mezotroficznego miały przeciętnie wyższe zawartości w suchej masie: popiołu, N og., P og., K, Ca, Mg, Na oraz na granicy istotności $S - SO_4$ (tab. 7). Wykazano odmienne charakterystyki powierzchniowo--zlewniowe oraz oddziaływanie zlewni (czyli zagłębień) na występujące w nich mokradła (tab. 8) w obu ciągach. Dowiedziono na podstawie bilansu zlewniowego, że typ zasilania wodą decyduje o trofii siedlisk bagiennych w stosunku do wszystkich rozpatrywanych pierwiastków (tab. 9). Do badań szczegółowych wybrano 8 zbiorowisk roślinnych stanowiących ogniwa obu ciągów sukcesyjnych. W ciągu dystroficznym były to: Caricetum lasiocarpae, Caricetum limosae, Ledo-Sphagnetum magellanici oraz Vaccinio uliginosi-Pinetum. W ciągu mezotroficznym wytypowano: Typhetum latifoliae, Caricetum elatae, Salicetum pentandro-cinereae oraz Carici elongatae-Alnetum. Zarówno biomasy jak i produkcja pierwotna zbiorowisk roślinnych ciągu mezotroficznego są przeciętnie wyższe od analogicznych wartości dla ciągu dystroficznego (tab. 10, 11, rys. 4, 5). Spośród badanych zbiorowisk roślinnych Typhetum latifoliae i Salicetum pentandro-cinereae wytwarzają rokrocznie największą ilość masy roślinnej wchodzącej w obieg materii, przy czym w łozowisku zagęszczenie osobników było najwyższe (tab. 12). Przeciętna zawartość składników mineralnych (N og., P og., K, Ca, Mg i Na) związanych w biomasach zbiorowisk roślinnych ciągu mezotroficznego jest wyższa w porównaniu z analogicznymi wartościami ciągu dystroficznego. Trend ten uwypukla się w przypadku produkcji pierwotnej badanych zbiorowisk roślinnych w odniesieniu do wszystkich wymienianych pierwiastków, a dodatkowo wobec S-SO₄ (tab. 13, 14, rys. 6, 7). Największe wymagania pokarmowe stwierdzono w zbiorowiskach: Typhetum latifoliae i Salicetum pentandro-cinereae, co w zestawieniu z faktem, iż właśnie te zbiorowiska produkują największe ilości fitomasy pozwala przypuszczać, że są to zbiorowiska roślinne bardzo ekspansywne w przekształceniu swoich siedlisk. Także konsumpcja związków biofilnych na jednostkę wytworzonej suchej masy (kg/t s.m.) jest przeciętnie wyższa w zbiorowiskach roślinnych ciągu mezotroficznego, zarówno w stanie biomasy jak i produkcji pierwotnej (tab. 15, 16, rys. 8, 9). Z ogólnych prawidłowości wyłamuje się niekiedy siarka $(S - SO_4)$, co dowodzi selektywności bagiennych układów roślinnych w pobieraniu tego pierwiastka. Wykazano, że przeciętna wydajność produkcji zbiorowisk roślinnych ciągu dystroficznego jest wyższa (tab. 17), a w drzewostanach tego ciągu - retencja materii jest silniejsza (tab. 18) w porównaniu z analogicznymi wartościami ciągu mezotroficznego.

W ciągu mezotroficznym przeciętny udział procentowy pierwiastków wchodzących w obieg materii - w stosunku do ich zasobów globalnych związanych w biomasach zbiorowisk roślinnych - jest zawsze wyższy niż w ciągu dystroficznym (tab. 19). Konsekwencją wymienianych prawidłowości jest odmienne

funkcjonowanie zbiorowisk roślinnych w ciągach: w mezotroficznym - gospodarowanie materią jest mniej oszczędne, a w dystroficznym - bardziej oszczędne i bardziej ekonomiczne (rys. 10). W ciągu dystroficznym zakresy zmienności wszystkich badanych parametrów są mniejsze; w ciągu mezotroficznym

amplituda zmienności analizowanych cech jest znaczna. Również analiza statyczna (nieparametryczny test liczby znaków) potwierdza odrębność ekologiczną zbiorowisk roślinnych obu ciągów (tab. 20). Kolejną konsekwencją wymienianych prawidłowości wydaje się być inaczej przebiegające krążenie i rozkład materii: szybsze – w ciągu mezotroficznym, a wolniejsze – w ciągu dystroficznym.

Przebieg sukcesji w obu ciągach zbiorowisk roślinnych jest podobny. Prawidłowości w obu przypadkach są analogiczne: m.in. wraz z postępującą sukcesją odnotowano zmniejszanie się procentowego udziału produkcji w ogólnym stanie biomasy, wzrost wskaźnika B/P, wzrost heterogeniczności zbiorowisk roślinnych, zmniejszanie się procentowego udziału roślin zielnych w stanie biomasy zbiorowisk roślinnych, wzrost akumulacji składników mineralnych w fitomasach, zmniejszanie się procentowej ilości popiołu i związków biofilnych wchodzących rocznie w obieg materii etc. Mimo że zbiorowiska roślinne obu ciągów sukcesyjnych są na różnych poziomach zasobności troficznej, ostatecznie osiągają bardzo podobne pod względem funkcjonalnym stadia końcowe (bór bagienny i oles), co można zinterpretować jako zbliżony funkcjonalnie klimaks edaficzny obu ciągów sukcesyjnych. Mechanizmem odpowiedzialnym za taki przebieg sukcesji jest przede wszystkim wydajność produkcji. Zwaloryzowano roślinność bagienną w krajobrazie rolnicznym. Analiza porównawcza otrzymanych danych chemicznych z analogicznymi wartościami dla okolicznych agrofitocenoz wykazała wyższe zawartości niektórych związków biofilnych w roślinności bagiennej (tab. 21). Dotyczyło to zwłaszcza zarośli łozowych, szuwarów wodnych oraz w mniejszym stopniu szuwarów błotnych.

Zestawiono ilości pierwiastków dopływające do 1 ha mokradła rocznie z zawartościami pierwiastków biofilnych w produkcji pierwotnej bagiennych zbiorowisk roślinnych ciągu dystroficznego (tab. 22) i ciągu mezotroficznego (tab. 23). Okazało się, że istnieje potencjalna możliwość, aby roślinność bagienna całkowicie zakumulowała w swojej produkcji pierwotnej dopływające ze zlewni ilości NPK, a w przypadku zbiorowisk roślinnych ciągu dystroficznego – również Ca, Mg, S–SO₄. W tym kontekście istotnego znaczenia nabierają zbiorowiska roślinne, w których pierwiastki są retendowane w tkankach wieloletnich, tj. drewnie (tab. 24). Najbardziej efektywne pod tym względem okazały się łozowiska. Uzyskane rezultaty poddano dyskusji z literaturą (tab. 25, 26, 27).

9. REFERENCES

- A s s m a n E. 1968 Nauka o produkcyjności lasu [Scientific principles of forest productivity] – PWRiL, Warszawa, 626 pp.
- B a j k i e w i c z-G r a b o w s k a E. 1985 Factors affecting nutrient budget in lakes of the river Jorka watershed (Mazuria Lakeland, Poland). I. Geographical description, hydrographic component and man's impact – Ekol. pol. 31: 257-286.
- 3. B a z i l e w i c z N. I., R o d i n L. J. 1976 Prawidłowości przestrzennego zróżnicowania produktywności i obiegu pierwiastków chemicznych w głównych typach roślinności kuli ziemskiej [Regularities of spatial diversity of productivity and element cycling in main types of world vegetation] (In: Biosfera i jej zasoby [Biosphere and its resources]) Państwowe Wydawnictwo Naukowe, Warszawa, 228–241.
- B e 11 a m y D. J. 1968 − An ecological approach to the classification of European mires − Quebec, 74-79.
- 5. Bellamy D. J., Bellamy R. 1966 An ecological approach to the classification of the lowland mires of Ireland Proc. Roy. Ir. Acad. B, 65: 237-251.
- Bellamy D. J., Rieley J. 1967 Some ecological statistics of a "miniature bog" Oikos, 18: 33-40.
- B i a ł o b o k S., Ż e l a w s k i W. (Eds.) 1967 Zarys fizjologii sosny zwyczajnej [An outline of physiology of pine tree] – Zakład Dendrologii i Arboretum Kórnickie PAN, Państwowe Wydawnictwo Naukowe, Poznań, 328 pp.

Botch M. S., Masing V. V. 1983 – Mire ecosystems in the USSR (In: Ecosystems of the world. 4B. Mires: swamp, bog, fen and moor. Regional studies, Ed. A. J. P. Gore) – Amsterdam – Oxford – New York, 95–152.

- 9. Bradbury J. K., Grace J. 1983 Primary production in wetlands (In: Ecosystems of the world. 4 A. Mires: swamp, bog, fen and moor. General studies, Ed. A. J. P. Gore) - Amsterdam --Oxford-New York, 285-310.
- 10. Braun-Blanquet J. 1964 Pflanzensoziologie. Grundzuge der Vegetationskunde -Springer, Wien-New York, 865 pp.
- 11. Clymo R. S. 1970a Ion exchange in Sphagnum and its relation to bog ecology Ann. Bot. 27: 309 - 325.
- 12. Clymo R. S. 1970b The growth of Sphagnum: methods of measurement J. Ecol. 58: 13-49.
- 13. Clymo R. S. 1983 Peat (In: Ecosystems of the world. 4A. Mires: swamp, bog, fen and moor. General studies, Ed. A. J. P. Gore) - Amsterdam-Oxford-New York, 159-225.
- 14. Crawford R. M. M. 1983 Root survival in flooded soils (In: Ecosystems of the world. 4A. Mires: swamp, bog, fen and moor. General studies, Ed. A. J. P. Gore) - Amsterdam - Oxford - New York, 257-283.
- 15. Czerwiński Z., Traczyk T., Wilpiszewska I. 1985a Akumulacja nutrientów w uprawach zbożowych (Accumulation of mineral elements in cereal plants) - Pol. ecol. Stud. 11: 349 - 360.
- 16. Czerwiński Z., Traczyk T., Wilpiszewska I. 1985b Contents and accumulation of mineral elements in some fodder and industrial crops - Pol. ecol. Stud., 11: 361 - 370.
- 17. Czuraj M., Radwański B., Strzemski S. 1960 Tablice miąższości drzew stojących [Tables of standing trees volume] - Państwowe Wydawnictwo Rolnicze i Leśne, Warszawa, 188 pp.
- 18. D a m m a n A. W. 1978 Distribution and movement of elements in ombrotrophic peat bogs - Oikos, 30: 480-495.

- 19. Dickinson C. H. 1983 Micro-organisms in peatlands (In: Ecosystems of the world. 4A. Mires: swamp, bog, fen and moor. General studies, Ed. A. J. P. Gore) - Amsterdam - Oxford - New York, 225-245.
- 20. D i x o n K. R. 1976 Analysis of seasonal leaf fall in north temperate deciduous forests Oikos, 27: 300 - 306.
- 21. Dykyjova D., Kvet J. 1982 Mineral nutrient economy in wetlands of the Trebon Basin Biosphere Reserve (In: Wetlands-ecology and management, Eds. B. Gopal, R. E. Turner, R. G. Wetzel, D. F. Whigham) – National Institute of Ecology and International Scientific Publications, 335-355.
- 22. F a b i s z e w s k i J. 1981 Badania nad wzrostem torfowców zasiedlających eksploatowane złoże torfowe [Studies on growth of peatmosses developing on peat deposit under winning] - Zesz. nauk. Akad. Roln., Wrocław, Roln., 38: 165-173.
- 23. Fried M., Broeshart H. 1967 Time soil-plant system in relation to inorganic nutrition - Academic Press, New York, 358 pp.
- 24. G o b a t J. M. 1984 Ecologie des contacts entre tourbieres acides et marais alcalins dans le Haut-Jura Suisse - Université de Neuchătel, Institut de Botanique Neuchătel, (Ph. D. Thesis, manuscript) 255 pp.
- 25. Gore A. J. P. 1961a Factors limiting plant growth on high-level blanket peat. I. Calcium and phosphate – J. Ecol. 49: 399–402.
- 26. Gore A. J. P. 1961b Factors limiting plant growth on high-level blanket peat. II. Nitrogen and phosphate in the first year of growth - J. Ecol. 49: 605-616.
- 27. Gore A. J. P. 1983 Wstęp [Introduction] (In: Ecosystem of the world. 4A. Mires: swamp, bog, fen and moor. General studies, Ed. A. J. P. Gore) - Amsterdam-Oxford-New York, 1-34. 28. G o r h a m E. 1956a – The ionic composition of some bog and fen waters in English Lake District - J. Ecol. 44: 142-152.
- 29. G o r h a m E. 1956b On the chemical composition of some waters from the Moor House Nature Reserve – J. Ecol. 44: 375–382.

30. Gorham E., Pearsall W. H. 1956 - Acidity, specific conductivity and calcium content of some bog and fen waters in Northern Britain – J. Ecol. 44: 129-141. 31. He i n s e l m a n M. L. 1970 – Landscape evolution, peatland types and the environment in the Lake Agassiz Peatlands Natural Area, Minnesota - Ecol. Monogr. 40: 235-261.

- 32. H o l m e n H. 1964 Forest ecological studies on drained peat land in the province of Uppland, Sweden, parts I-III – Stud. For. suec. 16, 303 pp.
- 33. Ingram H. A. P. 1967 Problems of hydrology and plant distribution in mires J. Ecol. 55: 711-724.
- 34. Ingram H. A. P. 1983 Hydrology (In: Ecosystem of the world, 4A. Mires: swamp, bog, fen and moor. General studies, Ed. A. J. P. Gore) Amsterdam–Oxford–New York, 67–158.
- 35. Jenik J. 1983 Struktura a biomasa slatinnych vrbin na Mokrych Loukach (In: Studie zaplanovanych ekosystému u Trěboně) Akademia, Praha, 4: 123–126.
- 36. K a m i ń s k i E., L a u r o w Z. 1966 Główne użytkowanie lasu. T. I. Nauka o surowcu drzewnym [Main forms of forest exploitation. Vol. I. Studies on timber] SGGW-AR, Warszawa, 285 pp.
- 37. Karney J., Pawłowicz A. 1952 Brzoza [Birch tree] Państwowe Wydawnictwo Rolnicze i Leśne, Warszawa, 86 pp.
- 38. K i m s a T. 1980 Seasonal dynamics of biomass and the production of the herb layer in selected pinewood communities in Central Roztocze. I. Above-ground parts of plants – Ekol. pol. 28: 367-392.
- 39. K i v i n e n E. 1933 Untersuchungen über den Gehalt an Pflanzen nährstoffen in Moorpflanzen und an ihren Standorten Acta Agr. fen. 27: 1-141.
- 40. K l o p a t e k J. M. 1975 The role of emergent macrophytes in mineral cycling in a freshwater marsh (In: Mineral cycling in southeastern ecosystems, Eds. F. G. Howell, J. B. Gentry, M. H. Smith)
 Technical Center Office of Public Affairs, Augusta-Georgia, 367-394.
- 41. Kloss M., Kruk M., Wilpiszewska I. 1987 Geneza, charakterystyka zagłębień bezodpływowych we współczesnym krajobrazie Pojezierza Mazurskiego [The genesis, description of natural conditions and anthropogenic transformations of undrained mired basins in present-day landscape of the Masurian Lakeland] – Kosmos, 36: 621–641.

- 42. Kloss M., Wilpiszewska I. 1983 O roślinności niewielkich zagłębień bezodpływo-wych okolic Mikołajek i potrzebie ich ochrony [On the vegetation growing in the small hollows without outflow in the environs of Mikołajki and the need for their protection] Chroń. Przyr. ojcz. 4: 25-29.
- 43. Kloss M., Wilpiszewska I. 1985 Vegetation of hollows without runoff in the Jorka River watershed Pol. ecol. Stud. 11: 209-214.
- 44. K ł o s o w s k i S. 1983 Amplituda ekologiczna i wartość bioindykacyjna głównych zbiorowisk wodnych i szuwarowych w Polsce północno-wschodniej [Ecological amplitude and bioindicatory value of main aquatic and reed plant communities in north-eastern Poland] – Uniwersytet Warszawski, Warszawa, (Ph. D. Thesis, manuscript), 117 pp.
- 45. K o b e n d z a R. 1930 Stosunki fitosocjologiczne Puszczy Kampinoskiej [Phytosociological relations in the Kampinoski Forest] Towarzystwo Naukowe Warszawskie, Warszawa, 200 pp.
- K o n d r a c k i J. 1972 Polska Północno-Wschodnia [North-eastern Poland] Państwowe Wydawnictwo Naukowe, Warszawa, 272 pp.
- 47. K o z l o v s k a j a L. S., M e d v e d e v a V. M., P' j a v c ě n k o N. I. 1978 Dinamika organičeskogo veščestva v processe torfoobrazovanija Nauka, Akademija Nauk SSSR, Karelskij Filial, Institut Lesa, Leningrad, 172 pp.
- 48. K r u k M. 1988a Types of basins without drainage and factors affecting the water cycle in them in present-day landscape of Masurian Lakeland Ekol. pol. 35: 655-678.
- 49. K r u k M. 1988b The influence of the mire proportion in a drainageless catchment area on the trophic status of mire waters Ekol. pol. 35: 679-698.
- 50. K r u k M. 1990 The processing of elements by mires in agricultural landscape: mass balance based on sub-surface hydrology Ekol. pol. 38: 73-117.
- 51. K u f e 1 L. 1979 Obieg fosforu w trzcinowisku [Phosphorus cycling in reeds] Instytut Ekologii PAN, Dziekanów Leśny, (Ph. D. Thesis, manuscript), 46 pp.

52. K u l c z y ń s k i S. 1939/1940 - Torfowiska Polesia, T. I i II [Peatlands of Polesie. Vol. I and II]



- 53. L a r g i n I. 1976 Investigation of water composition of natural and cultivated peat deposits (In: Peat and peatlands in the natural environment protection. 5th Int. Peat Congress, Poznań-Poland, September 21-25) – NOT, 4: 268-278.
- 54. L e m k e J. 1979 Struktura aparatu asymilacyjnego w okółkach koron sosen różnych klas wieku [Structure of assimilating apparatus in whorls of the canopy layer of pines of various age classes]
 Pozn. Tow. Przyj. Nauk. Pr. Kom. Nauk Roln. Kom. Nauk Leśn. 48: 61–68.
- 55. L e m k e J. 1983 Tabele do szacowania ciężaru igliwia i uiglonych gałązek sosny zwyczajnej [Tables for estimating the weight of needles and needled branches of pine] Sylwan, 127: 21-30.
- 56. L i e t h H. 1975 Modeling the primary productivity of the world (In: Primary productivity of the biosphere, Eds. H. Lieth, R. H. Whittaker) Ecological Studies 14, Springer-Verlag, New York Heidelberg Berlin, 237 264.
- 57. L i w s k i S. 1961 Mikroelementy Mn, Fe, B, Cu, Co, Zn, Mo w roślinności łąkowej i bagiennej [Microelements – Mn, Fe, B, Cu Co, Zn, Mo – in meadow and swamp vegetation] – Rocz. nauk roln. F, 75: 7–74.
- 58. M a c i a k F. 1963 Badania nad formami azotu w torfach. I. Bilans azotowy w roślinności torfotwórczej i w torfach [Studies on nitrogen forms in peats. I. Nitrogen balance in peat generating vegetation and in peats] Rocz. nauk roln. 87, A, 4: 563–594.
- 59. M a d g w i c k H. A. J. 1970 Biomass and productivity models of forest canopies (In: Analysis of temperate forest ecosystems, Ed. D. F. Reichle) – Ecological Studies 1, Springer-Verlag, New York-Heidelberg-Berlin, 47-55.
- 60. M a k s i m o w A. 1965 Torf i jego użytkowanie w rolnictwie [Peat and its use in agriculture]
 Państwowe Wydawnictwo Rolnicze i Leśne, Warszawa, 396 pp.
- 61. M ä l k ö n e n E. 1975 Annual primary production and nutrient cycle in some Scots Pine stands
 − Commun. Inst. Forest. Fen. 84: 1−88.

- 62. Mälkönen E. 1977 Annual primary production and nutrient cycle in a birch stand Commun. Inst. Forest. Fen. 91: 1-35.
- 63. M a s o n C. F., S t a n d e n V. 1983 Aspects of secondary production (In: Ecosystems of the world. 4A. Mires: swamp, bog, fen and moor. General studies, Ed. A. J. P. Gore) Amsterdam Oxford New York, 367 382.
- 64. M a t u s z k i e w i c z W. 1981 Przewodnik do oznaczania zbiorowisk roślinnych Polski [A guide for identifying plant communities of Poland] – Państwowe Wydawnictwo Naukowe, Warszawa, 298 pp.
- 65. M c N a u g h t o n S. J. 1966 Ecotype function in the Typha community type Ecol. Monogr.
 36: 297-325.
- 66. M o l č a n o v A. A. 1974 Produktivnosť organičeskoj massy v berezovych drevostojach Moskovskoj Oblasti (In: Produktivnosť organičeskoj i biologičeskoj massy lesa, Ed. A. A. Molčanov) Nauka, 141–162.
- 67. M o s z y ń s k a B. 1970 Estimation of the green top production of the herb layer in a bog pinewood Vaccinio uliginosi-Pinetum Ekol. pol. 18: 779-803.
- 68. M o s z y ń s k a B. 1973 Methods for assessing production of the upper parts of shrubs and certain perennial plants Ekol. pol. 21: 359-367.
- 69. M o s z y ń s k a B. 1983 Some problems on ecology of Vaccinium myrtillus L. in pine forest communities Pol. ecol. Stud. 9: 565–643.
- 70. Newbould P. J., Gorham E. 1956 Acidity and specific conductivity measurements in some plant communities of the New Forest Valley Bogs J. Ecol. 44: 118–128.
- 71. O b m i ń s k i Z. (Ed.) 1975 Kształtowanie krajobrazu a ochrona przyrody [Landscape modelling and nature protection] Państwowe Wydawnictwo Rolnicze i Leśne, Warszawa, 823 pp.
- 72. O d u m E. P. 1977 Podstawy ekologii [Foundations of ecology] Państwowe Wydawnictwo Rolnicze i Leśne, Warszawa, 678 pp.
- 73. O k r u s z k o H. 1969 Kierunki i zasady gospodarki na torfowiskach [Directions and principles

of peatland management] – Państwowe Wydawnictwo Rolnicze i Leśne, Warszawa, 167 pp. 74. Okruszko H. 1981 – Charakterystyka siedlisk hydrogenicznych akumulujących materię

- organiczną [Characteristic of hydrogenic habitats accumulating organic matter] IMUZ, Falenty, (mscr.), 12 pp.
- 75. Olkowski M. 1972 Budowa i roślinność torfowisk Pojezierza Mazurskiego [Structure and vegetation of peatlands in the Masurian Lakeland] - Zesz. nauk. ART, Olsztyn, A, Suppl. 13: 3-79.
- 76. Orlov A. Ja. 1980 Dinamika massy chvoi v sosnovych kul'turach Lesovedenie, 1: 34-42.
- 77. Oświt J. 1977 Charakterystyka dolinowych siedlisk glebotwórczych [Characteristic of soil generating habitats in valleys] - Zesz. probl. Post. Nauk roln. 186: 37-48.
- 78. O ś w i t J. 1980 Rola roślinności bagiennej w środowisku przyrodniczym doliny Narwi w aspekcie oczyszczania się wód [The role of swamp vegetation in natural environment of the Narew river valley in self-purification of water] - Zesz. probl. Post. Nauk roln. 234: 87-102.
- 79. O ś w i t J. 1984 Różnicowanie się siedlisk hydrogenicznych i zbiorowisk roślinnych w nawiązaniu do ewolucji dolin rzecznych w zlewni Narwi [Differentiation of hydrogenic habitats and plant communities in relation to evolution of river valleys in the Narew river catchment area] - IMUZ, Falenty, (mscr.), 229 pp.
- 80. Oświt J., Sapek B. 1982 Ocena zawartości składników mineralnych w roślinach łak naturalnych i zdolność gatunków do wykorzystania zasobów glebowych [Assessment of the content of mineral components in plants of natural meadows and species ability to use soil resorces] - Rocz. Gleb. 33: 145-151.
- 81. O świt J., Sapek B. 1983 Zawartość mikroelementów w glebie i roślinach na przekroju dolinowym Góra-Lipniki w dolinie Narwi [Microelement content in soil and plants in Góra--Lipniki valley section in the Narew river valley] - Zesz. probl. post. Nauk roln. 242: 311-321. 82. Ovington J. D., Madgwick H. A. J. 1959a – Distribution of organic matter and plant
- nutrients in a plantation of Scots Pine For. Sci. 5: 344-355.

- 83. Ovington J. P., Madgwick H. A. 1959b The growth and composition of natural stands of birch. I. Dry-matter production – Plant Soil, 10: 271–283.
- 84. Panfil J. 1968 Pojezierze Mazurskie [The Masurian Lakeland] Wiedza Powszechna, Warszawa, 208 pp.
- 85. Pawłowski B., Zarzycki K. 1977 Dynamika zbiorowisk roślinnych [Dynamics of plant communities] (In: Szata roślinna Polski. T. 1 [Vegetation of Poland, vol. 1, Eds. W. Szafer, K. Zarzycki]) – Państwowe Wydawnictwo Naukowe, Warszawa, 481-502.
- 86. Perelman A. I. 1971 Geochemia krajobrazu [Landscape geochemistry] Państwowe Wydawnictwo Naukowe, Warszawa, 433 pp.
- 87. Pearsall W. H., Gorham E. 1956 Production ecology. I. Standing crops of natural vegetation - Oikos, 7: 193-201.
- 88. Pietsch W. 1976 On the relation between the vegetation and the absolute and relative ion content of mire waters in middle Europe (In: 5th Int. Peat Congress "Peat and peatlands in the natural environment protection") – Poznań-Poland, September 21–25, NOT, 2: 67–72.
- 89. Podbielkowski Z. 1960 Zarastanie dołów potorfowych [Plant overgrowing of pits after peat winning] - Monogr. Bot. 10: 1-46.
- 90. Podbielkowski Z., Tomaszewicz H. 1979 Zarys hydrobotaniki [An outline of hydrobotanics] – Państwowe Wydawnictwo Naukowe, Warszawa, 531 pp.
- 91. Polakowski B. 1963 Stosunki geobotaniczne Pomorza Wschodniego [Geobotanic relations in eastern Pomerania] - Zesz. nauk. WSR, Olsztyn, 15: 1-168.
- 92. Polakowski B., Dąbek E., Dziedzic J., Jutrzenka-Trzebiatowski A., Korniak T., Pietraszewski W. 1980 – Zarys stosunków geobotanicznych Mazurskiego Parku Krajobrazowego, IV. Zespoły roślinności wodnej i szuwarowej, V. Zespoły torfowiskowe [An outline of geobotanic relations of the Masurian Landscape Park, IV. Aquatic and reed plant communities, V. Peatbog associations] – Zesz. nauk. ART, Olsztyn, Roln. 30: 13-37. 93. Polakowski B., Endler Z. 1985 – Primary production of herb layer in forest and shrub communities of the Jorka River watershed - Pol. ecol. Stud. 11: 321-336.

94. R a d o m s k i Cz. 1969 – Szkodliwe dla rolnictwa zjawiska meteorologiczne w woj. olsztyńskim [Meteorological phenomena disadvantageous to agriculture in the province of Olsztyn] - Zesz. nauk. WSR, Olsztyn, A, 25: 941-955. 95. R a d o m s k i Cz. 1971 – Stosunki termiczne i wilgotnościowe na terenie woj. olsztyńskiego

w aspekcie rolniczym [Agricultural aspects of thermic and humidity conditions in the province of Olsztyn] – Zesz. nauk. WSR, Olsztyn, A, 27: 3-14.

- 96. R a d o m s k i Cz., H u t o r o w i c z H. 1969 Ocena porównawcza kilku ważniejszych cech agroklimatu Poj. Mazurskiego [Comparative evaluation of some more significant features of agroclimate in the Masurian Lakeland] Zesz. nauk. WSR, Olsztyn, A, 25: 955–966.
- 97. R a d o m s k i Cz. H u t o r o w i c z H. 1971 O niektórych charakterystykach agroklimatycznych Warmii i Mazur [On certain agroclimatic characteristics of Warmia and Masuria] – Zesz. nauk. WSR, Olsztyn, A. 27: 15-21.
- 98. Rejment-Grochowska I., Sobotka D., Mickiewicz J., Lepiarz--Wittner E. 1975 – Production of moss biomass in uncultivated meadows – Ekol. pol. 23: 627-635.
- 99. R i e l e y J. O. 1981 Productivity and nutrient turnover in mire ecosystems, II. Standing crop and nutrient content of plants from two ombrophilous mire associations in Poland – Zesz. nauk. Akad. Roln., Wrocław, Roln. 38: 157–164.
- 100. R u s a l e n k o A. I. 1983 Struktura i produktivnosť lesov pri podtoplenii i zatoplenii – Akademia Nauk Beloruskoj SSR, Čelovek i sreda, Nauka i Technika, Minsk, 176 pp.
- 101. R y s z k o w s k i L. 1979 Produkcja rolna a przepływ energii i obieg materii w agroekosystemach [Agricultural production with respect to energy passage and matter cycling in agroecosystems] – Zesz. probl. Post. Nauk roln. 228: 29-50.
- 102. S a t o o T. 1970 A synthesis of studies by the harvest method: primary production relations in the temperate deciduous forests of Japan (In: Analysis of temperate forest ecosystems, Ed. D. E. Reichle) – Ecological Studies 1, Springer-Verlag, New York-Heidelberg-Berlin, 55-72.
- 103. Sharpe D. M. 1975 Methods of assessing the primary production of regions (In: Primary

- productivity of the biosphere, Eds. H. Lieth, R. H. Whittaker) Ecological Studies 14, Springer-Verlag, New York-Heidelberg-Berlin, 147-166.
- 104. S i e g e 1 S. 1956 Nonparametric statistics for the behavioral sciences McGraw-Hill, Auckland, 312 pp. –
- 105. S j ö r s H. 1961 Some chemical properties of the humus layer in Swedish natural soils Bull. Roy. School For. 37: 1-51.
- 106. S j ö r s H. 1983 Mires of Sweden (In: Ecosystems of the world. 4B. Mires: swamp, bog, fen and moor. Regional studies, Ed. A. J. P. Gore) Amsterdam–Oxford–New York, 69–94.
- 107. S o b o t k a D. 1967 Roślinność strefy zarastania bezodpływowych jezior Suwalszczyzny [Vegetation of the overgrowing-subject zone in nooutflow lakes in the region of Suwałki]
 Monogr. Bot. 23: 175-258.
- 108. S o l i ń s k a B. 1963 Dynamics of vegetation in tiny water bodies as basis for their classification (on the example of Mikołajki vicinity) Ekol. pol. A, 11/16: 369-420.
- 109. S o l o n e v i č N. C. 1971 K metodike opredelenija biologičeskoj produktivnosti bolotnych rastitel'nych soobščestv Bot. Ž. 56: 497–511.
- 110. Sonesson M. 1970 Studies on the mire vegetation in the Torneträsk area of Nothern Sweden, IV. Some habitat conditions of the poor mires Bot. Notiser. 123: 67–111.
- 111. Stachurski A., Zimka J. 1975a Leaf fall and the rate of litter decay in some forest habitats Ekol. pol. 23: 103-108.
- 112. Stachurski A., Zimka J. 1975b Methods of studying forest ecosystems: leaf area, leaf production and withdrawal of nutrients from leaves of trees Ekol. pol. 23: 637-648.
- 113. Stachurski A., Zimka J. 1976 Methods of studying forest ecosystems: microorganism and saprophate consumption in the litter Ekol. pol. 24: 57-67.
- 114. Stachurski A., Zimka J. 1984 The budget of nitrogen dissolved in rainfall during its passing through the crown canopy in forest ecosystems Ekol. pol. 32: 191-218.
- 115. Stachurski A., Zimka J. 1987 Niektóre konsekwencje dużych dopływów pierwiastków z atmosfery dla ekosystemów leśnych [Some consequences of large inflows of chemical elements



. .

- 117. Stuart Chapin III F. 1980 The mineral nutrition of wild plants An. Rev. Ecol. System. 11: 233-260.
- 118. Summerfield R. J. 1974 The reliability of mire water chemical analysis data as an index of plant nutrient availability - Plant Soil, , 40: 97-106.
- 119. Szczepański A. 1979 Ecology of macrophytes in wetlands Pol. ecol. Stud. 4(4): 45-94.
- 120. Tolonen K., Seppänen P. 1976 Comparison of ombrotrophic and minerotrophic mire waters in Finland (In: 5th Int. Peat Congress "Peat and peatlands in the natural environment protection") – Poznań-Poland, September 21–25, NOT, 2: 73–89.
- 121. Tołpa S., Gorham E. 1961 The ionic composition of waters from three Polish bogs J. Ecol. 49: 127–133.
- 122. Traczyk T. 1967a Propozycja nowego sposobu oceny produkcji runa [Suggestions for new methods of assessment of herb layer production] - Ekol. pol. B, 13: 241-247.
- 123. Traczyk T. 1967b Studies on herb layer production estimate and the size of plant fall Ekol. pol. A, 15: 837-867.
- 124. Traczyk T. 1985 The role of plant subsystem in matter flow in the agricultural landscape Pol. ecol. Stud. 11: 445-466.
- 125. Traczyk H., Traczyk T. 1967 Tentative estimation of the production of herb layer Ekol. pol. A, 15: 823-835.
- 126. U s o l' c e v V. A. 1974 Fitomasa kron spelych berezovo-osinovych nasaždenij v severnom Kazachstane – Lesovedenie, 2: 86–88.
- 127. Usol'cev V. A., Kričun V. M. 1982 Zakonomernosti formirovanija nadzemnoj fitomassy berëzy i osiny v koločnych lesach Severnogo Kazachstana – Lesovedenie, 3: 41-52. 128. Utkin A. I., Ermolova L. S. 1979 – Biologičeskaja produktivnosť, kuľtur sosny

- obyknovennoj v Ul'janovskom povolž'e Lesovedenie, 3: 3–16.
- 129. Utkin A. I., Ivanova M. G., Ermolova L. S. 1981 Pervičnaja biologičeskaja produktivnosť kuľtur sosny obyknovennoj vo Vladimirskoj Oblasti – Lesovedenie, 4: 19-27.
- 130. Utkin A. I., Roždestvenskij S. G., Ermolova L. S., Oskina N. V. 1980 – Biologičeskaja produktivnosť 22-letnich kul'tur sosny obyknovennoj i listvennicy sibirskoj v Jaroslavskoj Oblasti – Lesovedenie, 5: 85-91.
- 131. V a k u r o v A. D. 1973 Osobennosti rosta sosny v nekotorych sfagnovych bolotach Bassejna r. Onega — Lesovedenie, 6: 31 - 37.
- 132. Virri K. 1976 Exchange characteristics in twelve organic profiles in south Finland (In: 5th Int. Peat Congress "Peat and peatlands in the natural environment protection") - Poznań-Poland, September 21-25, NOT, 2: 229-235.
- 133. V y s k o t M. 1976 Tree story biomass in lowland forests in South Moravia Academia, Praha, R. 86, 10, 166 pp.
- 134. Walczyna J., Kuczyńska J., Sapek B. 1976 Pobieranie mikroelementów przez gatunki roślin łąkowych z gleb torfowych [Microelement absorption from peat soil by meadow plant species] - Zesz. probl. Nauk roln. 179: 237-244.
- 135. W a r n c k e E. 1980 Spring areas: ecology, vegetation and comments on similarity coefficients applied to plant communities – Holarct. Ecol. 3: 233-308.
- 136. W a u g h m a n G. J. 1980 Chemical aspects of the ecology of some south German peatlands - J. Ecol. 68: 1025-1046.
- 137. Whittaker R. H., Marks P. L. 1975 Methods of assessing terrestrial productivity (In: Primary productivity of the biosphere, Eds. H. Lieth, R. H. Whittaker) - Ecological Studies 14, Springer-Verlag, New York-Heidelberg-Berlin, 55-119.
- 138. Whittaker R. H., Woodwell G. M. 1968 Dimension and production relations of trees and shrubs in the Brookhaven Forest - J. Ecol. 56: 1-27.
- 139. Zimka J. (in press) Nutrient transfer in forest ecosystems Pol. ecol. Stud.

fow z atmosforyedia exertystemotivitation (and consequences of three shows of

