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THE EFFECT OF LAND RECLAMATION ON SYNANTHROPIC PLANTS IN THE REGION OF NITROGEN PLANTS IN PUŁAWY

ABSTRACT

The study was carried out in 1972—1974 in destroyed, partly reclaimed (fertilized and watered), and completely reclaimed, cultivated areas of the deforested zone adjoining nitrogen plants in Puławy. The Braun-Blanquet [2] method of phytosociological surveys and the Traczyk [8] method were used to determine changes in the plant cover, succession of sociological units, the rate of natural plant regeneration, and primary production. It has been found that the development and differentiation of plant communities, the number of species, as well as production depend on both industrial emissions and reclaiming treatments.

INTRODUCTION

The location of nitrogen plants in Puławy on poor sites of dry coniferous forests (54%) and damp forests (27%) had a destructive effect on the whole of natural relationships in this region [3].

A rapid destruction of forests by nitrogen emissions was followed by the development of the zone of biological death, also called the "deforested zone" [4, 5].

The biological life was restored in this zone in two ways. First of all by reclamation and agricultural treatments, but also by the natural recovery of plants [5, 6].

Among the pollutions emitted by the nitrogen plants, the most harmful are such as ammonium nitrate, urea, nitrogen oxides, and sulphur dioxide. The range and rate of emissions are presented in Figure [1].

STUDY AREA AND METHODS

The study was conducted in four plots: destroyed, fertilized, watered, and cultivated. There were differences among them in the

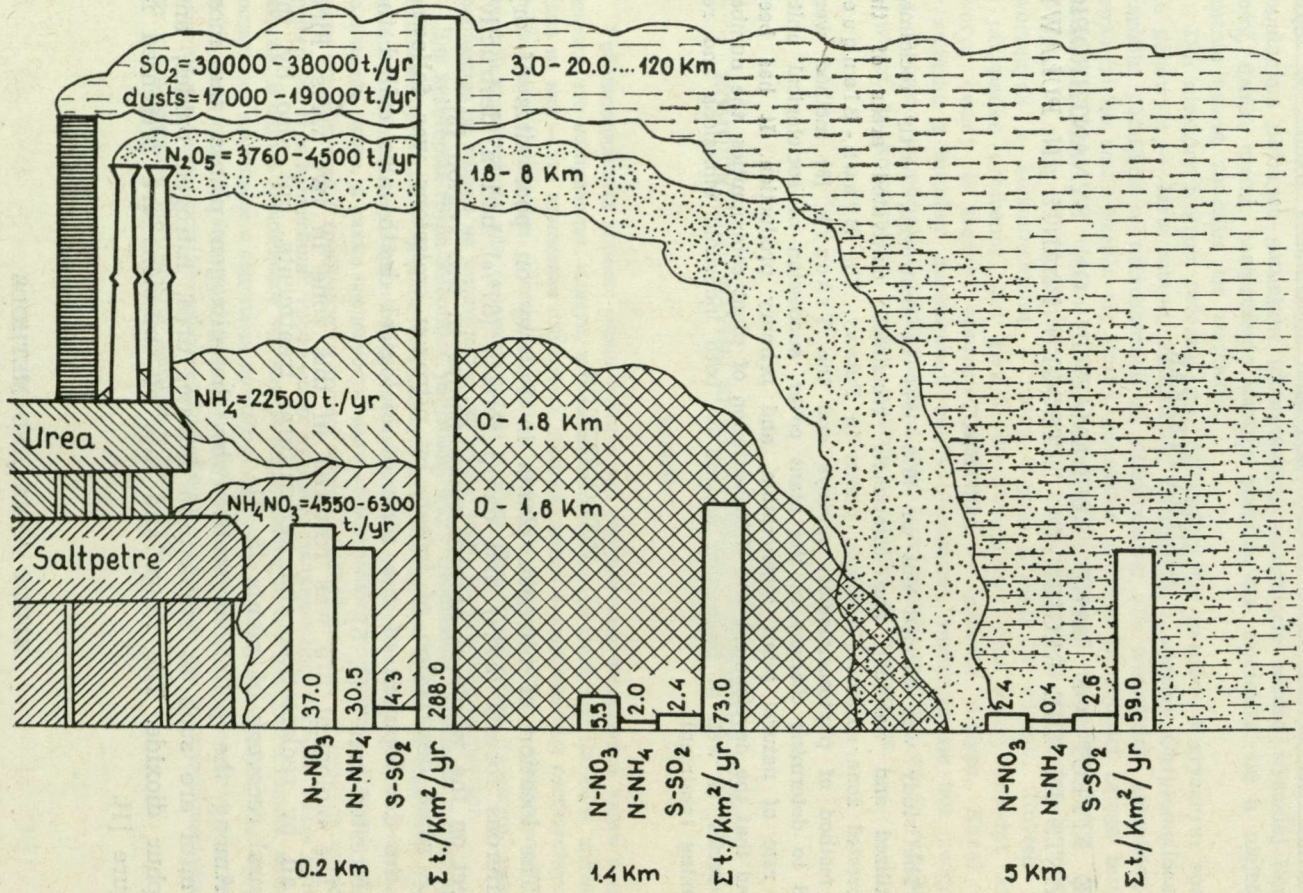

Fig. 1. Range and rate of emissions from the Nitrogen Plants in Puławy in 1967—1974.

treatments applied, these treatments being called here the ways of reclamation (Fig. 2).

It has been expected that there will be rather significant qualitative and quantitative differences in the pattern of plant restoration, resulting from differences in the way of reclamation. Thus the destroyed plot, unfertilized and without any other treatments, is considered as the control.

The simplest way of reclamation was an addition of calcium fertilizers (60 q/ha and slag (30 t/ha), without phosphorus-potassium fertilizers (the fertilized plot).

Fertilizing with calcium, slag, phosphorus and potassium, as well as watering were used for intense reclamation, but without the introduction of crop plants (the watered plot).

The plot with crop plants was reclaimed in the same intense way. The difference was that besides the phosphorus and potassium fertilizers, also fertilizers for successive crops were added. Nutrients contained in fertilizers were removed from this plot in the form of yield (the cultivated plot).

To show relationships between the synanthropic plants and the ways of reclamation, such processes were analysed as dynamic changes in the plant cover, the spontaneous recovery rate of plants, and the productivity of the populations of particular plant species, as well as of the whole study plots.

For these analyses the following methods were used: floristic check-lists valorized by the Braun-Blanquet [2] scale, permanent inventory of selected plant stands, and the modified method described by Traczyk [8] to determine primary production.

RESULTS

Geobotanical studies carried out in 1972—1976 showed that the vegetation was able to regenerate even after a violent destruction in the most heavily polluted region. But the species composition and, consequently, the adaptive possibilities of the restored plants were quite different.

In the deforested zone at the nitrogen plants in Puławy, the natural forest vegetation has almost completely been replaced by synanthropic plants, including both wild-ruderal species and species typical of clearings. Some very scarce forest species have been preserved, but their proportion decreased with the progressing reclamation

of the natural evironment. The higher the degree of habitat reclamation, the lower was the proportion of forest species (Fig. 3).

The percentage contribution of species together with the total number of species show that the forest habitat polluted with industrial emissions is firstly enriched in species, this being already noted by Kawecka [4] and Sokołowski [7] in their studies of this area during earlier stages of destruction. And so, in the forest covering the control, nonpolluted plot there were 29 plant species typical of this habitat; they accounted for 100% of the species composition. In the forest destroyed by pollution the total number of species increased up to 71, but many nonforest species appeared. The species characteristic of forest habitats accounted for only 41% of the total.

A similar proportion of forest and nonforest species was recorded in the destroyed plot and in the fertilized plot, i.e., either in the plot not reclaimed at all or preliminary reclaimed by liming and addition

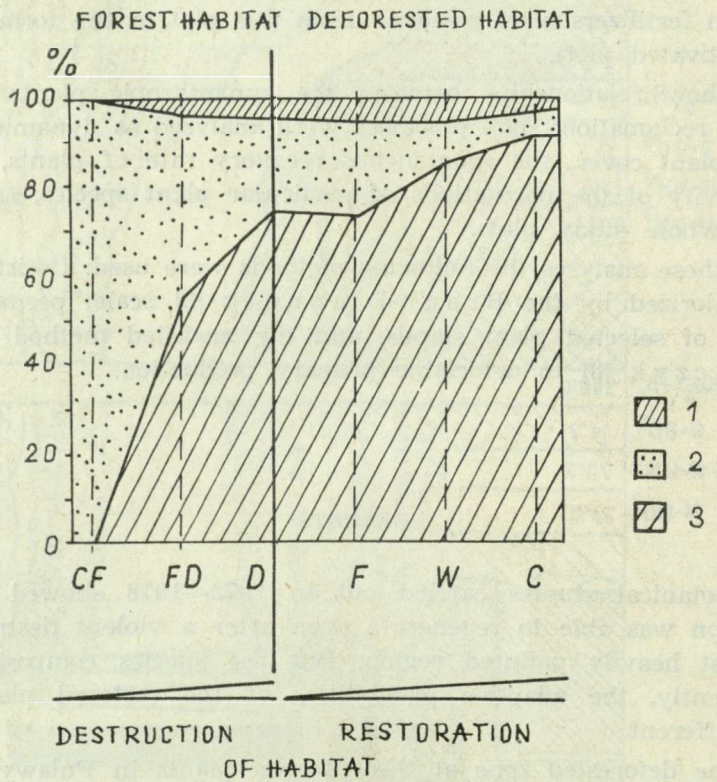

Fig. 3. Proportion of particular groups of species in various study plots. 1 — clearing species, 2 — forest species, 3 — crop and ruderal species. CF — control forest, FD — forest in the course of destruction. D, F, W, and C — as in Fig. 2.

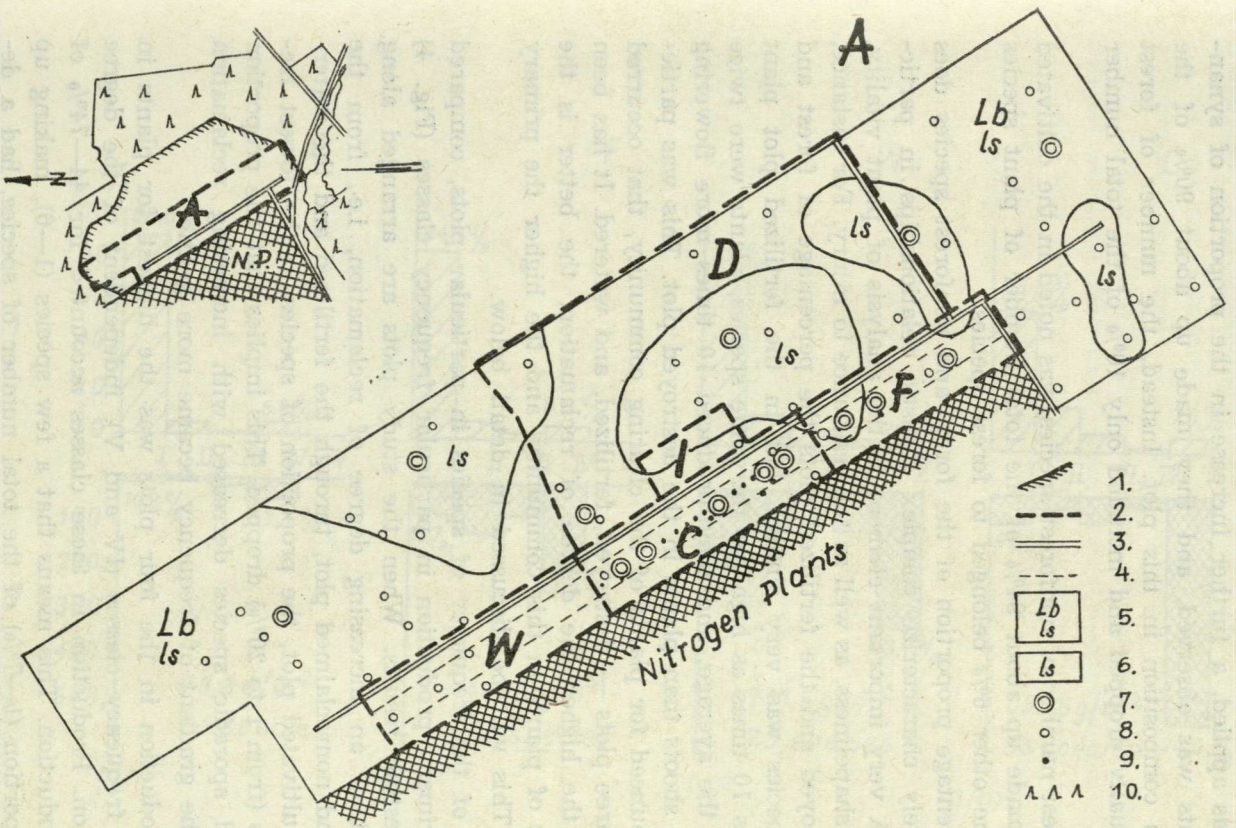

Fig. 2. A map of the study area (A) and location of the study plots in the region of the Nitrogen Plants in Puławy.
Legend: 1. the range of deforested zone in 1972—1974, 2. study plots, 3. roads, 4. transect for phytosociological survey, 5. leached acid brown soils formed from loose sands (Lbls), 6. raw soils formed from loose sands (ls), 7. soil pits where samples were taken for laboratory analyses, 8. soil pits for soil characteristics, 9. places where soil samples were taken for agrochemistry characteristics, 10. forests.
Explanations: N.P. — Nitrogen Plants, D — destroyed plot, W — watered plot, C — cultivated plot, F — fertilized plot, I — inventorial plot.

of slag. Forest plants accounted for 22% of the total species composition, while the remaining 88% were represented by synanthrophic plants.

In the watered plot, where the complete reclamation, including watering, was applied, a further increase in the proportion of synanthropic plants was observed, and they made up about 90% of the total species composition in this plot. Instead, the number of forest species gradually dropped and included only 10% of the total number of species.

The highest number of nonforest species was noted in the cultivated plot. They made up about 94% of the total number of plant species recorded. The other 6% belonged to forest species.

The percentage proportion of the forest and nonforest species does not completely characterize complex floristic relationships in particular plots. A very important element is the analysis of plant vitality, habitus and shapeliness, as well as the resistance to injury. For instance, in the destroyed and the fertilized plots the percentage of forest and nonforest species was very similar, but in the fertilized plot plant coverage was 10 times as high for the same species, plants were twice as high, on the average, and they produced 10 times more flowering and fruiting shoots than plants in the destroyed plot. This was particularly pronounced for plants of the clearing community, that occurred in all the three plots — destroyed, fertilized, and watered. It has been found that the higher the degree of reclamation, the better is the development of plants in this community, and the higher the primary production. This will be discussed in detail below.

Analysis of the frequency of species in particular plots, compared with the primary production in particular frequency classes (Fig. 4) yields interesting results. When the study plots are arranged along the gradient of an increasing degree of reclamation, i.e., from the destroyed and nonreclaimed plot, through the fertilized and the watered, to the cultivated plot, the proportion of species in the lowest frequency class (from 1 to 20%) dropped. This implies that the proportion of rare and sporadic species decreased with increasing reclamation level, and the gradient of frequency became more gentle.

Plant production in the four plots was the highest for plants in the highest frequency classes (IV and V), independent of the degree of reclamation. Production in these classes accounted for 44—74% of the total production. This means that a few species (1—6), making up a small proportion (1—7%) of the total number of species, had a decisive effect on the primary production. This fact shows that the domination structure of some groups of plant species was accomplished.

To sum up, it can be stated that the processes of reclamation were accompanied by a decrease in the percentage of species from the lowest

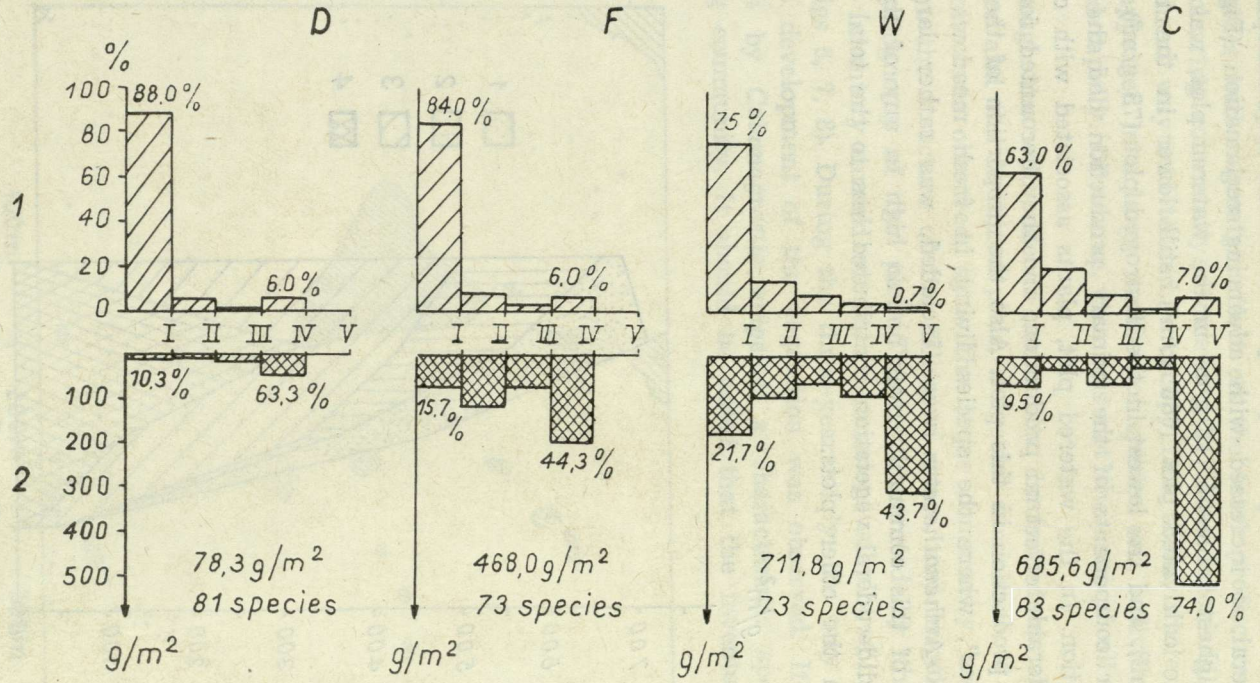

Fig. 4. Frequency distribution of species and primary production in particular plots in 1973—1974.
1 — proportion of species, 2 — mean production. D, F, W ,C — as in Fig. 2.

frequency classes, and an increase in the percentage of species from the highest frequency classes.

There were differences in the production of synanthropic plants but, in general, it increased with advancing reclamation (Fig. 5). It reached a highest value of 712 g/m² in the watered plot, was a little lower in the cultivated plot (686 g/m²), still lower in the fertilized plot (468 g/m²), and the lowest in the destroyed plot (73 g/m²).

Particular components of the primary production had the following contribution. In the watered plot, plants associated with clearings had a considerable effect on production, and they accounted for a half of the total production in this plot. Also the proportion of the groups called "others", where the species living in fresh meadows of the class *Molinio-Arrhenatheretea* were included, was rather large. The contribution of this community was not so high in any of the other plots. The wild-ruderal vegetation contributed less to the total production than in the other plots.

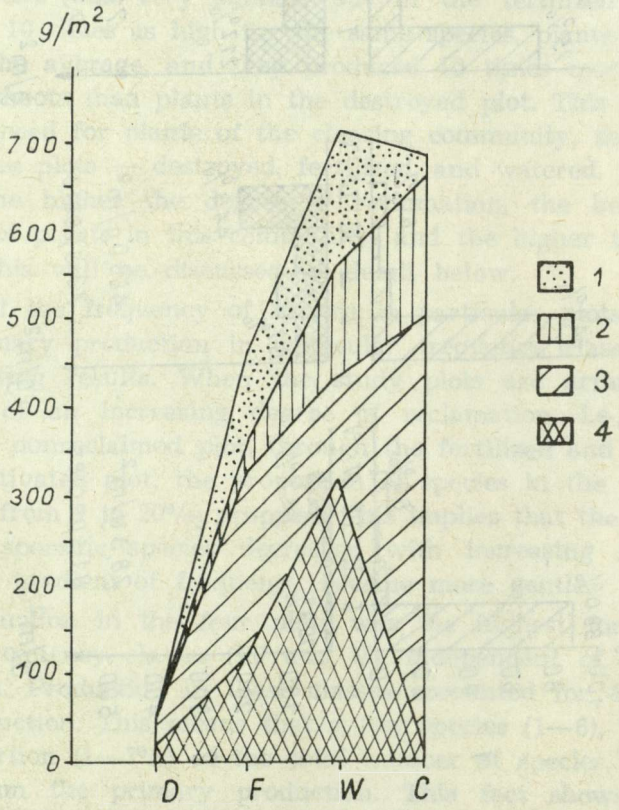

Fig. 5. Components of primary production in particular plots (in g/m²). 1 — other species, 2 — ruderal species, 3 — crop species, 4 — clearing species. Remaining explanations as in Fig. 2.

The wild-ruderal species dominated in the cultivated plot, where the production of clearing plants and "other" species was at minimum.

In the destroyed and the fertilized plots, species of the wild-ruderal communities had a greater effect on the total production than those of the clearing community. However, the latter colonized the area in a permanent way and tended to occupy new areas, while wild-ruderal plants appeared in a large number of species and individuals but disappeared rapidly. Of course, this was not the case of all wild-ruderal species.

Although the wild-ruderal community dominated by weight in the destroyed and the fertilized plots, a spatial dominance of the clearing community was observed, since the latter community had a decisive effect on the structure of the filling of space, and largely influenced the physiognomy of the plot. This is illustrated by the results of a plant inventory carried out in a permanent subplot of the destroyed plot (Figs 6, 7, 8). During the three-year study, the way of the spontaneous development of the vegetation was observed. It was predominated by *Calamagrostis epigeios*, a characteristic species of the clearing community. It should be noted that the inventory was con-

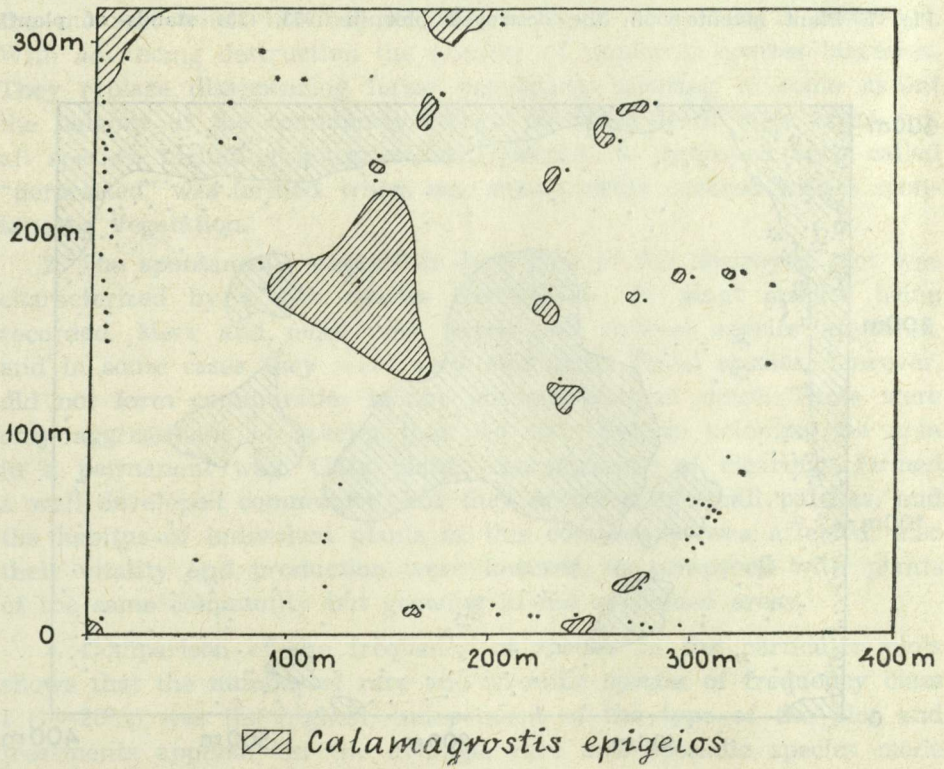

Fig. 6. Plant inventory in the destroyed plot in 1972. (80 stands of plant).

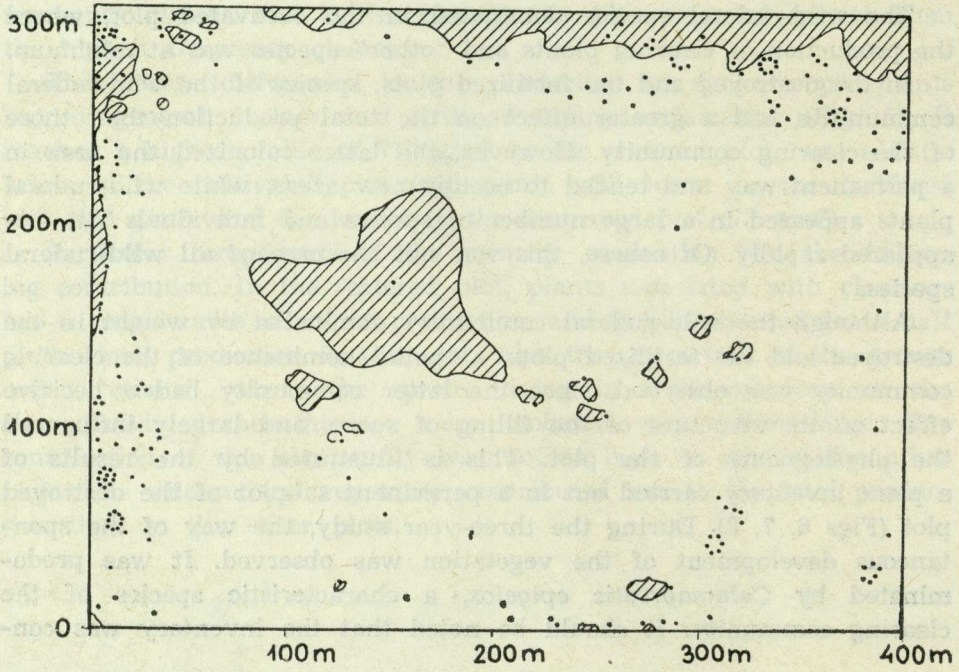

Fig. 7. Plant inventory in the destroyed plot in 1973. (231 stands of plant).

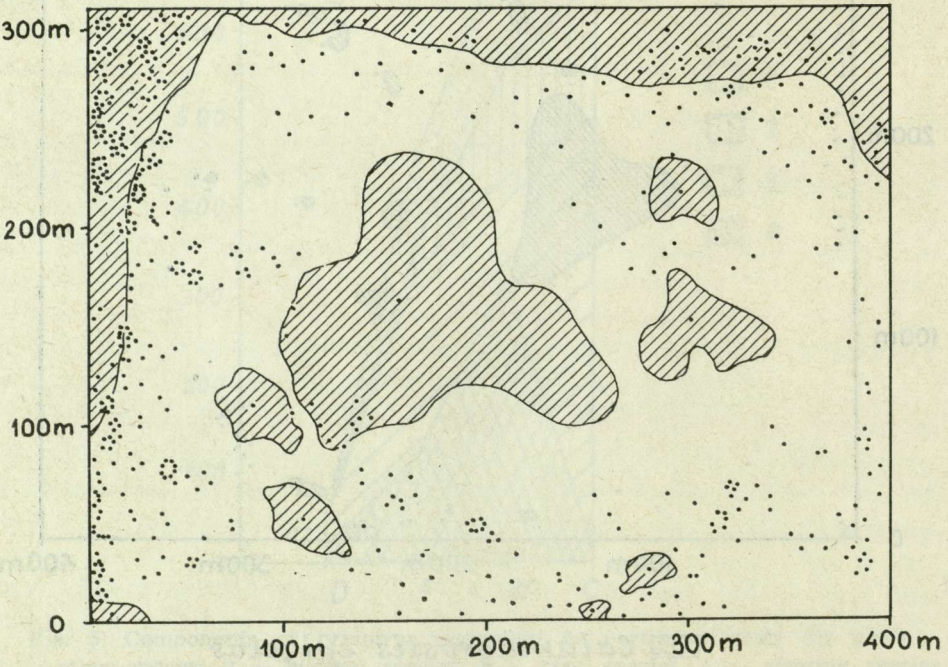

Fig. 8. Plant inventory in the destroyed plot in 1974. (603 stands of plant).

ducted in the area not subjected to any reclaiming treatments up to the beginning of the study. Only at the end of 1972 this area was preliminary fertilized, which resulted in large changes in the plant cover. The number of species increased from 16 in 1972 to 29 in 1973, and the number of stands from 80 to 231. In the following year, 1974, phosphorus-potassium fertilizers were added and, as a result, a further increase in the number of species and stands was noted. There were 27 species in 603 stands. During the period of inventory the percentage area covered with *Calamagrostis epigeios* increased.

SUMMING-UP

The following conclusions can be suggested from the results presented above:

1. The negative response of forest vegetation to pollution leads to destructive changes in the forest communities. Many species characteristic of forests disappear or their growth is heavily affected. The response counteracting the habitat destruction is the appearance of nonforest species, mainly weeds characteristic of crops and gardens, at the moment when the balance of the forest ecosystem is disturbed. With advancing destruction the number of nonforest species increases. They replace disappearing forest vegetation, securing to some extent the balance of the community. When the dead trees were clear cut, all species, including nonforest, disappeared. A destroyed zone called "deforested" was formed, which was subsequently covered with a spontaneous vegetation.

2. The spontaneous vegetation developed in the destroyed plot was characterized by a rich species composition, 81 plant species being recorded. More and more new weeds and ruderal species appeared, and in some cases they were very abundant. These species, however, did not form communities in the phytosociological sense. These were only aggregations of species that did not tend to colonize the area in a permanent way. Only plants characteristic of clearings formed a well developed community, but they occurred in small patches, and the habitus of individual plants of this community was affected, also their vitality and production were lowered, as compared with plants of the same community but growing in the reclaimed areas.

3. Comparison of the frequency of species in the particular plots shows that the number of rare and sporadic species of frequency class I (1—20%) was the highest, independent of the type of the plot and treatments applied. On the average, rare and sporadic species made up more than 70% of all species. Conversely, the species of the highest

frequency classes were very scarce and they accounted for 1—7% of all species. The frequency distribution of the species in the plots reclaimed to a higher degree was more gentle than in the plots with a low reclamation level.

4. Preliminary reclamation, which included liming and slagging, was followed by deep changes in the appearance of plants, species composition, and production. The average production in the fertilized plot was 468.0 g/m², i.e., about 6 times higher than in the destroyed plot. The total number of species, in turn, was lower than in the destroyed plot, 73 species being recorded. But these species had better habitus, higher vitality, and lower susceptibility to injury. The coverage as well as the number of flowering and fruiting plants were almost 10 times as high as those in the destroyed plot. Also the degree of the organization of plant communities was higher. The clearing community covered large areas, forming mosaic aggregations of different sizes. Free spaces of this mosaic supported other plant species, mostly crop and garden weeds.

5. In the watered plot, where in addition to the preliminary fertilization also watering was applied and phosphorus-potassium fertilizers were added in the proportion corresponding to the amount of nitrogen emissions, the vegetation was high and shapely. It was predominated by *Calamagrostis epigeios*, which is typical of clearing communities. Individuals of this species forming carpets were more than 120 cm high, produced many flowers and fruits, and contributed to about 50% of the production, which in this area reached 712 g/m². But not only plants from the clearing community found suitable conditions in the watered plot. Also numerous species of the community of fresh meadows *Molinio-Arrhenatheretea* were recorded, and they made up about 20% of the total production, on the average. The watered plot supported the richest sod. The number of grass species was the highest there.

6. The agricultural way of land reclamation in the deforested zone, which involved the addition of N and K fertilizers, watering, complete soil reconstruction, and plant cultivation, resulted in a sound plant development, a high degree of the organization of wild-ruderal communities, and a high plant production amounting to 686 g/m². The plot with the agricultural type of management was mainly colonized by the vegetation typical of agricultural lands. The proportion of the species from other communities was low. A high dominance of the wild-ruderal communities was recorded.

7. Gradual disappearance of the forest vegetation and its replacement by nonforest vegetation, although the natural environment was reclaimed, implies that the forest habitat destroyed by emissions is

not albe to regenerate spontaneously, and cannot be maintained in the zone adjoining the source of nitrogen pollution.

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WPŁYW DZIAŁALNOŚCI REKULTYWACYJNEJ W REJONIE ODDZIAŁYWANIA EMISJI ZAKŁADÓW AZOTOWYCH W PUŁAWACH NA ROŚLINNOŚĆ SYNANTROPIJNĄ

STRESZCZENIE

Badania botaniczne przeprowadzono w latach 1972—1974 w północno-wschodniej części Zakładów Azotowych w Puławach na obszarze najsilniejszego oddziaływania emisji przemysłowych.

Do badań wydzielono cztery powierzchnie — zniszczoną, nawożoną, deszczowaną i pola uprawne, które różniły się między sobą stopniem zrekultywowania.

W badaniach zastosowano metodę zdjęć fitosocjologicznych Brauna-Blanqueta [2] oraz metodę Traczyka [8] w celu określenia wielkości produkcji pierwotnej.

Badania dotyczyły dynamicznych zmian szaty roślinnej, sukcesji jednostek socjologicznych, tempa opanowywania powierzchni zniszczonych przez roślinność spontaniczną, a także oceny produktywności populacji poszczególnych gatunków jak również całych powierzchni badawczych.

Wykazano, że mniej lub bardziej ukształtowane i zróżnicowane zbiorowiska roślinne, liczba gatunków roślinnych i wielkość produkcji są uwarunkowane zarówno działaniem emisji przemysłowych, jak i zabiegami rekultywacyjnymi.

Stwierdzono także realizowanie się struktury dominacyjnej w zbiorowiskach roślinnych, które wykazywały różny stopień wypełnienia przestrzeni, zagęszczenia populacji, dorodności, produkcji itp., w zależności od stopnia zniszczenia i odbudowy środowiska.

ВЛИЯНИЕ РЕКУЛЬТИВАЦИОННЫХ МЕРОПРИЯТИЙ В РАЙОНЕ ВОЗДЕЙСТВИЯ ЭМИССИЙ АЗОТНОГО КОМБИНАТА В ПУЛАВАХ НА СИНАНТРОПНУЮ РАСТИТЕЛЬНОСТЬ

РЕЗЮМЕ

В 1972—1974 г.г. произведены ботанические исследования на территории северо-восточной части Азотного комбината в Пулавах, которая наиболее подвержена влиянию промышленных эмиссий. Были выделены 4 площадки: уничтоженная, удобряемая, орошаемая и культивируемые поля, которые отличались степенью рекультивации.

В исследованиях применялся метод фитосоциологической съемки Браун-Бланкета (1951) и метод Трачика (1967) для оценки первичной продукции.

Проведенные исследования касались динамики смены растительного покрова, сукцессии социологических единиц, скорости занятия уничтоженных площадей непроизвольной растительной, а также оценки продуктивности популяций отдельных видов, как и целых исследованных площадей.

Констатировалось, что более или менее сформированные и дифференцированные растительные сообщества, число видов растений, а также величина продукции обусловлены как действием промышленных эмиссий, так и рекультивационными мероприятиями.

Констатировалось также формирование структуры доминирования в растительных сообществах, которые характеризировались различной степенью развития в пространстве, плотности популяций, дородности, продуктивности и т.п., в зависимости от степени уничтожения и восстановления среды.