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Lichens as Indicators of the Ecological Conditions of the Habitat

INTRODUCTION

In view of the increasing industrialization and of the rapid growth of urban areas, hygiene of town life has become one of the important scientific and social problems of the XXth century. Human health is seriously threatened by the products of coal, oil and gasoline combustion and by other substances with which industry pollutes the atmosphere of large cities. The unnatural environment produces local climatic changes, which, in turn, have a harmful effect on the whole biocenosis in and near the city. A number of scientific studies and social campaigns of local, national, or even world extent (e.g. that sponsored by the World Health Organization) have been undertaken in order to reduce this negative influence of cities. The vast circle of problems connected with urbanization comprises also the question of the occurrence and distribution of lichens in the city and in its surroundings, in view of the well-known fact that cities exercise a distinctly harmful influence on the lichen flora. The susceptibility of these organisms to the urban conditions could therefore make them good indicators of the intensity of this noxious influence. For this purpose, a number of large and small towns, mostly European, were examined, and in some of them (Munich (15), Dresden (14), London (11) the research was repeated after many years. The results of these investigations and the literature on this subject are given, among others, in the publications by Barkman (1), Beschel (2), Natho (16—18), Rydzak (22—30), and Steiner (36—38).

The poverty of lichen vegetation in cities has been the subject of discussion among lichenologists for several years. Some workers advocate the "toxic hypothesis", which ascribes the harmful influence on lichens to air pollution only; others are in favour of the "drought hypothesis", according to which the absence of suitable ecological conditions is responsible for the decreased lichen growth in cities. Still others regard both hypotheses as equally true.

OBJECTIVE AND METHOD

The objective of the present work was to compare, after 18 years, the lichen flora of Lublin with the results obtained in the years 1948—1950 (22) and to interpret the data in the light of the "drought hypothesis". During these years the town considerably increased its area, density of built-up plots, number of inhabitants, factories, streets and grounds provided with sewerage (Table 1) *.

Table 1. Size of the city of Lublin

Year	Area in km^2	No of residential houses	No of inhabitants	Yearly use of coal in tons
1948	32	6395	110000	130000
1966	92	10373	207000	370000

The method applied here does not differ from that used previously (22), and consists in: a) most careful exploration of the greatest possible number of lichen stations with regard to species composition, degree of coverage (according to a 5-grade scale), distribution of the individual plants over the given station, exposition, degree of development, and vitality. b) Comparison between such data from all stations. c) Comparison by observation of the ecological conditions of the habitat in which lichens were found with the conditions present in an adjacent substratum which was free from lichens. d) Comparison between the stations from the years 1948—1950 and those from 1966. Since the area of tree trunks is only a small fraction of the total area of stones, pavement, houses, squares etc. of the city, special attention was paid to the stations of lichens growing on walls, plaster, fence post, and monuments.

RESULTS

About 2,000 trees and places with a mineral substratum were examined in the urban area, except fenced plots. In about 50% of the examined places no lichens were found. About 25% of the species most characteristic of the given region of the town were selected from the stations in which at least one normally developed specimen had been found;

* The author thanks Mgr. Bogusław Sałata and Bogumiła Żabińska for their assistance in collecting material for the present work.

the plants are listed in Tables 2 and 3 and in Fig. 1. Below the numbers of some stations from 1966, the tables also give the numbers of stations published in 1953 (22). Figure 1, apart from the numbers of the stations, indicates the situation of the spots (1—16) in which meteorological conditions were studied (Table 4) on 13 VII 1956 (40, Table 19). The climatic conditions of Lublin were presented by Zinkiewicz and Warakomski (40) in the years 1952—1966; of those data, the present work gives only the mean values of relative air humidity (Table 5, Fig 2) meas-

Table 2. Epilithic lichens

No.	Species	No. of localities, region, substratum, degree of coverage																													
		50	76	79	83	84	85	87	90	92	97	101	104	116	119	124	125	126	137	143	144	145	152	105	106	168	171	173	174	175	178
			105		150	148		149		148						237			249					85	139	11	6/0		12	67	68
		A_5	D_3	D_4	D_5	-	-	-	-	-	-	D_5	D_6	E_6	D_7	-	D_7	D_8	-	E_3	E_4	E_5	-	F_3	-	-	-	-	-	-	F_3
		s	m	m	m	gr	gr	gr	gr	gr	b	m	m	b	b	m	b	mp	b	m	m	b	m	g	g	m	gr	c	c	s	s
1	Caloplaca citrina Th.Fr.												2																		
2	Caloplaca decipiens J.Stein		•	•	2					1	•			2	•	1	•	4			5		•	•		2	•		•	•	
3	Caloplaca murorum Th.Fr.				2									1			•	•					•					1			•
4	Candelariella vitellina Arg.		1	1	2			•			•	1		4		1	5	1	1		2	•	1	1	1	2			•		1
5	Lecanora dispersa Somm.	•	2	1	1		2	•		2	•	3	3	2		3	2		5	2	•	2	1	1	1	1	•			•	2
6	Lecanora albescens Flörke				•								1					•			•			1	1	•				•	
7	Lecanora goniophila Flörke									•																					
8	Physcia caesia Hampe					1			5																						
9	Physcia orbicularis Poetsch							•							1			1				•									
10	Physcia sciastra Du Riets																														
11	Lecanora muralis Rabenh.					1				2							•														
12	Xanthoria parietina Th.Fr.	1						•							•							•									

No.	Species	No. of localities, region, substratum, degree of coverage																													
		172	174	175	180	181	182	183	184	185	186	187	188	189	190	201	203	205	206	20[illegible]	219	223	225	232	234	239	244	249	250	251	252
		69	85	96	97	94	94	89	90	94			191	193	196	187	226	221	235	200	15	16	18		50	52			52	57	53
		F_3	F_3	F_3	-	-	F_3	F_4	-	-	-	F_4	F_5	-	-	F_2	F_6	-	F_8	F_8	G_2	-	-	G_2	G_3	G_3	G_4	G_{11}	H_3	-	H_3
		m	m	m	m	b	b	m	m	m	m	m	m	m	m	b	b	m	c	m	m	gr	m	m	m	c	b	m	m	m	gr
1	Caloplaca citrina Th.Fr.		1		1																			1							
2	Caloplaca decipiens J.Stein	•	1					•						1	•	1	•			•	•		1			1	•	•	2	3	
3	Caloplaca murorum Th.Fr.																		•		•				•	•	•	2	1	2	
4	Candelariella vitellina Arg.	1			1	2	1	•					•	1	•	1	•			•	1		2					2	2	3	
5	Lecanora dispersa Somm.	2	1	3	1	3	3	•	2	3	3	1			2	1	•	•		•	1		2	1	3	2	1	2	2	2	
6	Lecanora albescens Flörke	•	1	2	1		•	•	1				1	3	1	•							•		1	1		•	1	•	•
7	Lecanora goniophila Flörke																					•									•
8	Physcia caesia Hampe																														2
9	Physcia orbicularis Poetsch		2																		1				•		2				2
10	Physcia sciastra Du Riets		•																		3						2				1
11	Lecanora muralis Rabenh.																				•	•									
12	Xanthoria parietina Th.Fr.																						•	•			1				

Explanation: b — brick, c — concrete, s — plastered pillars, p — fence, g — cornice, m — plastered wall, gr — tombstone, mp — wall of sandstone, d — wooden rail, k — board

ured at two meteorological stations situated within the town boundaries (Fig. 1). The station of the Maria Curie-Skłodowska University lies in the centre of the town, at 195.3 m. above sea level. The other, synoptical station of the State Hydrological and Meteorological Institute (PIHM) is situated in the valley of the Bystrzyca river, on meliorated meadows and near a young park, at 171 m. above sea level, about 1,600 m. southwards from the University station.* It results from these data that the mean relative humidity was usually lower at the University station. However, the monthly means cannot express the microclimatic values in the given station during the period which is most favourable for the assimilation of the lichens in daytime. It results from Table 5 that the differences of temperature recorded at various points reached 2.3°C, and that relative humidity differed even by 7%, and was lowest in spots

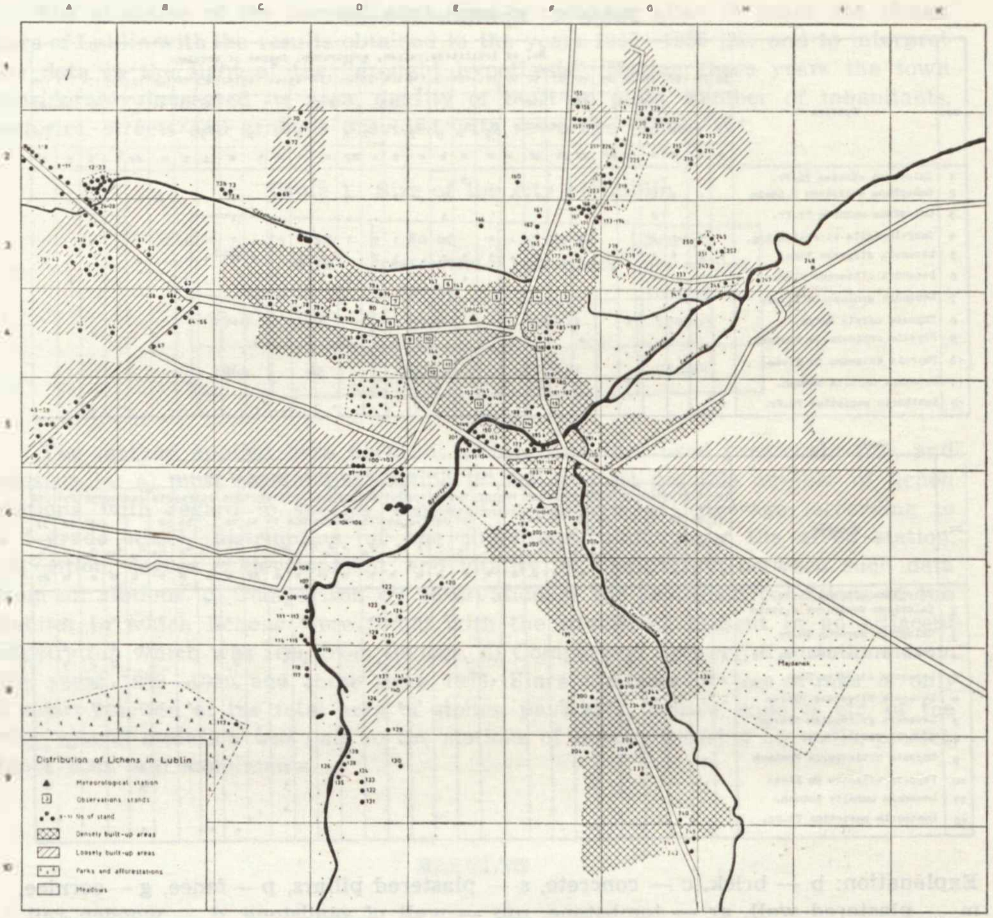

Fig. 1

protected from wind and surrounded by buildings. In relation to the monthly mean from July 1956, relative humidity, as recorded during the present investigations, was by more than 50% lower. This is a good example of the range of microclimatic differences in different stations,

* The author thanks the management of the stations for this information.

and points to the necessity of frequent measurements for exact assessment of the ecological conditions in the stations under study.

It results from numerous observations, from the analysis of Tables 1 and 2, and from the comparison with the data from 1948 (22, pp. 242—277, Tables II—V, Fig. 10) that the lichen vegetation has considerably changed during these 18 years. The number of species, the covered area, and the vitality of the individual plants have decreased. These changes are due to various factors, of which the most important are: the growth of the urban area, extension of the sewer system and paving over new

Table 4. Temperature and relative humidity of observation points 1—6 (Fig. 1) on the 13th of July, 1956, in Lublin

Observation point	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Hour	13^{30}	13^{32}	13^{38}	13^{42}	13^{47}	13^{51}	13^{56}	14^{02}	14^{11}	14^{15}	14^{20}	14^{24}	14^{29}	14^{36}	14^{41}	14^{45}
Dry bulb °C thermometer	25.9	24.9	25.1	25.9	26.0	25.7	27.1	28.9	26.9	25.7	26.3	26.1	26.1	24.8	25.9	25.9
Wet bulb °C thermometer	17.5	16.4	16.5	16.4	16.5	17.0	17.7	15.3	17.5	17.1	17.2	17.1	17.0	16.4	17.0	16.9
Relative humidity - %	40	38	37	33	33	38	36	37	35	38	36	37	36	38	37	36

quarters of the town, drainage of meadows situated in its centre, demolishing or plastering of old houses where lichens had their stations, cutting down of numerous old trees, ageing of trees, death of old lichen thalli. It appears that under these modified conditions the growth of young thalli is not always possible.

Very poor lichen vegetation or its complete absence on trees was found in various quarters of the town: 1) in newly built quarters, sectors B 5, C 3, C 5, D 5, H 4, 5, 6; 2) in the centre situated on an elevation and crowded with houses, as well as in the old town, in sectors E—F 3, 4, 5; 3) in sectors F 7, G 5, 6, 7, H 7, where the houses are crowded and old trees are mostly absent; in that part of the town particular attention was paid to epilithic lichens; 4) in the western areas D 7, E 6, G 4 and H 4, where the meadows situated along the Bystrzyca river have been drained during the last 15 years and converted into garden allotments and into a park; 5) in other areas, not marked in Fig. 1, arable fields prevail.

On the outskirts of the town, independently of the prevailing winds, normal lichen vegetation is found, such as it occurs on roadside trees, far from the city. These are sectors A 1, 2 to K 1, 2 (Fig. 3, 4) A B 6—10, C 9, 10, D 10 to K 10, (Fig. 5), K 3—9. The vegetation is particularly abundant in sectors G 1, 2 (Fig. 6), H 2 and I 3 (Fig. 7) although winds

Table 5. Monthly average values of relative humidity at the meteorological stations UMCS and PIHM

UMCS Months / Years	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XI, XII I, II	III, IV V	VI, VII VIII	IX, X
1952	83	88	80	69	70	70	70	69	82	89	90	91	88	73	70	86
1953	92	87	76	65	66	72	75	75	73	80	86	88	88	69	74	77
1954	85	82	84	78	71	74	78	74	79	82	88	90	86	78	75	80
1955	86	85	84	75	70	71	73	78	75	83	88	89	89	76	74	79
1956	83	82	84	77	65	69	79	79	77	83	89	91	86	75	74	80
1957	88	86	72	65	72	63	73	78	79	81	87	80	85	70	71	80
1958	85	84	87	81	70	70	78	82	83	86	93	92	89	79	77	85
1959	87	88	76	67	66	75	72	76	72	70	88	89	88	70	74	71
1960	87	84	75	74	68	73	81	78	80	86	89	87	87	72	77	83
1961	86	88	80	62	73	70	72	75	71	72	88	85	87	72	72	71
1962	86	86	85	70	79	72	80	81	82	85	87	88	87	78	78	82
1963	86	90	64	73	67	67	65	72	79	88	83	88	87	74	68	82
1964	90	88	89	70	61	63	65	74	77	78	86	90	89	73	67	78
1965	87	84	82	73	71	72	71	76	76	80	88	87	87	75	73	78
1966	91	88	80	75	67	68	77	75	77	83	90	91	90	74	73	80
PIHM																
1952	86	88	76	73	74	73	66	77	83	87	87	89	87	74	72	85
1953	89	86	76	68	71	75	74	77	77	81	81	87	86	72	75	79
1954	83	79	82	78	71	74	77	76	80	80	85	86	83	77	75	80
1955	84	83	80	77	72	73	78	79	80	85	88	88	86	76	77	82
1956	84	82	78	78	70	72	78	80	81	86	84	89	85	75	77	84
1957	88	84	70	69	75	67	76	81	82	82	86	86	86	71	75	82
1958	88	85	85	83	73	74	77	78	84	87	92	90	89	80	77	86
1959	88	88	79	71	69	74	74	79	77	72	89	89	89	73	75	75
1960	88	83	76	77	74	75	83	83	81	87	91	88	87	76	80	84
1961	84	89	83	67	77	74	78	82	78	75	90	89	88	76	78	74
1962	87	89	86	75	83	77	80	82	80	88	90	89	89	81	80	84
1963	90	89	79	77	70	70	70	74	81	89	82	86	87	75	71	85
1964	65	84	84	76	68	64	67	77	80	80	89	90	87	76	69	80
1965	87	83	81	75	74	76	75	79	79	82	88	84	86	77	77	80
1966	87	86	76	77	68	64	74	74	79	83	91	89	88	74	71	81

blow in Lublin mostly from SW (40) and carry into these regions smoke from the town and from the near Truck Factory.

The points and numbers presented in Fig. 1 and in the tables do not cover all lichen seats in Lublin because from a given group of trees or from an avenue only one or two stations are indicated as characteristic of the given area, especially on the outskirts of the town. According to Tables 1 and 2 (Fig. 1), the stations discussed below deserve special attention. Numbers of stations from 1953 (22) are given in brackets.

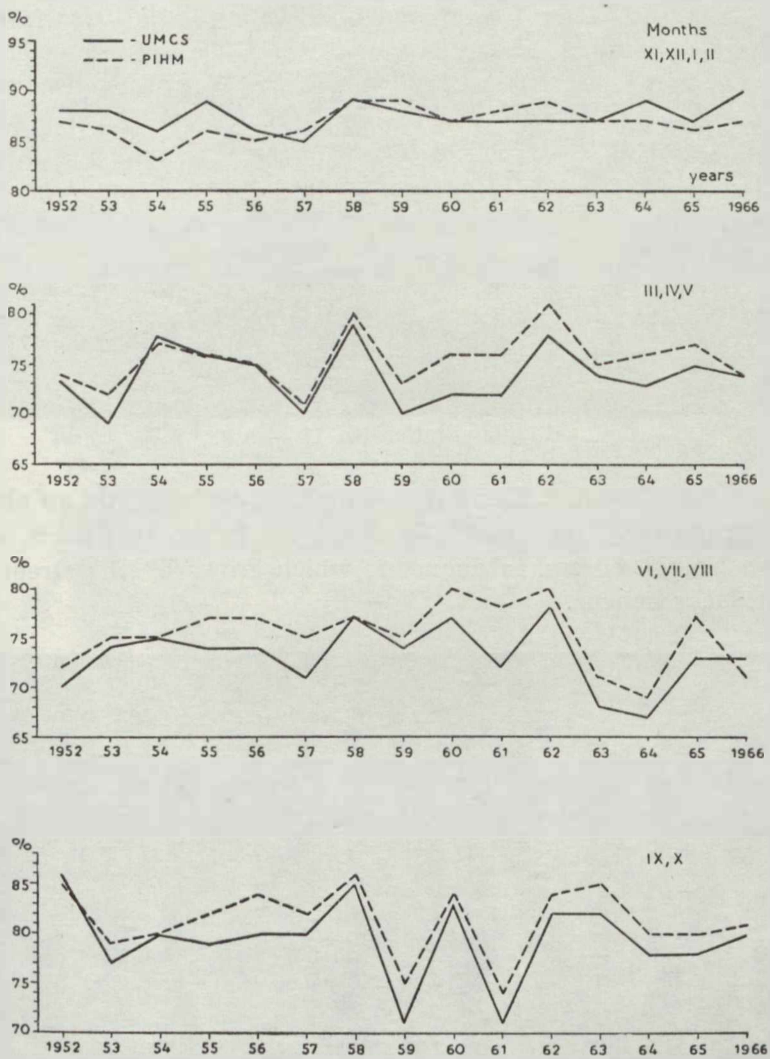

Fig. 2. Average values of relative humidity at the meteorological stations of UMCS and PIHM

Stations No. 15 and 16 (174—179), sector A 2. Two lime trees of the same age, 1 m. in diameter, growing in an avenue, 15 m. apart, apparently under the same conditions, have entirely different lichen floras.

Fig. 3. Station No. 17 — A 2.

Station No. 72 — C 2. Lime tree, 30 cm. in diameter, on an elevation, total coverage 40%, large, normally developed lichen specimens, whereas lime tree No. 73, 80 cm. in diameter, which grows by the street in full sunlight, lacks lichens.

Fig. 4. Station No. 44 — A 4.

Station No. 73 a. On the other side of the street, on poplars 30 cm. in diameter, the coverage reaches 60%. The degree of air pollution cannot be different from that in station No. 73 (Fig. 8, 9).

Stations No. 80—80 c (157) — D 4. The whole park has a poor lichen vegetation. Numerous trees have no lichens at all. In comparison with 1948 (22) the condition of the lichen flora has deteriorated.

Stations No. 83—93 (148—150) — D 5. At a distance of about 300 m. to the south of the park, in a cemetery, corticolous species can be found, although, generally speaking, the lichen vegetation is not abundant. Trees do not stand here close together and there is less shade. There is also an open vista to arable fields from the west. Abundant epilithic flora is found on old walls and on some monuments. The condition of the lichen vegetation has not deteriorated here.

Fig. 5. Station No. 242 — G 10.

Station No. 94 (180) — D 5. Lime trees, 80 cm. in diameter. In comparison with 1948, considerable deterioration of the lichen vegetation has been found.

Station No. 111 — C 7. *Salix fragilis;* the lichen flora is poor although the tree grows on the bank of the river, far from the centre of the town. On some other willows and alders there are equally few lichens. The present writer is unable to explain this fact. There is no doubt that air pollution is not higher here than in other stations, e.g. No. 210, 211 or 149—154 (183).

Station No. 119 — D 8. Numerous lichens. On a sunny day the wood of the bridge rail was very dry, in spite of the vicinity of water.

Station No. 117 a — C. 8. Mixed wood. Normal, but not abundant lichen vegetation. The species *Usnea* and *Alectoria* are absent; *Ramalina* and *Evernia* are found sporadically.

Fig. 6. Station No. 215 — G 2.

Station No. 146 (144) — E 3. *Robinia pseudoacacia,* on an elevation, strong insolation. Drained meadows. Lichen flora greatly impoverished. About 300 m. eastward, near a monument (137, 138), on four *Fraxinus excelsior* and on the concrete wall of the monument lichens disappeared completelly, probably after whitewashing.

Stations No. 149—154 (183) — E 5. Eighteen years ago, lichen vegetation was very abundant on poplars — coverage about 40%. *Xanthoria parietina* grew on 3 m. of the trunk height, and individual plants reached 8 cm. in diameter. In these lowest regions of the town, gases could have their highest concentration. At present the coverage is 20% on the average, on some trees only lichens are more abundant. The thalli lack vitality, some are falling off (Fig. 10). The adjacent meadows were drained 15 years ago. A park was then established, in which poplars and willows completely lack lichens. The closer to the bridge and to the river, the richer is the flora — 201 (187), 197 (183) — E 5. In the lanes approaching the crossroads to the east, the flora becomes poorer —

No. 172, 191—196 (183—186) — F 5/6. By the river (No. 195 a — F 5). *Acer nugundo* and *Salix* sp. (with pendulous branches) have no lichens.

Stations No. 163, 164, 167—169, 171—174 (1—12) — F 3. The vegetation has become much poorer in the old cemetery. Some trees have been cut, all gravestones have been destroyed. The number of houses in the vicinity has increased. There is also an increased motorcar traffic in comparison with 1948.

Fig. 7. Station No. 248 — I 3.

Stations No. 175—176 (67—68) — F 3. Trees round a church on an elevation. Very considerable impoverishment of the lichen flora.

Station No. 177 (69) — F 3. A high wall surrounding a loess hill on which a church stands. Epilithic lichens grow in some parts of the wall, which in the publication of 1953 (22) are shown in Fig. 3. Lichens appear in those parts where the wall is more moist and where dew forms more frequently. There are no lichens on other parts of the wall. It is evident that gas concentration cannot be different in spots which are distant ten or so centimeters from one another.

Fig. 8. Station No. 73a — C 2.

Station No. 198, 205 (226—235) — F 6. On the premises of the gas works lichen vegetation has completely disappeared. On a thick poplar, in a cleft of the bark near the ground, only one specimen of *Physcia ascendens* was found. Very few *Lecanora dispersa* grow on the remnants of the socket of an old fence. A group of poplars, 60 cm. thick, and of *Robinia pseudoacacia* lack lichens. During recent years part of the trees have been cut, and old walls have been removed. On the other hand, on concrete posts by the street, close to the ground and on the cornices, epilithic species occupy up to 10% of the surface — No. 203 (226) — F 6.

Station No. 207 a — F 6. A square and a small park with shady trees. Complete absence of lichens, in spite of the vicinity of a small river.

Stations No. 210, 211 (213) — G 8. Round a church a group of *Acer negundo*, 50 cm. thick, with abundant vegetation of *Xanthoria parietina* with thalli reaching 4 cm. in diameter (Fig. 11). On the trees which grow

Fig. 9. Station No. 73b — C 2.

by the street at a distance of some metres only, no lichens are found. It is difficult to find the reason for the rich lichen vegetation in this group of trees, when another spot (207 a — F 6) is quite empty. The toxic gas hypothesis would be of no use here.

Stations No. 217—226 (15—18) — G 2. As in 1948, lichen vegetation on the cemetery wall is well developed, but the coverage of the trees has decreased. Lichens are completely absent from the oaks, and on the adjacent poplars and ash-trees the coverage reaches 20%.

The conditions of the lichen vegetation in other stations is shown in Tables 1 and 2. These lists of species point to some possibility of including them into federations distinguished under natural conditions (7, 1). In the present writer's opinion, however, they do not form associations because the thalli of the individual species cover too small an area, and the

Fig. 10. Station No. 153 — E 5.

species compositions is greatly altered by the peculiar ecological conditions. Stations are often found with one thallus of a species only. Observation and comparison of great number of stations poor in lichens have demonstrated that the thalli of individual species occupy spots which are ecologically similar. Lichens avoid places exposed to excessive insolation or those where there is too much shade. They prefer the lower parts of tree trunks, they hide in the crevices of the bark, where they are protected from insolation and wind. On walls and plaster, lichens avoid exposed and dry vertical surfaces, but grow in the corners of cornices or on the upper, often oblique surface of plastered walls and posts, where dew is often formed. Numerous observations have de-

Fig. 11. Station No. 210 — G 8.

monstrated that the places where lichens are found are moist more often and for a longer time than those from which lichens are absent. In places which are more moist and shady, algae grow abundantly. Much information on the ecological conditions of other stations is given in the publication of 1953 (22).

DISCUSSION

It results from the above observations that the condition of the lichen vegetation in Lublin has deteriorated during 18 years. The amount of coal burned up has trebled during that time, and the number of motorcars has also increased. It could be therefore believed that this impoverishment was due to the stronger toxic action of air pollution on the lichens. However, the present writer is of the opinion that the problem is not so simple and that more complex reasons are involved. The "toxic gas hypothesis" fails to explain numerous facts, and even contradicts some of them. A few examples will suffice:

1. Many stations of over a hundred lichen species were found in cities; the young thalli developed and survived for many years in a polluted atmosphere. The assumption that these species are toxitolerant is groundless. Such species would not be hindered from covering the open surfaces of tree trunks and walls, in the absence of competition of toxiphobe lichen species and of other plants. Thus lichen vegetation would be possible on some spots in spite of the presence of toxic gases, whereas the same gases would produce a lichen desert in adjacent areas.

2. The frequent occurrence of saxicolous species in towns can be explained by the neutralizing action of the alkaline substratum on SO_2 and acids. Such interpretation is not sufficient because gases act directly on the cells of the thallus. Moreover, it is not known why these species do not occur on the adjoining surfaces of the same substratum.

3. About 370,000 metric tons of coal are burned up in Lublin every year. SO_2, discharged in the amount of about 11,000 metric tons (the average content of sulphur in coal being 1.5%), does not interfere with the growth of corticolous lichens in the northeastern and eastern quarters of the town, in sectors G 1, 2, H 2, I 3, in spite of the prevailing SW and W winds. There is also a fairly rich lichen flora in the western part of the town, in sectors A 2—4 (Fig. 1, Table 2). On the other hand, corticolous lichens are very rare in sectors C 4, D 4, E 4 and F 4, although there is no major industry in that part of the town. Smoke from the dwelling houses situated in that highest quarter of the town is blown far away, mostly towards NE and E.

4. On the outskirts of large towns normal lichen vegetation is found, but in the centre of small towns, especially health resorts, where the air contains only traces of SO_2, the lichen flora is poor (2, 6—18, 23—30).

5. In the village Białowieża (26) there are very few lichens on roadside trees, but at a distance of some metres, in the park, the vegetation is normal and abundant, even *Usnea comosa* is present. Seven hundred metres from this spot, in the National Park of Białowieża, the lichen flora is luxurious (31). At Białowieża, the toxic gas effect is out of the question.

6. At Tomaszów Mazowiecki (30), where the atmosphere is strongly polluted with SO_2, CS_2 and H_2S, the lichen flora is no less developed than in other small towns (23, 30).

7. In London, where the mean annual SO_2 concentration is 0.14 ppm in some districts (39), numerous lichen habitats have been found at a distance of 0—16 km. from the centre (11), and in New York, with the SO_2 concentration averaging 0.17 ppm (4), scarce lichen vegetation has been found as far as about 30 km. from the centre of Brooklyn.

8. Some writers believe that lichens perish because of a prolonged action of gases and of an accumulation of lethal amounts of toxic compounds in the thalli. In this connection, it is hard to explain why young thalli of various species do not abound in towns.

9. The yearly consumption of coal in New York is 32 million metric tons, and the maximum concentration of SO_2 reaches 0.98—1.20 ppm; consequently lichens are completely absent within a radius of many miles (39, 4). On the other hand, Pišut states that in the locality Rudňany in Czechoslovakia, the SO_2 concentration reaches 0.034 mg/l, or 11.6 ppm, i.e. about ten times more than in New York. Nevertheless, saxicolous lichens were found at Rudňany at a distance of 200 m. from the gas source, at an average SO_2 concentration of 0.024 mg/l. At a distance of about 760 m. the lichen vegetation was already normal (20, p. 483 and Fig. 1), i.e. at a SO_2 concentration of 0.005 mg/l (1.7 ppm). At a distance of 2,700 m. from the gas source, where the SO_2 concentration is 0.004 mg/l (1.3 ppm), corticolous lichens cover up to 40% of the tree trunks. At such exceptionally high SO_2 concentration, several thousands of people died in London in 1952. These observations speak against the hypothesis that lichens are particularly sensitive to SO_2. According to Skye (32), at a distance of 5.4 km. from a factory in Kvantorp, at a gas concentration of 35 μg S/m³, grow even *Alectoria jubata*, *Cetraria glauca* and others, while at 4.5—8 km, there is a normal lichen vegetation at a SO_2 concentration averaging 10—30 μg S/m³. It is evident that the growth of lichens is enhanced by the climatic and ecological conditions of that locality, in spite of the presence of gases. In Poland these species are not common and can be found in natural forests, very far from all air impurities. Since there is normal lichen vegetation at the concentrations given by Pišut and Skye, it is difficult to understand from the viewpoint of the "toxic hypothesis" why the influence of New York is felt as far as 40 miles from the centre of Brooklyn. According to the "ecological hypothesis", the reason is to be sought in changes of the climatic and ecological conditions. It is equally difficult to explain why in small towns or even mountain and sea resorts this vegetation is scarce, although only traces of SO_2 can be present in the atmosphere of these localities (2, 16, 25, 28, 29). Evidently, "the influence of towns" (23—29), or "the city effect" (4) on these conditions and on the lichen flora depend on the size of the town and on the area of the habitat changed by the industry, but not on the concentration of combustion gases.

10. Laboratory investigations conducted by Pearson and Skye (19) on the assimilation and respiration of the thalli of *Parmelia sulcata* placed in an atmosphere containing SO_2, at a concentration varying

between 0.1 and 10%, demonstrated that higher concentrations of this gas inhibited or completely abolished the assimilation process. Rao and Le Blanc (21) studied in the laboratory the behaviour of lichen thalli exposed for 24 hours to the action of SO_2 at a concentration of 5 ppm, under different conditions of relative humidity. These authors found an abnormal appearance of the gonidium of *Trebouxia* and the transformation of chlorophyll *a* into pheophytin *a*. These investigations can be of interest for a physiologist or biochemist, but their conclusions cannot be applied to the ecology of lichens because neither under natural conditions nor in towns have such high SO_2 concentrations ever acted on lichens. Everybody knows that all factors, if applied in excess, can be not only harmful, but even fatal for organisms. Much lower SO_2 concentrations, viz. from about 1.3 to 2.0 ppm, caused the death of many people at Mastal in Belgium, at Donara in USA, and in London (39). However, according to the above workers, lichens exposed to such high SO_2 concentrations survived. Evidently, even the highest SO_2 concentrations found in big cities are many times lower than the maximum tolerance of the species studied. The results of these investigations contradict the opinion that lichens are particularly sensitive even to traces of SO_2 in the air; thus, the "toxic hypothesis" finds no confirmation. Numerous other plants, both green and chlorophyll-less live in towns, but neither SO_2 nor other air-polluting substances which act on the plants for many years cause their elimination from the urban environment. The alga *Pleurococcus viridis*, whose cells are not covered by a fungus thallus, as in the case of the gonidia of *Trebouxia*, thrives in numerous seats in the centre of big cities. It is true that some trees can be damaged by exceptionally high air pollution, but the survival of these plants is possible in all towns.

11. Brodo (3), and LeBlanc and Rao (12) found that lichens and mosses, transplanted on bark discs from natural conditions to the urban environment with polluted air, died within some months. This proves only that these organisms cannot survive in a new habitat with unfavourable conditions. Similarly, Schubert and Fritsche (35) transplanted terricolous species together with the substratum into urban environment and found a slight decrease of the respiration intensity. It does not follow from these experiments that it is only air pollution which creates unfavourable conditions for the growth of the lichens. The author supposes that if there were favourable conditions in the new habitats, the lichens would grow there without transplantation. It was repeatedly observed in the National Park of Białowieża that lichens which grew in tree crowns, especially the fruticose species of the genera *Usnea*, *Alectoria*, *Ramalina* and *Evernia*, after the tree had been

overthrown by a storm, assumed in some days an unnatural appearance, withered, turned yellow and died. There were cases when the overthrown tree was still connected by its roots with the ground and remained alive for a long time; in such cases the crustose species retained their vitality for the longest time, whereas the fruticose and foliose species died much earlier.

The instances presented above indicate that air pollution, at concentrations which occur in towns, cannot be the cause of the paucity of the lichen flora in urban areas. For this reason, to provide facilities for further studies on the causes of impoverishment of the lichen flora in towns, the historical "toxic hypothesis" should be replaced with another hypothesis, which would treat the influence of towns on lichens more widely and more profoundly. The present writer is of the opinion that the "ecological hypothesis" called the "drought hypothesis", is more valuable because it is in agreement with the earlier and more recent investigations in various branches of science, and because it extends the purposefulness of further studies not only within the scope of the lichenology of towns (22—30).

The "ecological hypothesis" postulates that the occurrence and distribution of the individual lichen species, as of all organisms, underlie the basic influence of a complex of numerous macro- and microclimatic, edaphic, geographical, historical and other factors, which form the ecological conditions of the habitat under natural conditions, and under those modified by human activity.

Under natural conditions, even in primeval forests, the lichen flora is not the same all over the given area. Even the common species *Parmelia (Hypogymnia) physodes* can cover the pine trunks to a high percentage in one part of the forest, while a nearby group of pines of the same age bears a few specimens only. The ecologist has no doubt that where a species is absent, the conditions are unfavourable for its growth. By comparing many habitats, it is possible to roughly estimate the differences under these conditions. There are, however, habitats which apparently have the same ecological conditions, but which differ greatly in their flora of lichens. Special requirements must be met for the fruticase species of the genera *Usnea, Alectoria* and *Ramalina*. Their occurrence must be governed by some subtle differences in the intensity of the complex of the ecological factors, mainly the microclimatic ones. The present state of knowledge does not make it possible to assess these differences. Only prolonged, many-sided, comparative investigations of the microclimate would be able to determine the intensity of these factors. The individual lichen species are indicators of the complex of ecological factors which operate in different habitats for a long time.

A species can survive only where all the factors of the habitat allow it to maintain a positive balance of metabolism for several years. The nearer to the optimum conditions is the combination of numerous factors influencing the given species, the greater is the probability that the habitat will be occupied in large numbers by this species and by others, whose requirements are similar. One of the main factors causing a negative balance in lichens, i.e. when respiration prevails over assimilation, is a complex of conditions which reduce the humidity of the habitat and keep the thalli in a state of desiccation for a long time. Of these factors, the most important are: decreased humidity of the air and substratum, wind, insolation, increased temperature. As poikilohydric organisms, lichens are unable to regulate the water balance in their thalli, as higher plant can do, and dry up quickly under such conditions. Lange (9) demonstrated that desiccated lichens breathe, but do not assimilate. Of a similar opinion is Butin (5, p. 459). For this reason, "ecological hypothesis" can be called the "drought hypothesis".

The unfavourable ecological conditions, which already have caused changes in the lichen vegetation in natural and artificial forests and on roadside trees, become increasingly unfavourable when a town is penetrated from its outskirts to its centre. The town is a habitat completely changed by man — a paved, waterless, stony desert, whose rocky surface surpasses many times that of tree trunks and lawns. The substratum is heated by insolation, and combustion of coal, gasoline and gas add heat to the air. From the outskirts to the centre, the relative humidity of the air decreases, and the temperature increases (8, 6, 22). Temperature differences between the centre of the town and its environment reach several degrees. According to Laundon (11), these differences in London range between 1.9 and 9°C. The resulting convection air currents hinder the formation of dew needed by lichens. Under these highly unfavourable, general ecological conditions and highly differentiated microclimatic conditions found in different habitats (6, 8, 22), and especially in the centre of the town, the majority of the lichen species which live outside the town undergo elimination. According to the "ecological hypothesis", this is the reason of the formation in large and small towns of "lichen deserts" and "struggle zones" described by some authors. A correlation between these zones of the distribution of lichens and the gradually changing, from the outskirts to the centre, air humidity and temperature is shown in Fig. 12 (22). The larger the area the town, the more extensive are these zones. The influence of some very large cities can be felt far into the country, where air pollution is very small. Under such conditions, some species only can hide in ecological niches, where a minimum moisture content is always present; they survive there in spite of the gases which act on them. According to the "drought hypothesis", these species would live in the same atmosphere on the adjoining surfaces, if they found there suitable ecological conditions. In the present writer's opinion, the "toxic hypothesis" does not fulfill its task because, instead of making it easier, it renders the understanding of the ecology of lichens more difficult. The "ecological hypothesis",

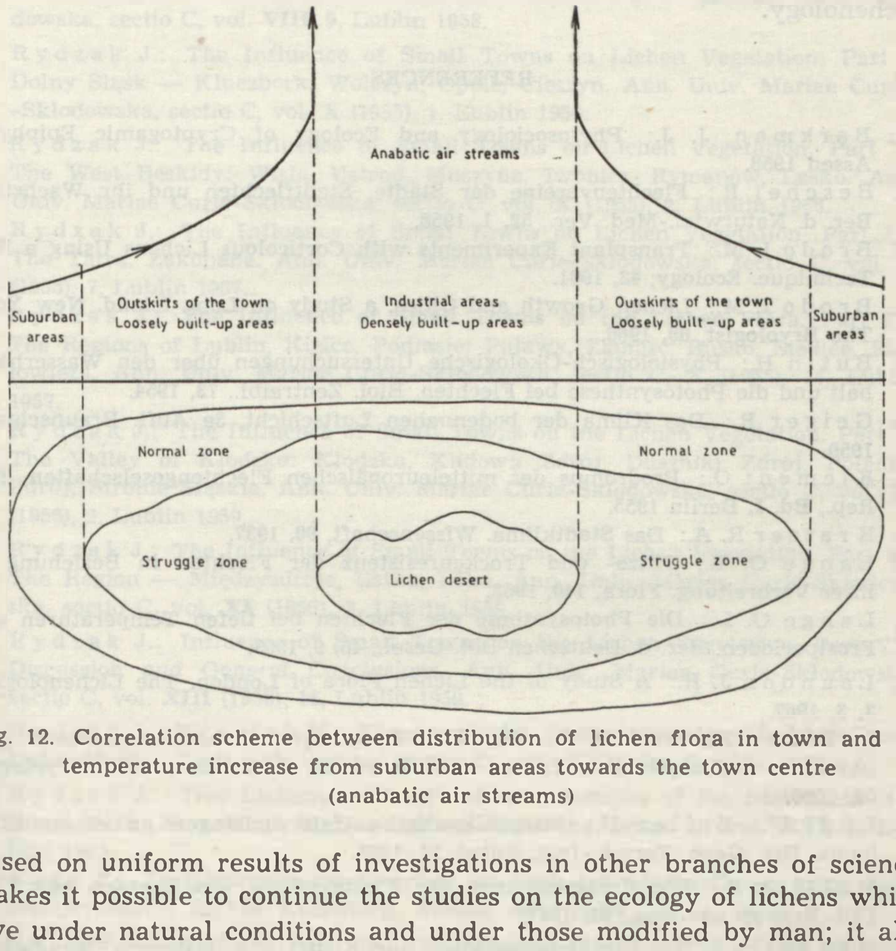

Fig. 12. Correlation scheme between distribution of lichen flora in town and air temperature increase from suburban areas towards the town centre (anabatic air streams)

based on uniform results of investigations in other branches of science, makes it possible to continue the studies on the ecology of lichens which live under natural conditions and under those modified by man; it also demonstrated that the individual lichen species can serve as excellent indicators of the macro- and microclimatic conditions of the habitat.

CONCLUSIONS

The growth of the urban area and the development of industry in Lublin have caused a deterioration of the ecological conditions for the growth of lichens. During the past 18 years, lichen vegetation in this town has impoverished. The "toxic hypothesis" does not suffice to explain the condition of the lichen flora in towns; it also makes further studies of the lichen ecology difficult. On the other hand, the "ecological hypothesis", also called "drought hypothesis", gives a uniform view of the problem and stimulates investigations of the ecology of lichens not only in towns, but also in their natural habitats. The conflict between these two hypotheses has been so far of profit for the advance of lichenology.

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Porosty jako wskaźniki ekologicznych warunków siedliska

Streszczenie

Autor zbadał ponownie po 18 latach stan flory porostów w Lublinie. Rozmieszczenie i skład gatunkowy stanowisk porostów epilitycznych i epifitycznych przedstawiono w tab. 2 i 3 oraz na ryc. 1. Porównanie wyników badań z r. 1948 (22) wykazuje zubożenie wegetacji porostów, a przyczyną tego był wzrost miasta i obiektów przemysłowych, co spowodowało pogorszenie się warunków ekologicznych, potrzebnych porostom do życia. Poszczególne gatunki porostów mogą żyć tylko tam, gdzie kompleks czynników ekologicznych i mikroklimatycznych umożliwia im utrzymanie dodatniego bilansu przemiany materii. Jako organizmy poikilohydryczne szybko tracą wodę, a w stanie wysuszonym nie asymilują. Dlatego osiedlają się na takich stanowiskach naturalnych lub sztucznych, na których mogą zdobyć odpowiednią ilość wody przy równoczesnej obecności innych sprzyjających warunków. To są też przyczyny bardzo niejednolitego rozmieszczenia porostów w warunkach naturalnych. Porosty są wskaźnikami subtelnych różnic natężenia czynników mikroklimatycznych siedliska. W miastach odpowiednich siedlisk dla porostów jest mało i dlatego rozwój ich jest tam utrudniony. Jeżeli jednak niektóre gatunki znajdą odpowiednie nisze ekologiczne, żyją tam mimo działania zanieczyszczeń powietrza. W dyskusji autor wykazuje większą użyteczność hipotezy ekologicznej zwanej „hipotezą suszy" w zestawieniu z „hipotezą trucizny". Dotychczas ścieranie się poglądów na tle tych dwóch hipotez było korzystne dla rozwoju nauki w tej dziedzinie.

Лишайники как экологические показатели условий местообитания

Резюме

Автор настоящей работы повторил исследования состояния флоры лишайников в Люблине, проведенные 18 лет назад. Размещение и видовой состав местонахождений эпилитических и эпифитических лишайников представлены в табл. 2—3 и на рис. 1.

Сравнение результатов этих исследований с исследованиями 1948 г. (22) показывает обеднение вегетации лишайников, вызванное развитием города и ростом числа промышленных предприятий, что в свою очередь вызвало ухудшение необходимых для жизни лишайников экологических условий. Отдельные виды лишайников могут жить только там, где комплекс экологических и микроклиматических факторов позволяет им сохранять положительный баланс метаболизма. Как пойкилогидрические организмы лишайники быстро теряют воду, а в сухом состоянии они не ассимилируют. Поэтому лишайники селятся в таких природных или искусственных местах, где они могут получать необходимое им количество воды при одновременном наличии других благоприятных условий. Всё это является причиной очень неравномерного размещения видов в природных условиях. Лишайники являются показателем едва заметных разниц в интенсивности микроклиматических факторов местообитания. В городах соответствующих местообитаний для лишайников мало и это является причиной бедности их вегетации там. А когда некоторые виды находят соответствующие экологические ниши, то произрастают там, несмотря на загрязненный воздух.

Автор указывает на большую пригодность экологической гипотезы, называемой „гипотезой суши", чем „гипотезы отравления". Столкновение этих двух взглядов на фоне вышеуказанных гипотез было полезным для развития этой области науки.

Table 3. Epiphytic lichens

Explanation: A — *Acer platanoides*, B — *Betula verrucosa*, C — *Carpinus betulus*, F — *Fraxinus excelsior*, G — *Alnus glutinosa*, H — *Aesculus hippocastanum*, J — *Juglans regia*, L — *Populus* sp., M — *Morus alba*, N — *Acer negundo*, P — *Picea excelsa*, Pa — *Prunus avium*, Pr — *Prunus cerasus*, Q — *Quercus* sp., R — *Robinia pseudoacacia*, S — *Salix fragilis*, So — *Sorbus aucuparia*, T — *Tilia cordata*, U — *Ulmus montana*, 1 = 10% of area, indicates more than one specimen of the lichen species

No.	Species	No. of localities, region, species and diameter of tree in cm, degree of coverage													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
													174	-	-
		A2													
		T	T	T	T	T	P	A	N	J	P	N	P	A	A
		60	60	60	80	70	40	80	30	20	30	25	30	40	90
1	Buellia punctata Mass.														+
2	Candelariella vitellina Arg.														
3	Candelariella xanthostigma Lett.	+	+			+			+			+			+
4	Evernia prunastri Ach.				+										
5	Lecanora albescens Flörke														
6	Lecanora carpinea Vain.														
7	Lecanora chlarona Nyl.									+					
8	Lecanora hageni Nyl.														
9	Lecanora subfusca coll.	+	+					+	+					+	
10	Lecanora subfuscata Magn.														
11	Lecanora varia Ach.														
12	Lecidea olivacea Mass.			+					+	+				+	
13	Lecidea euphorea Nyl.														
14	Lepraria aeruginosa Sm.														
15	Parmelia exasperatula Nyl.						+		+						
16	Parmelia glabratula Zahlbr.														
17	Parmelia furfuracea Ach.														
18	Hypogymnia physodes Nyl.														
19	Parmelia sulcata Tayl.	+	+	+	+	+	+	+	+			+			
20	Pertusaria globulifera Mass.			+											
21	Phlyctis argena Flot.				1	1									+
22	Physcia aipolia Hampe							1							
23	Physcia adscendens Oliv.	1	+						1	1	1	+	+	1	
24	Physcia adscendens for. subbreviata B.d.Lesd.		4		+	+	+								
25	Physcia grisea Zahlbr.			1			+	1	1	1	2	1	2		1
26	Physcia orbicularis Poetsch														
27	Physcia stellaris Nyl.						+		+		1	1			
28	Ramalina fraxinea Ach.														
29	Xanthoria candelaria Th.Fr.														+
30	Xanthoria parietina Th.Fr.	+	+	+			1	2	1	+	1	+	2	+	+
31	Xanthoria polycarpa Oliv.														
32	Xanthoria substellaris Vain.														

No.	No. of localities, region, species and diameter of tree in cm, degree of coverage																							
	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	31a	32	33	34	35	36	37
	-	-	-	-	-	-	179	173	179	168	-	-	-	-	172									
										A3							A3							
	T	T	S	L	P	L	F	H	A	S	H	R	H	L	T	C	H	Q	A	H	Pr	F	C	F
	100	100	120	150	40	130	60	80	30	30	60	25	30	100	40	15	60	10	70	30	10	23	20	25
1																								
2																								
3								1																
4	+				+													+						
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6		+														+				+			+	
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19	+	+			+												+	+						
20																								
21		2																						
22																								
23	1		2	+		+		5	2	+					+									
24																								
25				1		+			1	+	1		3	2					1	+		2		2
26																								
27																								+
28																								
29																								
30		+	1	2		+	1	2	2	1	+	2	2	1					+	+		1		1
31																								
32																								

No.	No. of localities, region, species and diameter of tree in cm, degree of coverage																						
	38	39	40	41	42	43	44	45	46	47	48	49	51	52	53	54	55	56	57	58	59	61	62	63
						A_4		A_5														B_5		B_6
	H	Pa	C	p	Q	N	L	T	Q	F	A	p	H	A	H	F	H	T	Pa	B	p	T	A	N
	30	10	10	-	60	40	50	50	80	40	20	-	90	30	100	10	80	50	20	40	-	30	30	25
1																								
2																								
3							+																	
4		+																						
5																								
6			1			+								+										
7							+				+													
8																								
9	+				+			+		+	+					+						3		
10							+																	
11																								
12							+																	
13																								
14																								
15												+												
16																								
17																								
18		+							+												+			
19	+	+						+	+			+							+					
20																								
21								+																
22									+															
23				+		2	1			1			+							+			1	2
24															+		+							
25						+																		
26				+																				
27						+	+			+								+	+					1
28																								
29																								
30				+	+	+	5			1			+		+		+	+	+				1	1
31																								
32																								

No.	No. of localities, region, species and diameter of tree in cm, degree of coverage																							
	64	64a	65	65a	66	67	68	68a	69	70	71	72	73	73a	73b	74	75	77	77a	78	78a	78b	79a	80
	56	-	-	-	56											162	162		164		154	154		157
	B_4								C_2							D_3		C_4			D_4			
	T	T	M	M	P	A	p	p	A	T	So	T	T	L	A	P	P	P	L	H	L	L	A	T
	45	45	25	25	50	30	-	-	30	30	15	30	60	30	30	30	30	20	30	40	25	25	30	80
1																								
2							+																	
3																								
4												+												
5																								
6																								
7									+	+		+		+	+									
8																								
9	+	+							+		+	+												
10																								
11																								
12												+		+										
13																								
14																								
15												+												
16																								
17																								
18							+				+	+												
19							+			+		+												+
20																								
21																								+
22																								
23			+	1							2	2	+	1								+	+	
24					+	+				1					+	+	1			+				+
25			+	1																				
26														+										
27		+							2	+		1		1	1			+	+	+				
28																								
29																								
30		+	1	1	1	+	+	+	1		1	2		5	+	+	+		+	+	+	+		
31									+			+												
32																								

No.	No. of localities, region, species and diameter of tree in cm, degree of coverage																							
	80a	80b	80c	81	81a	82	86	88	89	91	93	94	95	96	98	99	100	102	103	105	106	107	108	109
	-	-	157				148	-	-	150	148	180	180											
	D_4						D_5													D_6		C_7		
	S	H	P	L	A	p	P	A	N	P	Q	T	H	P	Ap	Ap	N	Ap	p	T	S	S	T	B
	40	40	20	25	20	-	90	50	30	60	25	80	60	80	30	20	40	25	-	80	120	70	50	30
1																								
2																								
3												+	+							+			+	
4										+	1													
5																			+					
6									+							+		+						
7																				+			1	
8																								
9			+															+		+				+
10																								
11																								
12																							+	
13																								
14																								
15																								
16																								
17																								
18										1														
19	+					+		+	+								+	+					1	
20																								
21																								
22																								
23	+		+																					
24		+		+	+	+						+			+		+	+		+		1	1	+
25							+		+	1			+	1				+						+
26						+											+		3	1	1	2		
27			2		+										+	+		1						
28																								
29																								
30			+	+	+	+	+					+			+		+	+	+	1	1	+		+
31																								
32												+	+	+						+				

No.	No. of localities, region, species and diameter of tree in cm, degree of coverage																							
	110	111	112	113	114	115	117	118	119	120	121	122	123	127	128	129	130	131	132	133	134	135	136	138
							250				243	243	245		246									
									D_8	D_7						D_{89}		D_9					D_9	
	H	S	G	p	S	k	S	T	d	L	S	L	L	L	L	R	B	S	N	H	B	H	P	G
	40	60	40	-	60	-	60	30	-	40	50	70	80	60	30	20	40	30	30	40	35	40	80	50
1																								
2									2															
3				2																				1
4						1											+							
5																								+
6																								
7																								
8		+							+							+				1				
9									1															
10																	+		1					
11																								
12																+			+					
13																								
14																								
15																								
16																	+							
17																								+
18																								
19	+									+				+		+	+			+				
20																								
21																								
22																								
23			+	1							+	1												
24	+	2			3		3	1						1		+		3		1				
25			+																1		2	3	2	
26			+	2	1		1		1			1	1						2					
27			+						+		+	+	+	+	2									1
28																								
29																								
30		+	+	+	+		1	+	+		+	+	1	+	3			+	3		1	1	+	
31																								
32								1																

No.	No. of localities, region, species and diameter of tree in cm, degree of coverage																							
	139	140	141	142	146	147	148	149	150	151	153	154	155	156	157	158	159	160	161	162	163	164	167	169
					144	116		183	183	-	-	185							79	82	14	3	5	1
		D_8			B_3		B_5						P_1		P_2				P_3					
	L	T	T	T	R	A	p	L	P	P	L	L	P	A	A	T	P	P	B	T	T	P	L	L
	120	30	30	35	30	25	-	80	25	25	80	80	70	50	40	40	50	60	40	60	30	40	120	110
1																								
2																								
3				1																				
4																								
5																								
6																								
7		+	+									+												
8																								
9																	+							
10													+		1									
11							+																	
12					1																			
13																								
14																								
15	1																							
16																								
17																								
18																								
19				+											1	+	1							
20																								
21	2																							
22																								
23	+		2																					
24		+				+		+			+					1	2		+	+			+	+
25													1		1			1						
26														+			2							
27		+							+	+	1										+	+		
28	+																							
29																								
30		+	1		+			+	+		1		1	1	+	+		+				+	+	
31																								
32																								

No.	No. of localities, region, species and diameter of tree in cm, degree of coverage																							
	170	172	191	192	193	194	195	196	197	198	199	200	202	204	208	209	210	211	212	213	214	215	216	217
	197	186	186	184	185	186	-	-	186	226	217				214		213	213	29	27	28	19		16
	P_5						P_5			P_6	P_7	P_8		P_9	G_9	G_9	G_8		G_1	H_2				G_2
	F	L	L	F	L	L	F	L	L	L	F	H	H	T	T	B	N	N	L	F	P	L	U	F
	30	80	80	40	100	90	40	70	70	80	40	40	30	40	60	40	30	50	60	40	45	50	40	30
1																								
2																								
3															+	+								
4														+						+	+			
5																								
6																								
7													+	+								1		
8		1	+												+	+								
9														+				1	2	1				
10			1									+				+								+
11																								
12														+				+	1	+				
13																					+	+		
14																								
15																					+			
16																								
17																								
18																							+	
19												+	+	+				1		1	1		+	+
20																								
21																								
22																								
23						+								2					4					
24	+			+	+				1	+	+		1		+	+	1			2		2	2	+
25																+						1		
26						+	1	1							+			1						
27				+			1				+	+		+			+			1	+	1		+
28																								
29																						+		
30			+			1	+	2	3					+			1	2	3	+	+	1-5	2	
31																								
32																								

No.	No. of localities, region, species and diameter of tree in cm, degree of coverage																							
	218	220	221	222	224	226	227	228	229	230	231	233	234	235	236	237	240	241	242	243	245	246	247	248
						18	21						211					210		35		32		
							G_2					G_3	G_9	G_9	H_8	G_9	G_9	G_{10}		H_3			H_3	J_3
	U	Ap	S	L	A	P	N	p	C	k	P	p	P	L	S	P	Q	H	L	H	T	P	N	N
	30	40	40	50	30	25	30	–	40	–	40	–	20	50	80	40	60	50	70	80	40	50	60	60
1							+														+			
2																								
3																								
4																								
5																								
6					+																			
7						+															+			+
8		+																						
9				+										1										1
10			+				+																	
11								3		1		1												
12																								+
13																								
14																								
15													+											
16																								
17																								
18								1																
19		+	+	+				2			1		+				1							1
20																								
21																								
22																								
23			+		+				1							1		2	1					1
24	2	+		2					3			+	2		2		1				+		1	2
25	1			1			4			+	2				+	1	+	+	4	1				1
26												+		2	+									2
27						+					+		+		+	2								+
28																								
29																								
30			+	3	+	+	2					+		1	2	2	2	2	2	1		+	2	2
31																								
32															+		1							

Papier druk. sat. III kl. 80 g. Format 70 × 100 Druku str. 34
Annales UMCS Lublin 1968 LZGraf. im. PKWN, Lublin, Unicka 4 Zam. 3233. 9.X.68
1100 + 125 egz. F-3 Manuskrypt otrzymano 9.X.68 Druk ukończono 31.I.69