ACTA SOCIETATIS
BOTANICORUM POLONIAE
Vol. 50, nr 3: 515—540
1981

The map of potential natural vegetation as a basis for comparative studies and geobotanical regionalization

JOANNA PLIT

Institute of Botany, Polish Academy of Sciences, Lubicz 46, 31-512 Kraków, Poland

(Received: October 10, 1979)

Abstract

A method of typology and regionalization of landscape units of vegetation on the basis of a map of potential natural vegetation is presented. Particular attention has been paid to the methodical basis of the conducted division. The map of potential natural vegetation was subsequently compared with maps of other elements of the natural environment and the result of geobotanical regionalization was compared to the complex physicogeographical regionalization.

INTRODUCTION

Geobotanical regionalization has rich traditions in Poland, going back to the beginning of the twentieth century. Pol (1847) formulated the first attempt at a geobotanical division of Polish territories. His ideas, continued and developed by Szafer (1972), for many years indicated the direction of investigations undertaken by Polish geobotanists. The newest expression of this theoretical and methodological line is the chapter "The basis of geobotanical divisions of Poland" (Szafer 1972) and the map on a scale 1:2 000 000 entitled "Szata roślinna Polski" (Szafer and Zarzycki 1972). The authors had the following basic criteria: 1) the contemporary character of the vegetation based on its historical changes; 2) the total of physiogeographical conditions.

As an index of the "contemporary character of the flora and plants mainly the range of occurrence of shrubs and trees were taken, partly supplemented by the differentiation of other characters (eg. the undergrowth) on the basis of physiognomical differences easily discernible in the field" (Szafer 1972). It should be stressed that this division,

Fig. 1. Geobotanical division of Poland (W. Szafer, B. Pawłowski, 1959 1972)
Boundaries of: sections (1), subsections (2), regions (3), districts (4).
Province: Central European
Subprovince: Lowland and Upland
Division: Baltic
Subdivision: Great European Lowland
Region — Mazowsze (5)
— Podlasie (6)
— Polesie Lubelskie (7)
Subdivision: Zone of Submontane Depressions
Region — Sandomierz Depression (8)
Subdivision: Zone of Central Uplands
Region — Miechów-Sandomierz (9)
— Świętokrzyska (10)
— Northern Edge Eminences (11)
— Lublin Upland (12)
— Roztocze (13)
Province: Pont-Pannonia
Division: Steppe-Forest
Region — Western Volhynia (14)
Province: Montane, Central European
Subprovince: Carpathian
Division: Western Carpathians (15)
Eastern Carpathians (16)

---

though in many cases based on intuition, is still the best of the existing geobotanical divisions of Poland (Fig. 1).

When a review map of the potential natural vegetation of Poland began to be elaborated, the possibility arose to base regionalization on a new basis, namely on the cartographically elaborated results of field investigations covering the whole area of the country, aimed at learning the spatial distribution of contemporary potential natural vegetation, understood according to Tüxen (1956) as an expression of the differentiation of the ecological and productive potential of natural habitats regardless of the actual utilization and exploitation of the physical and geographical environment. It can be expected that geobotanical regionalization based on such a synthetic premise will be a fuller and closer approximation of reality the hitherto accepted regionalization.

Even though the elaboration of the above-mentioned map has not yet been finished attempts have already been made to use it as a basis for geobotanical regionalization. Faliński (1972) has made such a regionalization on the basis of the map of potential vegetation of the Bielsk Height. He was the first to specify the criterion for distinguishing the northern and baltic sections, namely three associations (oak-hornbeam forest, mixed acidophilous coniferous forest and acidophilous coniferous forest) occur in two geographic variants, and the difference among the vicariants runs along the same line. Wojterski (1972) has used the map of potential vegetation for regionalization of Zie-


WARSZAWA
Siedlce
Bug
Wisła
Pilica
Wieprz
Radom
Puławy
Lublin
Kamienna
Sandomierz
Zamośc
San
Bug
Wisła
Tanew
Dunajec
Wisłoka
Rzeszów
Wisłok
Przemyśl
0
50 km
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16

mia Lubuska. Both authors ascribed an important function to the environment, therefore the proposed divisions have the character of complex physicogeographical regionalizations taking vegetation as the leading factor. There is no regionalization of vegetation as an autonomous element. Its theoretical bases have also not been elaborated.

In this work the aim was to use a medium-scale review map of potential natural Polish vegetation as the basis of geobotanical regionalization and to determine the relationship of the geographical division based on the differentiation of vegetation to analogous physicogeographical divisions, based mainly on abiotic elements of the environment.

From the methodical point of view there are two parallel trends. One is based on the idea of landscape phytocomplexes (J. M. Matuszkiewicz 1978, 1979). The second is called provisionally the statistical and comparative method of plan analysis. This work represents the second trend and is a development of the previous work (W. Matuszkiewicz and Plit 1978). The aim of the present paper is: 1) to present the method of obtaining a map of geobotanical division from a review map of potential vegetation on a more differentiated and richer materal; 2) to specify the bases of regionalization, especially to specify the criteria for boundaries; 3) confrontation of the map of vegetation taken as the basis of the elaboration with maps of selected elements of the physical and geographical environment; 4) comparison of the obtained geobotanical division with a complex physical and geographical regionalization.

MATERIALS AND METHODS

A large area lying between 50°15′ and 51°30′ N and 21°50′ E to the boundary of Poland, ie. 25 sheets of a 1:100 000 map was elaborated. The following reasons determined this selection: 1) the existence of a good map of the potential natural vegetation of this area, 2) the course of several boundaries of various ranks in this area (according to previous geobotanical divisions), 3) a strong differentiation of the natural environment.

Regionalization was performed by a combined method: induction and deduction.

By the method of induction basic units were chosen, this method was used at the stage of analysis of content typology of units and during elaboration of a map of fractionation. The method of deduction was used to determine regionalization and the rank of boundaries.

In selection of basic units the method of subjective boundary creation was used, and the criteria were defined in order to obtain maximum objectivity. The division of the surface of the map was made uniquely on the basis of the phytosociological content in a normal way, ie. disregarding the content of the isolates and giving each of them the same rank. The sequence of action in selecting basic units: 1) isolation of units on the basis of definitely dominant associations; 2) isolation of surfaces based on the combination of colored spots, taking into consideration changes in quantitative relations; 3) isolation of areas characterized by different structures and textures (specific arrangement of coloured spots).

The content of the map was analyzed by a method similar to that of Pawłowski (1972). Basic units were characterized by an inventory of potential natural associations. Homogeneous areas of plants were characterized by the participation of the occurring plant species. On the map the whole unit was analyzed and not a selected test area. As there is no basis for the qualitative valorization of particular associations as characters of a given set, all associations were similarly treated, regardless of their taxonomic rank, and valorized only on the basis of their surface participation and by means of a modified Braun-Blanquet (1954) scale. All classes were expressed as numbers, in order to make numerical operations possible. A scale variant (1 — up to 1% surface, 2 — 1.1-10% surface, 3 — 10.1-25% surface, 4 — 25.1-50% surface, 5 — 50-75% surface, 6 — 75.1-100% surface) favoring rare associations occurring on a small area was chosen as during the trials they proved to be the most differentiating.

The basic units were assembled in a "crude table". Each column corresponds to one unit, each line to an association described in the legend. In ordering the crude table the Wrocław taxonomic method ie. the diagraphic methods of Czekanowski (1909) was used. In order to determine the taxonomic distance a so-called "Euclidian distance" $D_{(A,B)}$ was chosen:

$$D_{(A,B)} = \sum_{j=1}^{j=n} \sqrt{(x_{A_1 j} - x_{B_1 j})^2}$$

x_{Aj} — designates the degree of coverage of the surface of the association in the basic unit A;

x_{Bj} — designates the degree of coverage of the surface area in the basic unit B with an associations presented in the table.

By this method the compared elements can only be arranged in a linear fashion, which rarely corresponds to the real situation, therefore the dendrite method has also been used (Florek et al. 1951). To check this result the crude table was ordered in a statistically determined order and then elaborated as a normal phytosociological table (Ellenberg 1956), using associations occurring in particular units as ordering characters. The ordered table makes it possible to conduct a typological division and the distinguishing of plant landscapes.

The distribution of content on the map was followed. Within the fundamental units a calculation was made in how many isolates each of the associations was found. The size (in square kilometers) of an average isolation in each unit was calculated. The result was taken as a measure of fragmentation. Czekanowski diagram, dendrites, tables and fragmentation maps show a clustered arrangement of units, showing a high degree of similarity in respect to the analyzed characters. On the basis of groups of similar units types of plant landscape were distinguished.

In order to perform a homogeneous hierarchical spatial division in a given area the following hierarchy of character importance was taken: 1) the change of dominant zonal associations, eg. beech woods for forest growing on dry grounds; 2) the regional variation of the zonal association (the formation of forms substituting for each other geographically); 3) the change of the dominant association not showing a zonal distribution within Poland; 4) differences in characteristic combinations of associations, that is coexistence of subdominant associations in a specific spatial arrangement (when a decisively dominant association is absent); 5) differences in quantitative relationships between condominants; 6) areas differing from each other by distinctly different structure, and the maximum of occurrence of accompanying associations. As hierarchization only to a small extent pays attention to differentiation derived from formal analysis of the map, in cases of significant differences in fragmentation the rank of the boundary was elevated by one class.

RESULTS AND DISCUSSION

ORIGINAL RESEARCH

93 basic units were distinguished (Fig. 2). In strongly differentiated areas no difficulties were encountered in boundary formation, they did, however, occur in division of large homogeneous areas. Czekanowski's diagram (Fig. 3) divides a collection of units into 5 large groups. The first three groups with a considerable internal cohesion, show a weak relationships with the rest of the diagram. Groups 4 and 5 have a distinct inner division, into a typical part very homogeneous internally, and a transit part showing cross solutions. Moreover unit 40, which has no relations with the other groups must be treated as a separate type. Fig. 4 shows a dendrite, to make interpretation easier the units have been enriched with a typological content. The dendrite is basically composed of 8 parts. Two branches are the landscapes of Central Polish and Wołyń oak-hornbeam forests are connected with va-

Table 1 Types of plant landscapes

	93	91	38	29	90	86	92	89	39	88	87	1	22	20	23	8	7	6	59	19	16	60	12	10	11	15	17	14	18	62	56	61	57	58
Ficario-Ulmetum typicum	4	3	4	3	3	4	4	4	6	4	2																							
Salici-Populetum	3	3	3	2	3	2	5	6		3	3																							
Tilio-Carpin. var.Central Polish fertile								2				3	4	2	2	2	3	3																
Tilio-Carpin. var.Central Polish poor					2			2				4	4	5	4	4	3	3																
Ficario-Ulmetum chrysosplenietosum	4	2																	1	2	2	2	3	2	2	2	1	2	2	3	2	2	2	2
Tilio-Carpin. var. Wołyń poor		2																	2	6	5	4	4	4	3	3	3	2	2		2	2	1	
Tilio-Carpin. var. Wołyń fertile	2	1																	2			2	3	3	4	4	5	4	4	5	6	6	6	6
Tilio-Carpin. var. Little Poland fertile										3	4																							
Tilio-Carpin. var. Little Poland poor			3	3		2				1	2																							
Leucobryo-Pinetum														1	2																			
Abietetum polonicum																																		
Vaccinio uliginosi-Pinetum															1		1	2																
Oxycocco-Sphagnetea																																		
Peucedano-Pinetum																2																		
Pine - oak forest																																		
Carici elongatae-Alnetum	1	2	1	2				2	2	1		2		1	2	2	4	4	2		2	2	2	3	3	2	2	2	1					
Pino-Quercetum		3	3	2	1						1		2	2	3	3	2	1	4	2	2		2	2	1	1								
Potentillo albae-Quercetum														2	2	3	2	2		2	2	3	1	2	3	1	2	2	2		2	2		2
Festucetalia valesiacae																								1	1		1	1	1	1		1	1	
Fertile high oak forest																		2						2	2	1	2	3	2	3	1	2	1	
Dentario glandulosae-Fagetum																																		
Galio-Abietion																																		
Circaeo-Alnetum	2	2	2	4	3	2		2	1	1	3	3	2	2	2	2	2	2	4	2	2	2	2	2	2	3	2	2	2	1	2	1	1	
Industrioklimaks																												2	1					
Bushy oak forest																																		

	74	48	50	43	52	41	36	30	37	42	33	26	46	47	55	49	45	51	44	35	31	25	24	13	27	54	9	84	80	28
Ficario-Ulmetum typicum																					1								1	
Salici-Populetum																2					2									
Tilio-Carpin. var.Central Polish fertile																														
Tilio-Carpin. var.Central Polish poor																														
Ficario-Ulmetum chrysosplenietosum															2												1			
Tilio-Carpin. var. Wołyń poor																														
Tilio-Carpin. var. Wołyń fertile																														
Tilio-Carpin. var. Little Poland fertile	5	6	6	6	6	6	6	6	6	6	6	6	5	6	6	6	6	6	5	5	6	5	3	3	4	4	2	3	1	2
Tilio-Carpin. var. Little Poland poor	2	3				2	2	2	2	2	2	2	2	1	2	2	3	2	4	2	2	2	4	4	6	6	5	5	4	4
Leucobryo-Pinetum																														
Abietetum polonicum																														
Vaccinio uliginosi-Pinetum																														
Oxycocco-Sphagnetea																														
Peucedano-Pinetum																														
Pine - oak forest																														
Carici elongatae-Alnetum		2								1	1	1		2		1		1	1		2	1		2		2	2		2	2
Pino-Quercetum	1								1	1	1	1						2				2	2	2	2	3	2	1	1	3
Potentillo albae-Quercetum									1			1		2	2					3	2	2	3	3	2	2	2			
Festucetalia valesiacae								1							1	1	1	1	1	1	1	2	1							
Fertile high oak forest	1		1	1	1		1	2	2	2	1		3	2	2	2	2	2	1	2	2	2	3	2						
Dentario glandulosae-Fagetum															2	2	2	2	1									2		
Galio-Abietion																												2		
Circaeo-Alnetum	2	2	2	2	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3	2	2	3	2
Industrioklimaks																						1	2							
Bushy oak forest																														

	34	73	32	79	83	85	77	53	75	76	78	72	64	81	82	70	71	67	66	65	68	69	63	21	4	3	2	5	40
Ficario-Ulmetum typicum																													
Salici-Populetum												2				2											2	1	
Tilio-Carpin. var.Central Polish fertile																								3	2	3	2	2	
Tilio-Carpin. var.Central Polish poor							2																						
Ficario-Ulmetum chrysosplenietosum																													
Tilio-Carpin. var. Wołyń poor																													
Tilio-Carpin. var. Wołyń fertile																													
Tilio-Carpin. var. Little Poland fertile	3	1	2	1	1	2	3	4	3	1	2	2			1	1	2											1	2
Tilio-Carpin. var. Little Poland poor	5	5	3	3	4	3	3	2	2	2	1	3	2	2	3	3	2	1	1									2	2
Leucobryo-Pinetum	2	1	2	2	2	2	2	2	2	2	2	3	2	4	5	4	6	3	4	4	5	5	5	4					2
Abietetum polonicum							2	2	2	2	2	2				1	1	3	2	3	2	2							
Vaccinio uliginosi-Pinetum									1				2	1	2		1	2	2	2	2	2	2	1	2	2	2	2	
Oxycocco-Sphagnetea													1			1	2	1	2	1	2	2	1		1	1	1	1	
Peucedano-Pinetum																									4	2			
Pine - oak forest																												3	3
Carici elongatae-Alnetum	2	1	2	2	2	1	2	2	2	1	1	1	3	2	1	1	2	3	2	3	2	2	1	3	2	3	4	4	1
Pino-Quercetum	2	2	4	4	4	4	4	3	3	2	3	3	5	5	4	2	2	2	3	3	3	2	3	4	3	4	4	2	2
Potentillo albae-Quercetum							1																	2		2	2	3	
Festucetalia valesiacae												1																	1
Fertile high oak forest	2	1	2				2	2	2	2	1	2																	4
Dentario glandulosae-Fagetum								2	2	2	3																		1
Galio-Abietion							2			2	2																		
Circaeo-Alnetum	2	2	3	2	2	3	2	2	2	2	2	2	2	2	2	2	2	1	3	2	2	1	2	3	2	2	2	2	2
Industrioklimaks																								3					1
Bushy oak forest																													1

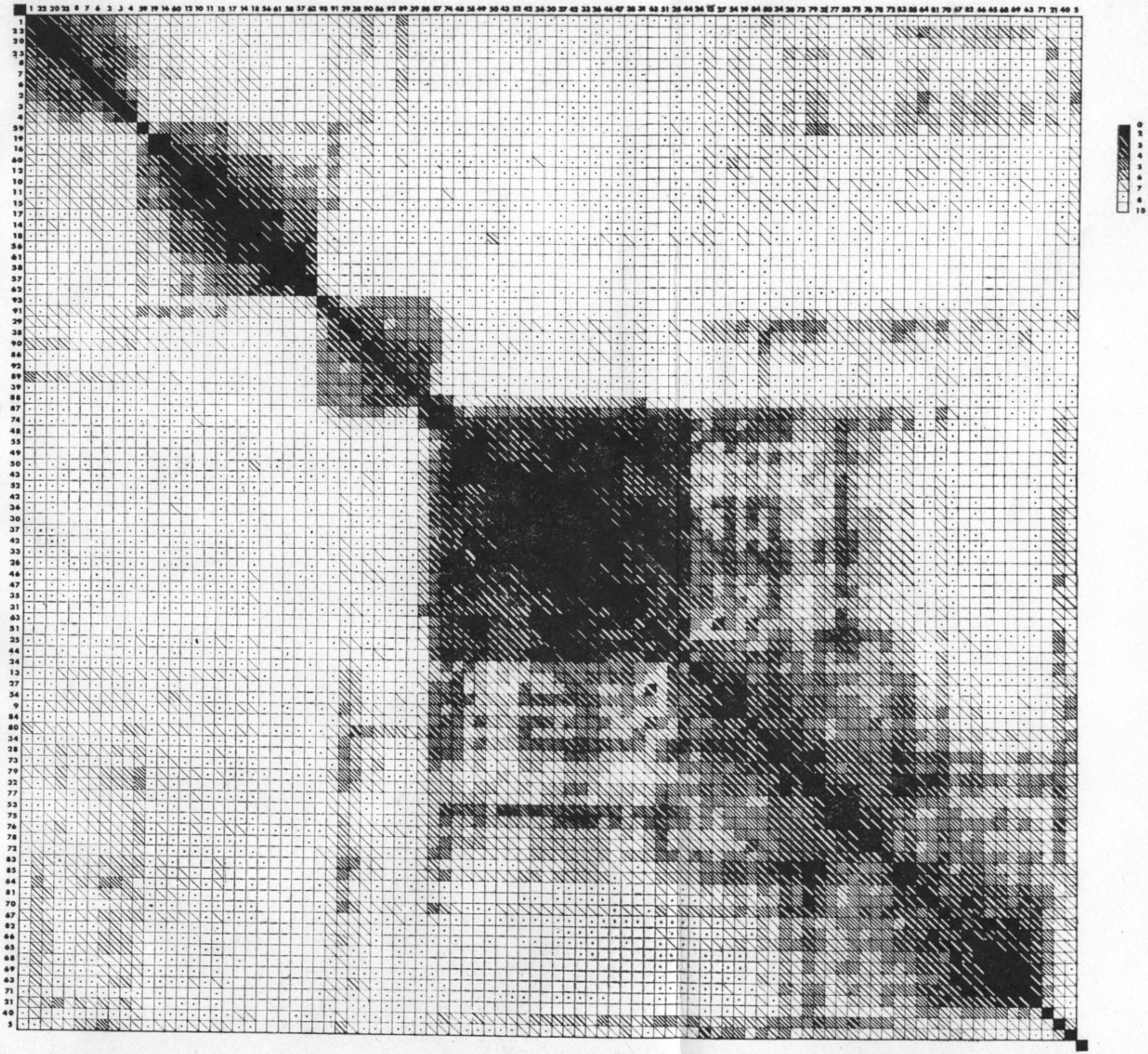


Fig. 3. Czekanowski diagram

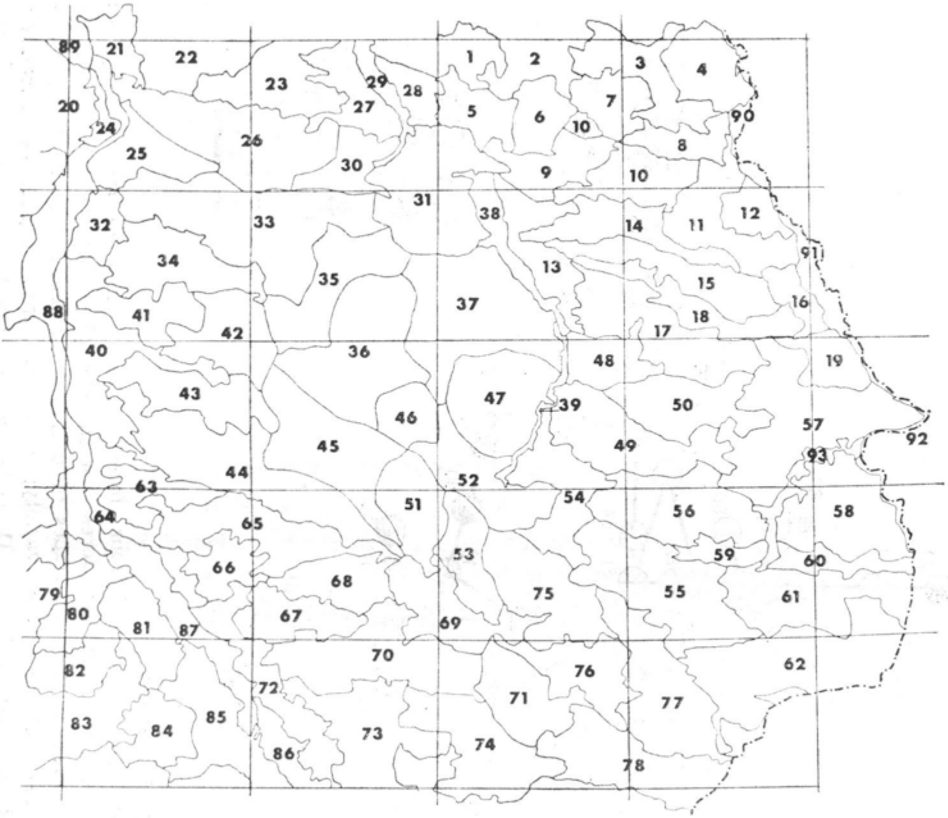


Fig. 2. Boundaries of the basic units

lues of D greater than 5. At the same level the acidophilous coniferous forest unit 21 is separated, unit 40 is characterized by a considerable specificity.

The ordered table (1) of types of plant landscapes gives a very distinct typological picture of the differentiation of basic spatial units. Regionally characteristic associations are easily distinguished. They form in all directions very large typological units which have a significant spatial differentiation. Therefore to define a basic unit we have used a characteristic combination of associations analogous to a characteristic combination of species (Szata roślinna Polski, 1972). On the basis of characteristic and distinguishing associations we have obtained a hierarchical typological division. 7 units of higher rank were isolated, which unite types of plant landscapes into so-called groups of types.

I. Group of elm-ash forest landscapes of great river valleys:

1. type of elm-ash forest landscapes of great river valleys.

II. Group of types of landscapes of oak-hornbeam forests in the Central Polish variety:

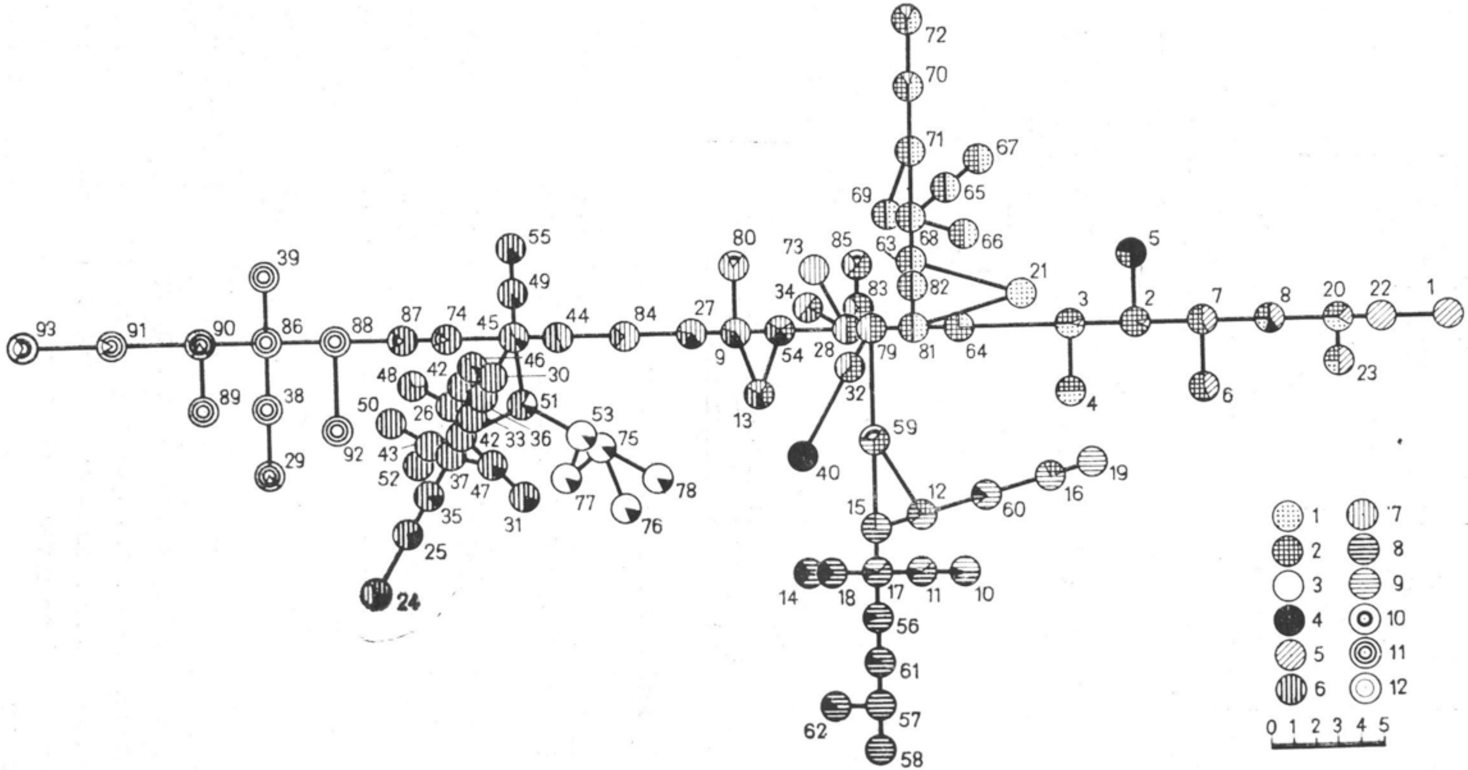


Fig. 4. Dendrite

1 — acidophilous coniferous forest landscapes; 2 — mixed acidophilous coniferous forest landscapes; 3 — beech fir forest landscapes; 4 — oak forest landscapes; 5 — landscapes of poor oak-hornbeam forests of the Central Polish variety; 6 — landscapes of fertile oak-hornbeam forests of the Little Poland variety; 7 — landscapes of poor oak-hornbeam forests of the Little Poland variety; 8 — landscapes of fertile oak-hornbeam forests of the Wołyń variety; 9 — landscapes of poor oak-hornbeam forests of the Wołyń variety; 10 — landscapes of alder and ash marshy forests, 11 — landscapes of willow and poplar marshy forests and elm and ash marshy forests; 12 — landscapes of elm forests

1. landscape of oak-hornbeam forests
2. landscape of alder forests and oak-hornbeam forests.

III. Group of landscapes of oak-hornbeam forests of the Wołyń variety:

1. landscape of mixed acidophilous oak-pine forests with marshy forests and oak-hornbeam forests,
2. landscape of poor oak-hornbeam forests,
3. landscape of alder forests and oak-hornbeam forests,
4. landscape of fertile high oak woods,
5. landscape of fertile oak-hornbeam forests.

IV. Group of types of landscapes of oak-hornbeam forests of the little Poland variety:

1. type of landscape of fertile oak-hornbeam forests,
2. type of landscape of poor oak-hornbeam forests,
3. type of landscape of mixed acidophilous oak-pine forests with oak-hornbeam forests.

V. Type of beech and fir wood landscapes:

1. type of beech and fir wood landscape with participation of acidophilous coniferous forests and oak-hornbeam forests.

VI. Group of types of landscapes of acidophilous coniferous forests:

1. type of landscape with predominance of mixed acidophilous oak-pine forests,
2. type of landscape of suboceanic acidophilous oak-pine pine forests,
3. type of landscape of continental acidophilous oak-pine pine forests.

VII. Group of types of oak forest landscapes:

1. type of poor oak forest landscape with participation of alder forests,
2. type of landscape of fertile thermophilic oak forests and xerotherms.

The above-mentioned types of landscapes were placed on a map (Fig. 5 — in the case of mixed types the two dominant hachures were placed on the map). The intensity of the hachure shows the proportional participation of the components. Thus a typological map of plant landscapes was obtained. All the spatially joined units of the same type form landscape areas.

The variation of the size of divisions in particular basal units distinctly distinguishes the surface of the map (Fig. 6). The map is divided into three parts: 1) the NE area characterized by considerable fragmentation, the average surface area of a separated area is 1.1 to 4.0 square kilometers; 2) from N to S along the Vistula river and to S of the investigated area there is a zone of great and very great fragmentation; 3) the whole middle section of the map is occupied by units with particularly small fragmentation. On the basis of the typological map a regional division was made based on the criteria described in

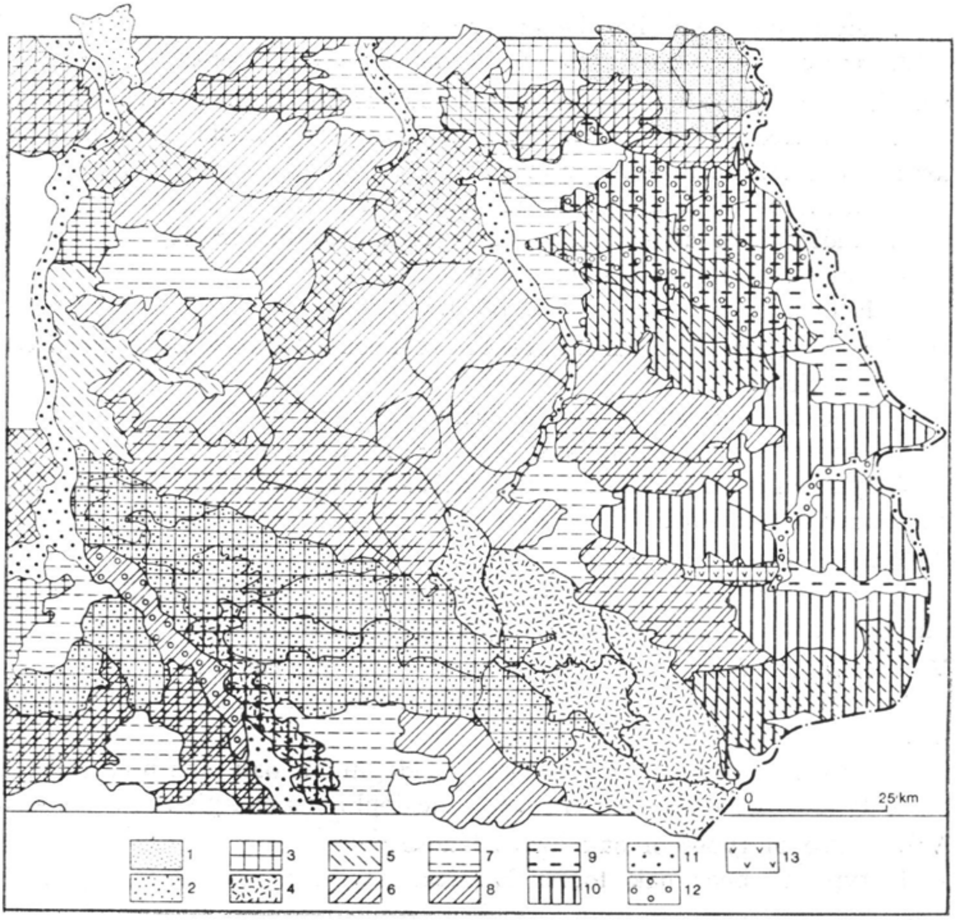


Fig. 5. Types of ecological landscapes
1 — landscape of subcontinental acidophilous oak-pine pine forests; 2 — landscapes of suboceanic acidophilous oak-pine pine forests; 3 — landscape of mixed acidophilous oak-pine forests; 4 — landscape of beech fir forests; 5 — oak forest landscape; 6 — landscape of poor oak-hornbeam forests of the Central Polish variety; 7 — landscape of poor oak-hornbeam forests of the Little Poland variety; 8 — landscape of fertile oak-hornbeam forests of the Little Poland variety; 9 — landscape of poor oak-hornbeam forests of the Wołyń variety; 10 — landscape of the fertile oak-hornbeam forests of the Wołyń variety; 11 — landscape of willow and poplar marshy forests and elm and ash marshy forests; 12 — landscape of alder and ash marshy forests; 13 — landscape of elm forests

the preceding chapter. Units similar in content and degree of fragmentation were joined, and ways of structural organization were taken into consideration. In putting together basic units into a regional unit the typological agreement is reliable up to a landscape variant (D smaller than 3) as well as a similar order of magnitude of the index of fragmentation. The formation of the hierarchy of boundaries yielded a 5 degree regional division (Fig. 7). When the map of potential Polish natural vegetation is taken as a basis for consideration no sufficient arguments can be found to maintain the ideas of Szafer (1972) who in Lubelszczyzna isolated the westernmost fragment of the Pontine Pannonian Province described as the Steppe-Forest section with the West Wołyń region. This region is potentially overgrown by an abundant compact oak-hornbeam forest (small but abundant fragments of forests of this type are conserved). The forms of warm and fertile *Tillio-Carpinetum* dominate, without beech and fir trees. In this region the number of thermophilic oak forests and xerothermic grasses does not increase — as would have been expected. The xerothermic species are numerous but occur disseminated in the forest and do not form swards.

This whole area is within the range of the zonal association, ie. oak-hornbeam forests. Second order boundaries, analogous to the

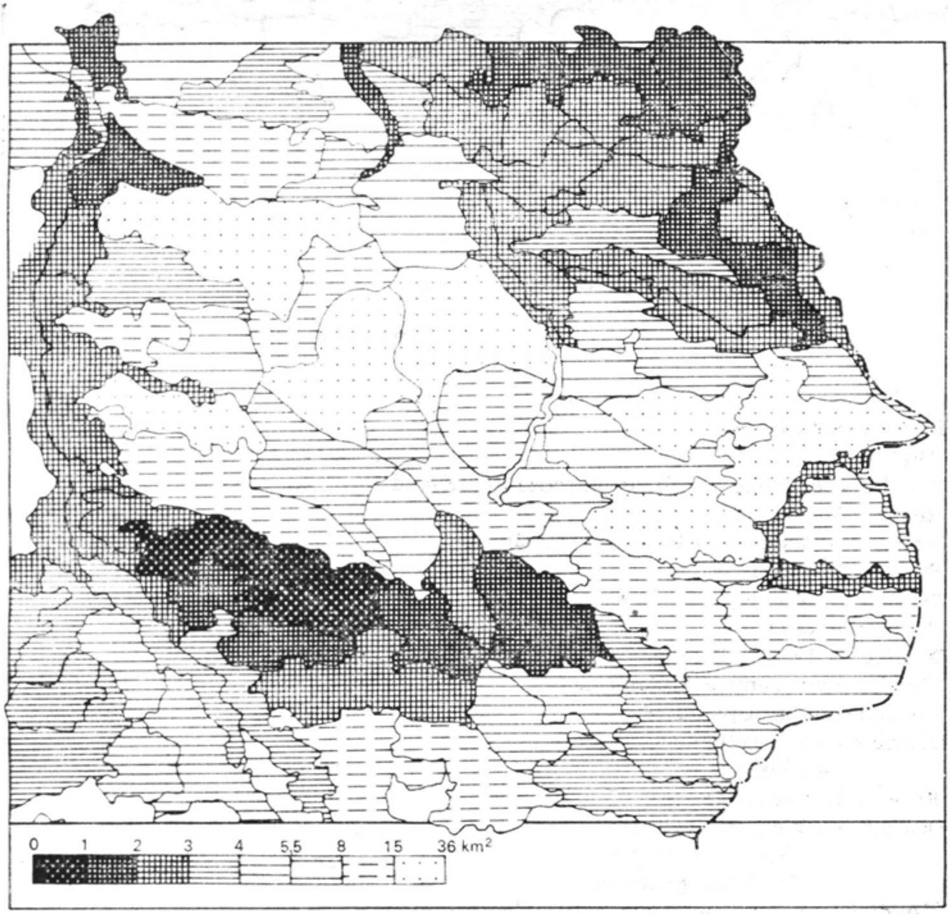


Fig. 6. Map of fragmentation (average isolated area)

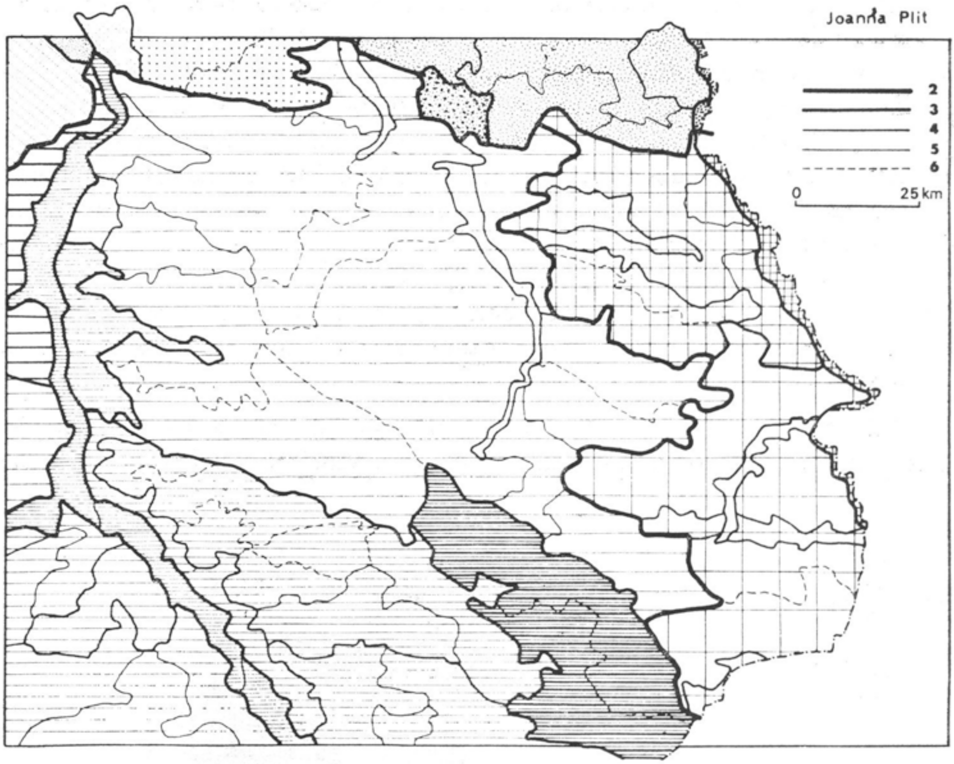
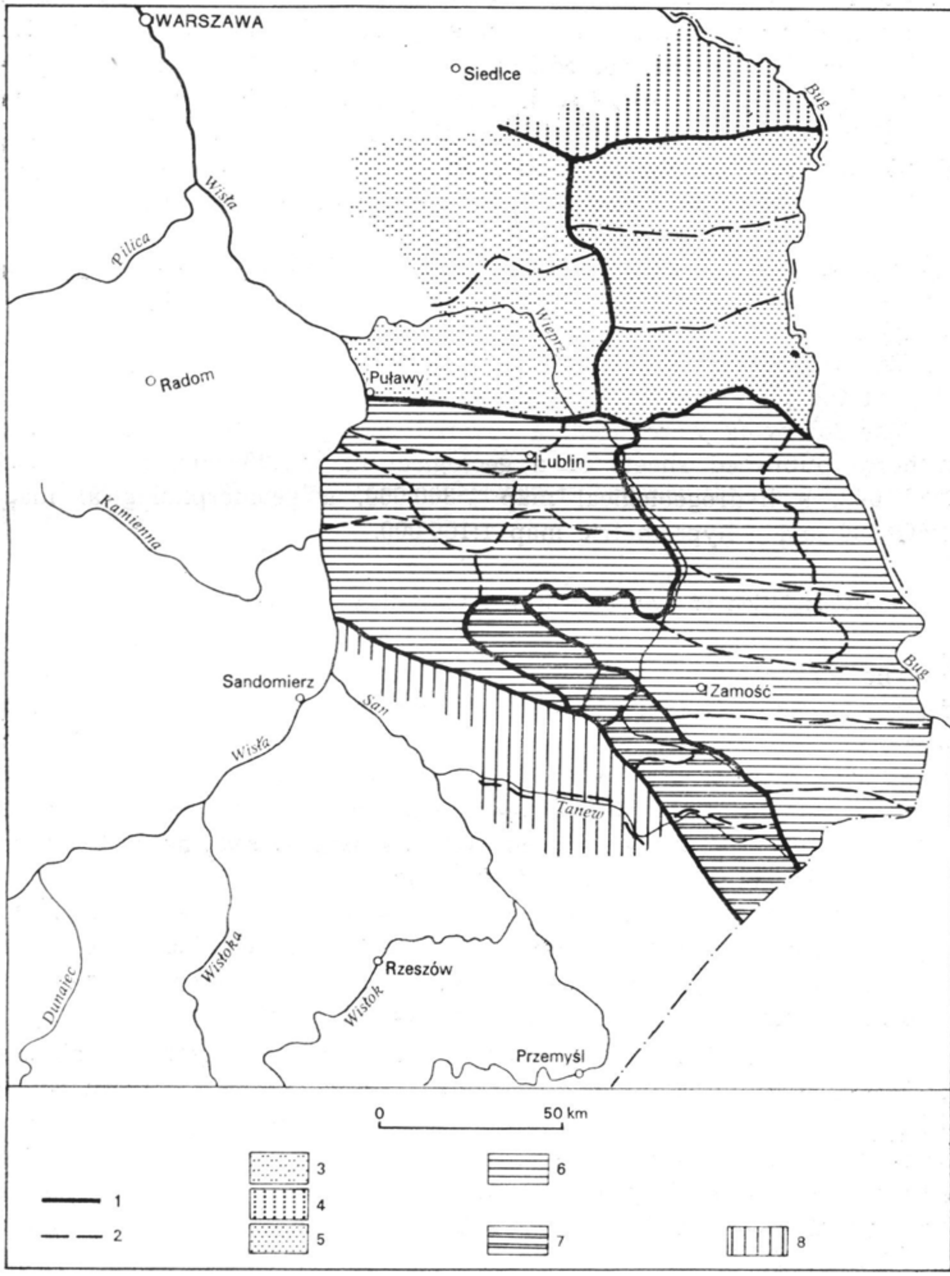


Fig. 7. Geobotanical regionalization (rank of a boundary)

Fig. 8. Boundaries of geobotanical subregions (D. Fijałkowski, 1972)
1, 2 — boundaries.
Division: Baltic
Subdivision: Zone of Great European Lowland
Region: Mazowsze
District — Małe (Small) Mazowsze (3)
Region: Podlasie
District — Mielnik (4)
Region: Polesie
District — Lublin Polesie (5)
Subdivision: Central Upland Zone
Region: Lublin Upland (6)
Districts — Subwolhynian
— Lublin
Region: Roztocze (7)
Districts — Western Roztocze
— Central Roztocze
— Southern Roztocze
Subdivision: Zone of Submontane Depressions
Region: Sandomierz Basin (8)
District — Lubaczów



boundaries of Szafer's division run together with the boundaries of geographical varieties of *Tilio Carpinetum* and divide the area into three parts. The third degree boundaries correspond to the land, of the fourth degree to the area, fifth order boundaries to sub-areas. The obtained division is remarkable by its detail both in respect to the isolated degrees and the precise boundaries between the units. A division with similar detail was presented by Fijałkowski (1972) for the Lublin voivodship. In comparing the obtained regionalization with the quoted division (Fi. 8) it is easy to notice that there is no relationship between these maps. The cause of this fact should be found in the methodological basis of Fijałkowski's division, as it is only a slightly modified physiogeographical division.

COMPARISON OF THE MAP OF POTENTIAL NATURAL VEGETATION OF POLAND WITH MAPS OF ELEMENTS OF THE NATURAL HABITAT

This comparison was treated as a form of analysis of the relationship of the plants with the geographical habitat.

The following were used: a covered geological map 1:300 000, the hitherto published sheets of a geological map 1:200 000, a soil map 1:300 000, a hydrogeological map 1:300 000, a geomorphological map 1:500 000 and a hypsometric map 1:100 000.

Correlation of map of potential vegetation with geological maps

The elaborated area is included within three geological units differing in their tectonic bases, different genesis and types of rock material.

Heights Lublin and West Wołyń Heights correspond to a chalk syncline forming part of a marginal synclinorium of the east-Carpathian platform; however, neotectonic movements have raised the rock layers from a height of 200 m to almost 400 m above sea level, in the southern part they are cut by fault towards the subcarpathian depression. On calcine forms (soft mare and hard bedrock) in some places there are marine Miocene layers (Kondracki 1977). A characteristic trait for this area is the almost common occurrence of a pulpy loess cover.

In the formation of the contemporary surface old trends of the Paleozoic and Mesozoic tectonics are expressed. There is a permanence of directions of geological structure as the tectonics of younger phases is adjusted to the bases of the older deep-seated structure. Three trends of morphological subsequence renewed in the tertiary have been isolated, the Wołyń (W-E), Lublin (WNW-ESE) and Roztocze (NW-SE) (Jahn 1956) (Fig. 9).

The isolations on the map of potential natural vegetation relate to the main trends of structural lines. On the West Wołyń heights sequences of oak woods (occurring on chalky bumps) and numerous fertile alder-ash forests which utilize the morphological lowerings are linked to the morphological lines. In Roztocze the relationship between the plants and the structural lines is expressed in a different way, as

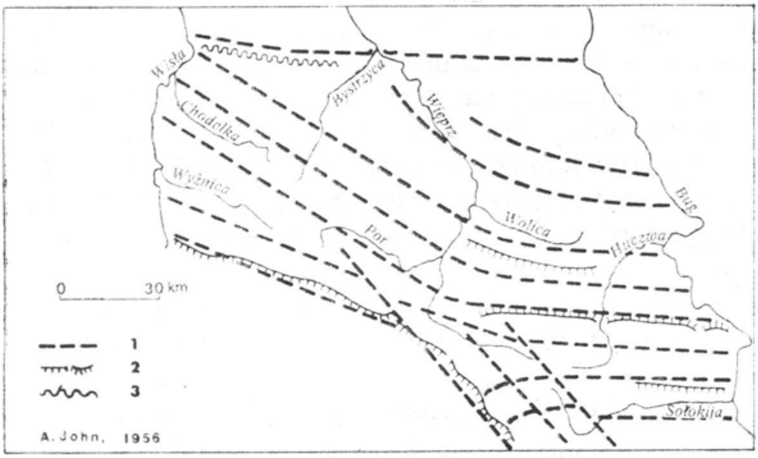


Fig. 9. Directions of morphological subsequences between the Vistula and the Bug rivers
1 — dominant morphological directions; 2 — some cretaceous and tertiary ledges; 3 — ledges in quaternary arrangements

the plant associations are perpendicular to the structural directions. This is due to the great numbers of valleys in this area. Almost all geographical formations occurring in the Lublin and West Wołyń heights form optimal conditions for the development of plants forming a fertile humus soil substrate which is warm rich in calcium carbonate. Therefore the differentiation of potential vegetation is slight. Fertile forests growing on dry ground distinctly dominate. The **Subcarpathian Depression** is a tectonic lowering on the outer side of the bow of the west Carpathians. It has been filled by sediments of the Miocene sea. The geological substrate, even though it is genetically homogeneous is mosaically variable. Forms of river accumulation dominate: sands, loams, river silts. In the south along the line Kolbuszowa-Leżajsk, there are clay or loess elevations. The correlation of the plants with the substrate is distinct, though not unambiguous.

In the northern part of the Sandomierz Lowlands poor or very poor habitats predominate. Acidophilous coniferous pine or fir forests correspond to them or mixed pine oak forests, alder forests, boggy pine forests. Heights are potentially overgrown by mixed pine oak forests, poor or fertile oak-hornbeam forests, sometimes even by beech forests.

Central Polish Lowland. On an old precambrian plate younger sediment forms lie monoclinally. The surface layer is formed by glacial sediments of the Central Polish glacialization (Riss) transformed into periglacials. Denudation or accumulation lowlands with small inclinations predominate. Gravel or sandy kemes and frontal moraines have remained in the form of monadnockes.

In Polesie a sandy lowland genetically related with a lake formed in the Mazowsze interglacial (Holstein) can be found. In some places cretaceous and tertiary monadnocks reach the surface. On soft chalky marls karstic phenomena have developed. The relationships between plants and geological structures are the most distinct here. After old lakes convertion into peat bogs alder forests and alder and ash forests are found, or sometimes boggy pine forests, whereas on moraine monadckoks and prequaternary bassets oak-hornbeam forests or oak forests are found.

Summing up, it may be said that the directions of the isolations and the regional structures are correlated. A number of correlations may be observed comparing the occurrence of plant associations with particular lithological associations. They are, however, not unambiguous. Here are some examples of correlations:

— on loess predominantly fertile oak-hornbeam forests are found, but poor oak-hornbeam forests can also occur, or an oak or, beech or fir forest or xerothermic associations, but never high peatbogs, boggy pine forests, acidophilous pine forests or alder forests;

— on chalky marls most commonly associations of oak forests occur, xerothermic swards, fertile oak-hornbeam forests, less commonly — fir forests beech forests, poor oak-hornbeam forests, or a mixed acidophilous pine-oak forests, but never high peatbogs, boggy pine forests, pine forests fir forests, or alder forests;

— on sands pine forests, boggy pine forests, fir forests, mixed acidophilous pine-oak forests can be found, rarely — poor oak-hornbeam forests or bright oak forests, but fertile high oak forests, fertile oak-hornbeam forests, beech forests and fir forests do not occur.

Correlation of the map of potential plants with a hypsometric and geomorphological map

The hypsometric map places the main stress on the form of the area, the geomorphological map on the chronology and genesis of the forms of relief. The two maps complement each other and therefore will be discussed together. A distinct effect of the form of the relief of the area on the plants can be observed. However, only in very specific areas it is the leading factor determining the differentiation of the vegetation. The observed correlations mainly have a regional character. The following correlations of the potential vegetation with the relief of the area can be observed:

1) Sandy lowlands, dune fields and high dune ridges are the habitats of acidophilous pine forests.

2) Deflation basins are often boggy and overgrown with boggy pine forests.
3) Steep southern and western slopes especially of structures of the limestone bedrock or marl type reach of the surface are overgrown potentially by oak forests, which are often accompanied by xerothermic swards.
4) From the map of potential natural vegetation the occurrence of influx cones at the mounths of small rivers (Opatowska, Kamienna, Wyżnica, Chodelka and Huczawa) may be seen. They have a different character depending on the fertility of the material transported by the river. The fertile variant is characterized by fertile oak-hornbeam forests, or ash forests with ash trees or with ash and elm forests. The poor variant is characterized by mixed acidophilous oak-pine forests, poor oak-hornbeam forests and marshy alder-ash forests.
5) The rolling area of the loess height often characterized by a varied relief is homogeneous on the map of potential vegetation. It seems that under conditions optimal for the development of plants the differentiation of associations is smaller, the main factor is fertility.

6) Hills of monadnock character are most commonly overgrown by oak forests or by fertile oak-hornbeam forests.

7) Wide flat valleys of large rivers with distinctly marked terraces with sequences of old river-beds on valley wings are distinguished on the map of potential plants by relatively narrow belts of forests *Salici-Populetum* and *Ficario-Ulmetum typicum* along the main channel. The higher terraces have oak-hornbeam forests, with fertile forms dominant. On valley wings alder forests and forests of the *Circaeo-Alnetum* type occur.

8) Rivers with narrow valleys and poorly developed higher terraces have a marshy forest character, *Ficario-Ulmetum typicum* dominates.
9) An interesting example of an old spill way, only fragmentally occurring within the area of the map is the valley of Solokija — on potentially areas large habitats of the elm marshy forest *Ficario-Ulnetum chrysosplenietosum* occur, and in some places alder forests and mixed acidophilous oak-pine forests.

10) Concave karstil forms are overgrown by alder forests. In areas where karstic forms occur on the surface there are numerous small area indentations without drainage overgrown by alder forests. On areas where the karstic forms are covered by a layer of sandy forms the indentations without drainage cover larger areas of patches alder forest in this area are large and have complicated shapes.

11) The macroregions of middle and South Roztocze have the greatest absolute height and have the most differentiated relief in the examined area.

The correlations of vegetation with the relief are outstanding here. Depending on the depth of occurrence of chalky marls on the tops either fertile oak-hornbeam forests or beech forests occur, the northern slopes are overgrown with beech forests. In the lower part of the slope and especially on northern slopes they become acidophilous fir forests. The flat valley bottoms are occupied — depending on the local aquatic relationships — by poor habitats of alder forests, acidophilous pine forests, boggy pine forests and even high peatbogs can be found. Fertile oak-hornbeam forests occupy the southern slopes and where there are considerable slopes – by a fertile high oak forests, at the foot there is a mixed acidophilous oak-pine forest.

Correlation of the map of potential vegetation with soil maps

The strong relationship between plants associations and soil conditions has been demonstrated in numerous investigations. During the mapping of a map of potential natural vegetation a very strong relationship between soils and plants can be observed. The most unexpected result is obtained when the map of potential natural vegetation is compared with soil maps as there seems to be no correlation between these elements. Such an interpretation is, however, contradictory to the results obtained through a long collaboration between phytosociology and soil knowledge. The difference between the maps is a result of different basic ideas. In the case of the soil map the processes which have the greatest aetiological significance for plants were not taken into consideration.

Correlation of the map of potential vegetation with hydrogeographic maps

The relationship between plants and the depth of occurrence of the first water-bearnig level are commonly known. The only available cartographic elaboration of this element is a review hydrogeological map. Comparing this map with the map of potential vegetation yields many correlations. These correlations are more unanymous than in the case of a many other elements of the environment though they often have a regional and not a general character. Oak forests grow on areas with the water level over 10 (often 20 m) distant, and oak-hornbeam forests of the Little Poland or Wołyń variety occur in the fertile form where the distance from the water exceeds 10 m and in the poor form when it is 2 to 5 meters. An inverse situation is found in the Mazowsze variety where the fertile form is found generally on a shallow (2-5 m) level of soil water. The acidophilous humid pine forests occur mainly on areas with shallow soil water (2-5 m). On dune areas for which the distance from soil water is considered to be 2-15 m a fresh or a dry acidophilous pine forests grow. When the water mirror is at 0-2 meters wet valley forests, a boggy pine forest or a high peat bog grow — depending on the mobility of the water. Depending on the varying character of the water surface there is a very distinct change in the potential vegetation.

The vegetation within the vallyes of great rivers is differentiated depending on the rate of the flow, force of accumulation or erosion of the river, character of the valley (whether it is ravined). Valleys in the zone of annual long floodings are overgrown with the *Salici-Populetum*, in the zone of irregular flooding are overgrown with *Ficario-Ulnetum typicum* and in the zone of sporadic flooding with oak-hornbeam forests, generally fertile. In valleys of small rivers with a large flow of fertile material from the banks and a distinct flow the elm forests (*Ficario-Ulnetum chrysosplenietosum*) is characteristic. The valleys of small rivers with a slightly limited flow are potentially overgrown by the *Circaeo-Alnetum*. In lowerings with difficult drainage alder forest grow, and in areas totally lacking drainage boggy pine forests and high peatbogs.

Correlation of the map of potential vegetation with the climatic maps

For comparison data from the Polish National Atlas were used. They consist of only small scale maps. On the examined area several associations reach the limit of their range of occurrence. It is commonly believed that the differentiation of vegetation has a historical and climatic character. Along about the middle of the map runs the northern boundary of beech forests. They occur on small areas under very specific habitat conditions. They grow on relatively cold and humid slopes with a northern exposition. It seems that the climatic factors limiting the occurrence of beech forests are the humidity and the distinctly negative temperatures in winter. On the line of the edge of Lublin and West Wołyń Heights runs the northern boundary of fir forest and acidophilous fir forests. Fir forests have even higher humidity requirements than beech forests. Their occurrence distinctly correlates with the area of greater rainfall in Roztocze and on the edge of the Lublin height (in comparison with the surrounding areas the rainfall is greater here by up to 100 mm). This is also an area of greater cloudiness. Pontine associations of fertile high oak forest and xerothermic swards reach the limit of their range of occurrence on the northern edge of Lublin Heights and Wołyń Polesie. Their occurrence depends on specific climatic conditions. High oak forests and xerothermic swards occur on dry, warm and sunny areas. Such conditions can be found on the steep slopes exposed to the west or south. The significance of climatic differences between slopes of elevations with various expositions in many places was found by patrol meteorological observations. The continental (as a type of vegetation) association of the acidophilous pine forest occurs in the investigated areas in two associations: *Leucobryo-Pinetum* and *Peucedano-Pinetum*. *Leucobryo-Pinetum* in a poorer variety, linked to the suboceanic character of the climate, dominates. Only in the northern (with the increase of the continentalization in the climate) the fresh acidophilous pine forest *Peucedano-Pinetum* occurs.

Tilio-Carpinetum occurs in the Little Poland and in the Wołyń variety. The Wołyń variety is more thermophilic and xerophilic than the Little Poland variety. The boundary between them on a large area is convergent between the division of waters of the Bug and Wieprz rivers. It is interesting that many other natural boundaries have a similar course: the west boundary of black soils, of cherry occurrence, of occurrence of the gopher (*Citellus suslica* Quld), a distinctly steppe species. It seems that all these boundaries have a climatic explanation. The area of Wołyń differs from the Lublin height and Roztocze by a lower cloudiness, slightly lower rainfall (less than 600 mm, locally even less than 550 mm). On the area the greatest total isolation in Poland can be observed (in a yearly scale it is expressed by the value of 255 cal/cm/day). The high value of isolation can especially be observed in the vegetative period, in winter there is no major difference as compared with heighboring areas. A certain role may be played here by eastern winds, which would explain why the boundaries run in parallel to the water sections.

Specific characters of the subregional climate cause the oak forest area on the right bank of the Vistula (between Kraśnik, Annopol and Opole Lubelskie). This area is drier, more insolated protected from the wind. The explanation of the specificity of this region can only be found in prolongation to the eastern bank of the Vistula of a well-known climatic anomaly — the dry area formed in the shadow of the Świętokrzyskie mountains. Rainfall maps (showing differences in the order of several dozen mm) may be a confirmation of this assumption. As can be seen the map of the potential natural vegetation shows several relationships with the maps of particular elements of the natural habitat even though it is difficult to grasp unanymous dependencies. The most distinct similarities occur when spatial relationships on the maps and arrangments of the surface forming characteristic structures and textures are compacted.

Comparison of the geobotanical and the physicogeographic regionalization

According to some authors (Schmithüsen 1968, Tüxen 1956; Matuszkiewicz 1974) potential vegetation is that element of the environment which may give the best information on the differentiation of the remaining elements of the habitat, therefore it seems worthwhile to compare regionalization based on the potential map of vegetation with an elaboration synthesizing all elements of the geographic and physical environment (Kondracki 1968, Fig. 10). Comparing the two maps one may observe considerable similarities in the course of the boundaries. The number of hierarchic degrees is very similar, nevertheless, the assignment of ranks to respective boundaries is somewhat different (on the map of geobotanical regionalization no unit corresponding in rank to the area was distinguished and in the hierarchy taxonomic units of lower rank than in the physicogeographical regionalization are considered).

The geobotanical division is more detailed on most of the area both due to the inclusion of units of lower rank and to the detailed marking of the boundaries. The Lublin Height area is an exception on the geobotanical map it is a unique area while in the physicogeographical division it is differentiated into a number of units. The reasons for the differences in these cases are the following:
1) Under conditions optimal for plant development the vegetation is less differentiated. Fertility is the dominant factor.
2) The activity of man which has been taking place since the neolithic in this area has significantly contributed to making not only the vegetation but also the habitat more uniform.

CONCLUSIONS

1) The map of potential natural vegetation is a good basis for conducting a geographical regionalization as it considers vegetation in a complex and dynamic manner. The potential vegetation is thus by definition only to a small extent burdened by deformation caused by man's activity.

2) The application of typological methods of phytosociology for performing geobotanical regionalization has proved to be a successful undertaking. It has made possible — by evaluation of the content of the map — the consideration of such characters which are considered as leading by phytosociologists in the differentiation of the vegetation.

3) The present work has helped to make some stages in the process of regionalization objective.

Fig. 10. Physical-geographical regionalization (J. Kondracki, J. Ostrowski, 1968)

Boundaries of: areas (1), subareas (2), provinces (3), subprovinces (4), mesoregions (5)

Area: Western Europe
Subarea: Transalpine Western Europe
Province: Central European Lowland
Subprovince: Central Polish Lowlands
Macroregions — Central Masovian Lowland (6)
— South Masovian Eminences (7)
— South Podlasie Lowland (8)
Province: Małopolska Upland
Subprovince: Central Małopolska Upland
Macroregions — Nida Basin (9)
— Kielce-Sandomierz Upland (10)
Subprovince: East Małopolska Upland
Macroregions — Lublin Upland (11)
— Roztocze (12)
Subarea: Alpine-Carpathian Lands
Province: Western and Northern Carpathian Foothills
Subprovince: Northern Carpathian Foothills
Macroregion: Sandomierz Basin (13)
Province: Western Carpathians
Subprovince: Outer Western Carpathian
Macroregion — Central Beskidy Foothills (14)
Area: Eastern Europe
Subarea: East European Lowland
Province: Polesie
Subprovince: Western Polesie
Macroregions — Podlasie Polesie (15)
— Wolhynia Polesie (16)
Province: Wolhyń-Podole Upland
Subprovince: Wolhyń Upland
Macroregions — West Wolhyń Upland (17)
Pobuże Basin (18)

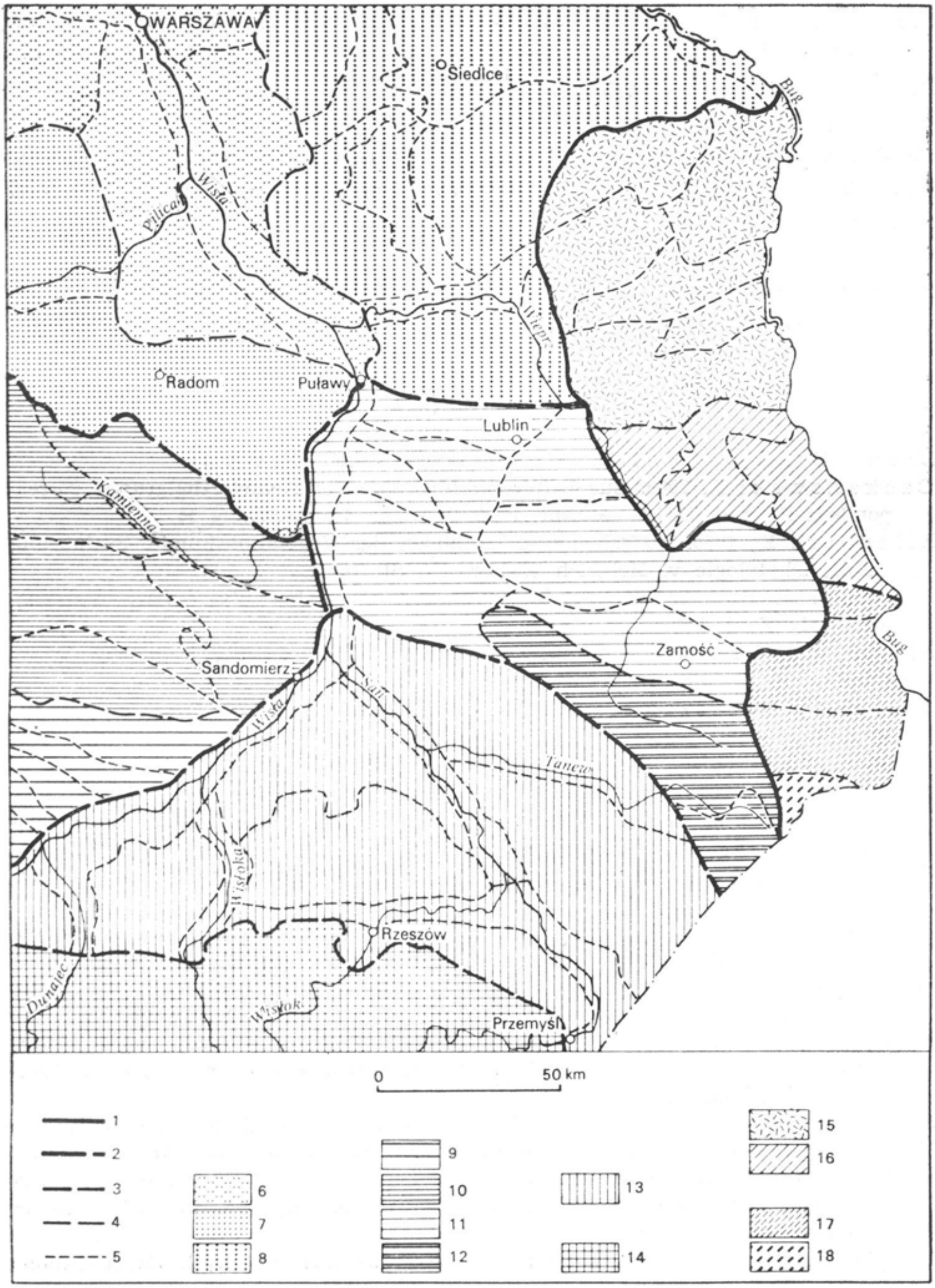
---

4) In comparison with hitherto used geobotanical divisions for the first time the criteria of the boundary hierarchy have been specified. Taxonomic units of the same rank are separated using the same criterion.

5) The distinguished units of the lowest rank do not have their counterparts in hitherto performel geobotanical divisions — the proposed division is thus more detailed.

6) Due to conducting regionalization using an inductive method a more precise course of the boundaries was determined the obtained division is thus also more precise.

7) The comparison of the map of potential natural vegetation with selected elements of the natural environment has shown a number of



relationships, but often smaller than was expected. The most distinct correlations are shown by the geobotanical division and the regionalization of the elements of the natural environment.

8) The fact of the relatively good agreement of the geobotanical division with the physicogeographical regionalization seems to confirm

the thesis that the vegetation also in its spatial differentiation forms a reflection of the effects of various elements of the geographic environment and is to some degree an outcome of these effects.

9) The method of geobotanical regionalization used in this work cannot be considered as finally elaborated. It is necessary to continue work on its perfection (this concerns predominantly formal analysis) and also on the elimination of subjective elements.

Acknowledgment

This work was partly supported by Problem 10.2 07 03 07.

REFERENCES

Braun-Blanquet J., 1954. Pflazensoziologie, Wien—New York.

Czekanowski J., 1909. Zur Differentialdiagnose der Neanderthalgruppe correspondenz-Blatt d. D.G.F. Aunthr. und Urgesch. Braunschweig 11.

Ellenberg E., 1956. Aufgaben und Methoden der Vegetationskunde. Einführung in die Phytologie v. Heinrich Walter. IV, Stuttgart.

Faliński J. B., 1972. Potencjalna roślinność naturalna Wysoczyzny Bielskiej. Materiały Zakł. Fitosoc. U.W. 24: 3-23.

Fijałkowski D., 1972. Stosunki geobotaniczne Lubelszczyzny. Lubelskie T. N., Ossolineum, Lublin.

Florek K., Łukaszewicz J., Perkal J., Steinhaus H., Zurzycki I. S., 1951. Taksonomia wrocławska, (Ogólna Grupa Zastosowań Państw. Inst. Matemat. we Wrocławiu) Przegląd Antropologiczny 17: 1-21.

Jahn A., 1956. Wyżyna Lubelska. Prace Geograficzne 7, Warszawa.

Kondracki J., 1968. Problemy regionalizacji fizycznogeograficznej. Prace Geograficzne 69 IG PAN, Warszawa.

Kondracki J., 1977. Regiony fizycznogeograficzne Polski. Wydawnictwa U.W., Warszawa.

Matuszkiewicz J. M., 1978. Fitokompleks krajobrazowy — specyficzny poziom organizacji roślinności. Wiadomości Ekologiczne 24: 3-13.

Matuszkiewicz J. M., 1979. Potential landscape phytocomplexes of Sudety Mountains. Acta Soc. Bot. Pol. 48: 3-25.

Matuszkiewicz W., 1974. Teoretyczno-metodyczne podstawy badań roślinności jako elementu krajobrazu i obiektu użytkowania rekreacyjnego. Wiadomości Ekologiczne 20: 3-13.

Matuszkiewicz W., Plit J., 1978. Versuch einer typologischen und regionalen Landschaftsgliederung auf Grund der Karte der potentiel natürlichen Vegetation (am Beinspiel eines südpolonischen Hügellandes). Berigcht ü. das internationale Symposion der Internationalen Vereigung für Vegetationskunde, Rinteln 1974. (in press).

Pawłowski B., 1972. Systematyka polskich zbiorowisk roślinnych. Szata roślinna Polski. PWN vol. I, Warszawa.

Pol W., 1847. Muzeum natury we Lwowie "Dzieła Wincentego Pola", 1 edition (1875-1878), Lwów.

Schmithüsen J., 1968. Allgemeine Vegetationsgeographie. Valter de Gruyer et Co., Berlin.

Szafer W., 1972. Podstawy geobotanicznego podziału Polski, Szata Roślinna Polski. vol. 2, PWN, Warszawa.

Szata Roślinna Polski (The plant cover of Poland), 1972. eds. Szafer W., Zarzycki K., PWN, Warszawa.

Tüxen R., 1956. Die heutige potentielle natürliche Vegetation als Gegenstand der Vegetationskartierung, Angew. Pflanzensoz. 13 Stolzenau/Weser.

Wojterski T., 1972. Próba podziału geobotanicznego w oparciu o mapę potencjalnej roślinności naturalnej. Wiad. Bot. 16: 229-240.

MAP BIBLIOGRAPHY

Map of Polish soils. 1:300 000 (sheets with Lublin, Radom, Kielce, Zamość).

Geological map of Poland. 1:200 000.

Review geological map of Poland. 1:300 000, covered series (sheets with Radom, Lublin, Kielce, Zamość).

Review geomorphological map of Poland. 1:500 000 (manuscript).

Review hydrogeological map of Poland. 1:300 000 (sheets with Radom, Lublin, Kielce, Zamość).

Review map of potential natural vegetation of Poland. 1:300 000 (author's manuscript 1:100 000).

Review topographical map of Poland. 1:300 000 (sheets with Radom, Lublin, Kielce, Zamość).

National Polish Atlas, Warsaw (in press).

Geobotanical division of Poland. 1:2000 000, Szafer W., Pawłowski B. Plant cover of Poland. 1959.

Mapa potencjalnej roślinności naturalnej jako podstawa regionalizacji geobotanicznej

Streszczenie

Przedstawiono taksonomiczno-typologiczną metodę regionalizacji geobotanicznej na przykładzie obszaru we wschodniej Polsce nazywanego tradycyjnie Lubelszczyzną. Przeprowadzony podział opiera się wyłącznie na interpretacji mapy potencjalnej roślinności naturalnej. Regionalizację przeprowadzono kombinowaną metodą indukcji i dedukcji. Metodą indukcji wydzielone zostały jednostki podstawowe; stosowano ją także na etapie analizy treści i rozdrobnienia jak również przy typologii mapy; metodą dedukcji ustalono hierarchię granic i wykonano regionalizację.

Na podstawie analizy mapy potencjalnej roślinności naturalnej w skali 1:300 000 wydzielono homotoniczne podstawowe jednostki przestrzenne. Zostały one scharakteryzowane powierzchniowym udziałem występujących w nich potencjalnych zbiorowisk roślinnych. Zestawione w tabelę jednostki uporządkowano stosując m.in. również statystyczne metody ordynacyjne taksonomii wrocławskiej i diagramu Czekanowskiego. Uporządkowana tabela jest podstawą wyróżnienia typów krajobrazów roślinnych, co umożliwia sporządzenie mapy typologicznej, która z kolei daje podstawę do przeprowadzenia podziału regionalnego. Przyjęto hierarchię kryteriów zróżnicowania przestrzennego roślinności, którym odpowiadają stopnie w podziale regionalnym:

1) Zmiana dominującego zbiorowiska zonalnego.
2) Regionalna zmienność zbiorowiska zonalnego.

3) Zmiana dominującego zbiorowiska, nie wykazującego zróżnicowania zonalnego na terenie Polski.

4) Różnice charakterystycznych kombinacji zbiorowisk.

5) Różnice relacji ilościowych między współdominantami.

6) Wyraźne różnice struktury przestrzennej roślinności oraz maksimum występowania zbiorowisk towarzyszących.

Przeprowadzony podział geobotaniczny Lubelszczyzny jest dokładniejszy (precyzyjniejszy przebieg granic) i bardziej szczegółowy (wydzielono jednostki niższego rzędu) w porównaniu z dotychczasowymi opracowaniami. W drugiej części pracy porównano mapę potencjalnej roślinności naturalnej z mapami geologicznymi, z mapą geomorfologiczną, hydrogeologiczną, glebową, hipsometryczną i z mapami klimatycznymi. Zaobserwowano wyraźne, choć nie zawsze jednoznaczne korelacje między roślinnością a pozostałymi elementami środowiska. Nawiązania mają charakter regionalny a nie ogólny. Ogromne podobieństwo obserwuje się w typach układów strukturalnych. Najwyraźniejszą zbieżność wykazuje podział geobotaniczny z regionalizacją fizycznogeograficzną. Fakt ten potwierdza tezę, iż roślinność, a zwłaszcza roślinność potencjalna, jest syntetycznym wykładnikiem wszystkich elementów środowiska przyrodniczego.