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PROCESSES OF RUNNING SANDS DECAY IN THE "BŁĘDÓW DESERT" DURING THE LAST 30 YEARS (SILESIAN UPLAND, SOUTH POLAND)

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A b s t r a c t. The Błędów Desert is situated in the south of Poland. In this area, sand-gravel sediments predominate. The origin of the Błędów Desert is not associated with climatic conditions but with a strong development of excavation industry which started in the region in the Middle Ages. The surrounding forests became the main fuel source for the development of mining and metallurgical industry. Therefore, the area of the Błędów Desert was completely deforested.

The paper presents reasons for the acceleration of biocenotical systems in the investigation area. For this purpose, transects representative for the following stages of plants successions: stage of encroachment plants, stage of sodding, stage of bushes (shrubs), stage of biogroup and stage of afforestation were made. Plant succession in the investigated transects developed in a multidirectional way.

The ground for plants settling in the Błędów Desert represents fluvoiglacial, fluvial and aeolian sand with various grain sizes. Locally, in the old deflation fields, relict horizons of older podzolic and rust-coloured soil are the ground for the invading plants. The process of plant and soil succession takes place at the same time. Content of the available mineral elements in the initial horizons is different; it depends on the plant species in the places where these horizons developed.

K e y w o r d s: Błędów Desert, psammophytes plant, primary and secondary succession, aeolian hillocks, fossil soil.

INTRODUCTION

The "Błędów Desert" is situated in the area of Odranian, Warthanian, Vistulian glaciofluvial and fluvial sands outcropping in the eastern part of the Silesian Upland (the south of Poland). Since the second part of the 19th century, this area has been described by geographers as the area, largest in Poland (30 km^2) and one of the largest in Europe, with running sands (Fig. 1).

Sandy substratum and climatic parameters are typical for a temperate zone influence with development of pine wood communities in this part of Europe. All

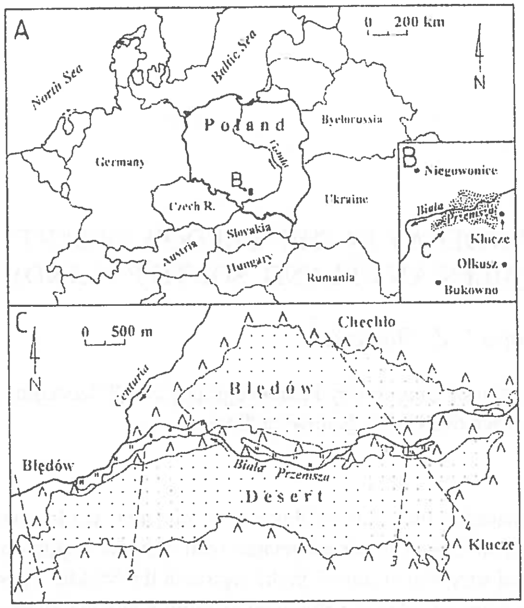

Fig 1. A-C location of the Błędów Desert. 1- 4 the investigated transects.

the papers on the Błędów Desert, associate its origin with zinc and lead mining which developed in this area [5].

The oldest data concerning raw material exploitation for the production of lead in the neighbouring Olkusz, comes from the 13th century. Wood-firing material necessary to melt lead ore caused first significant decrease of the wood area. Intensive deforestation in the 16th century resulted in shortages of wood-firing material in this area. But it is not sure if the running sand had already occurred in the mining areas. First reliable information about dunes in the area of Olkusz came from 1815 [6] together with information on their reclamation from 1851 [4].

Analysis of the archive of air photographs shows that vegetation in this are started to grow not earlier than in 1950 [5,7]. This suggests that the area off running sands initiated by the human activity occurred there during a period over 100 years long.

Sandy hills not covered by plants, sand storms and the phenomena of mirage, they all occurred in this area and gave a good reasons for calling it a desert. This area was used as an experimental range for special military units; such as African Corps and Polish Army which were trained there to fight in desert conditions.

Running sands in the middle of the European continent has always been very interesting as an atypical phenomenon in these climatic conditions. The altitude of the Błędów Desert is in the range of 332-302 m a.s.l. The mean annual precipitation is from 676 to 726 mm and the long-term annual air temperatures are in the range of 7.1-7.7 ^{o}C. Vegetation period starts in March and it is 210 days long.

The substratum of the Błędów Desert is built mainly of quartzite sands (90-97%). Sandy fractions (grains from 1 to 0.1 mm) take up more than 95% of the whole sand mass and the grains of 1-0.5 mm make more than 50% of it. The mean grain diameter is 0.297 mm [2]. Large sand porosity influences fast infiltration of the meteoric water. Due to a very deep horizon of groundwater, this is the only source of water for the vegetation which grows in this area. The predominance of quartz in the mineral composition of the sands causes small potential mineral abundance of the substratum. The total weight content of the main elements in sand deposits is: Ca - from 0.021 to 0.054 per mille; Na - from 0.059 to 0.079; K - from 0.22 to 0.37; Mg - from 0.011 to 0.015, respectively.

In the studied area, precipitation of natural and slightly alkaline reaction predominates. Its reaction and chemical composition depends on the weather situation. The content of Ca^{2+} may change during one year from 7 to 11 mg/l; SO_4^{2-} from 18 to 39 mg/l; NO_3^- from 9 to 12 mg/l, and Cl^- from 7 to 11 mg/l [3].

The setback of aeolian processes in this area was caused by the succession of vegetation introduced by man. In the 60-ties of this century, part of this area was planted with downy mountain willow *Salix arenaria* and sharp-leafed willow *S. acutifolia*. This caused reduction of sand migration and initiated a natural, original and secondary vegetation succession. At present, 106 species of plants with the dominant hemicryptophytes have been recognised in the area of former running sands. The plant adapted for full light, warm, dry and poor habitations predominate here [5].

The areas, which in 1950 were sandy surfaces with rare psammophytes plants have been selected to study plant succession in the Błędów Desert. They were selected basing on air photographs. The succession was investigated in 4 profiles with a total length of 7650.

METHODS

In the selected transects (Fig. 1), 20 m wide strips were marked. Their total length was 7650 m. Inside the strips, all the plants were mapped according to plant recognition according to the Braun-Blanquet's method [1]. A list of plant which occur in sandy areas was also compiled.

Under typical plant communities, soil exposures were prepared. Samples were taken to investigate grain size, total chemical composition, pH, content of free iron and aluminium oxides, humus and available forms of sodium, potassium, nitrogen and phosphorous. The analyses were carried out according to standard methods.

RESULTS

Vegetation-soil succession

Five succession stages have been determined in the studied profiles. They are as follows: plant encroachment stage (I); sodding stage (II); shrub development stage (III); stage of biogroups development (IV); afforestation stage (V).

Each stage shows a certain specific plant composition (Fig. 2): *Algae, Salix acutifolia, Salix arenaria* and grey haigrass *Corynephorus canescens* were pioneer plants which encroached the sands. As early as in the *Algae* stage, a 1 cm thick humus horizon develops. The humus content is quite high (0.68%). In this horizon, as compared to the substratum, availability of sodium Na^+ increases by 0.5 mg/100 g, nitrogen NO_3^- by 0.5 mg/100 g and phosphorous P_2O_5 by 0.03 mg/100 g. This horizon is acidic. Its pH in H_2O is 5.28 and its pH in KCl is 4.69.

Considerable changes occur on the surfaces where *Salix acutifolia* and *Salix arenaria* encroach. Their clusters contain cryptogamic plants such as *Cladonia*, vascular plants such as *Koeleria glauca* and hawkweed *Hieracium pilosella*, seedlings of scotch pine *Pinus sylvestris,* common birch *Betula pendula* and often also commom juniper *Juniperus communis*. They start the succession of willow-pine-juniper-birch communities. They go from the stage I to III.

The rich in humus horizon O/A develops under willows. It contains from 2.32 to 7% of humus. Below, the in horizon A, humus content decreases and it is in the range from 0.3 to 0.4%. Epipedons reactions do not change much in relation to the substratum. Due to litter mineralization, the initial soil is enriched in potassium K^+ and phosphorous P_2O_5 (Table 1, 2).

Table 1. Available mineral elements under *Salix acutifolia*

Soil horizon	Na^+	K^+	NO_3^-	P_2O_5
		percent in weight		
O/A	2.7	10.05	10.0	0.14
A	2.8	3.85	8.5	0.045
C	2.5	3.5	7.0	0.045

Table 2. Available mineral elements under *Salix arenaria*

Soil horizon	Na^+	K^+	NO_3^-	P_2O_5
		percent in weight		
O/A	2.7	10.05	10.0	0.14
A	2.8	3.85	8.5	0.045
C	2.5	3.5	7.0	0.045

Another pioneer way to subdue a sandy surface, is an encroachment of *Corynephorus canescens*. It is accompanied by *Coelocaulon acueatum* and, in places, *Stereocaulon incrustatum* with rare of psammophytes mosses *Ceratodon purpureus, Polytrichum piliferum* and *Rhacomitrium canescens*. Such grass develops in places where sand is loose.

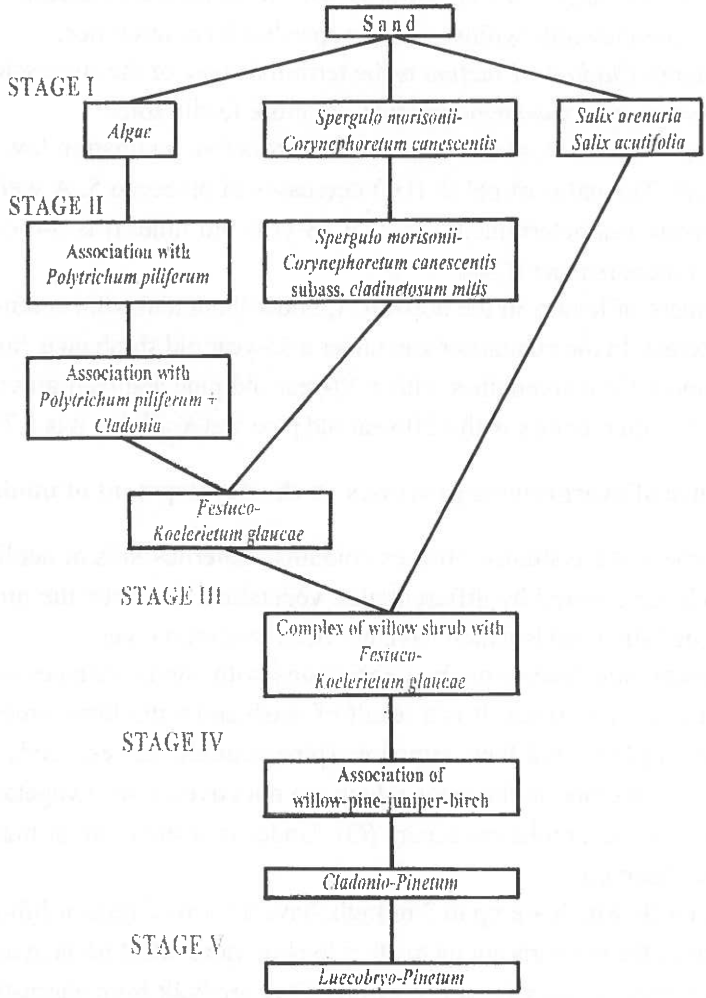

Fig. 2. The sequence of plant succession in the Błędów Desert.

Association with *Corynephourus canescens* gradually retreats and association with *Koeleria glauca* encroaches the sandy surface. The thickness of humus horizon reaches 5 cm under grasses and the humus content is close to 3%. Reaction is slightly acidic. The organic horizon under grass shows a considerable enrichment in NO_3^-. Its content is two or three times larger than the content of organic matter in the horizons which occur below. Availability of potassium, calcium and phosphorus in all of these horizons, is similar.

All the initial stages evolve towards willow shrub with *Fescuto-Koelerietum glaucae* and then towards willow-pine-juniper-birch communities.

Association *Cladonio-Pinetum* is the terminal stage of the succession in the investigation area and *Leucobrio-Pinetum* - in more fertile soils.

In the soils below these communities, a distinctive inclination towards acidification occurs. The value of pH in H_2O decreases in places to 5. A well-developed humus horizon was determined under an 18-year old pine. It is 5-6 cm thick and its humus content reaches 0.8%.

The content of humus in the horizon A, under the initial plant communities with pine, is different. In the humus horizon under a 35-year old shrub pine, humus content is 2.84%; under the communities with a 30-year old pine and reed grass, it is 1.53% and under the communities with a 20-year old pine and *Koeleria*, it is 1.75%.

Influence of overgrowing processes on the development of modern relief

The surface of the studied profiles contains numerous hills of aeolian accumulation which are covered by differentiated vegetation. Between the hills, there are still active deflation fields which have not been overgrown yet.

A characteristic feature of the depressions with sandy surfaces is a development of an organic horizon. It is a result of wash and wind blow processes which transport dead plants and their remnants (pine needles, leaves, seeds, etc.) to the depressions. Therefore, in the areas which are not covered with vegetation, the horizon of organic accumulation occurs (O). Under it, a thick initial humus horizon (A) may be observed.

Aeolian hills which are up to 2 m high, have a form of regular hillocks or ramparts. Some of the ramparts are up to 20 m long or more. Most of them are symmetrical, and they show a characteristic structure. They are built from alternating layers of horizontally laminated sand and initial humus horizons. The humus horizons are from 2 to 3 mm thick. The humus content is in the range from 0.16 to 0.27%. In the base of sand-humus series, remnants of cartridge shells have been found.

Under the laminated deposits which form the hills, remnants of fossil podzolic and rust-coloured soils occur. They are the remnants of the surface which was there before deforestation in this area. The horizon B shows an increased content of Fe_2O_3 (0.44% in relation to 0.2% in mother sands) and Al_2O_3 (2.32% in relation to 1.2% in mother sands) and a slight enrichment in available alimentary components. Due to a large ability of this horizon to retain water, many roots grow inside it.

These hillocks developed during the time when the studied area became overgrown. Vegetation present in clumps and tufts captured sand in the periods of increased deflation from the adjacent areas which were not covered with vegetation. In the periods of poor aeolian activity, the sandy hillocks were consolidated by vegetation. Even when the aeolian accumulation was very intensive, the plants were able to survive on the surface of the blown sand due to the ecological adaptability of these species (e.g. *Koeleria glauca*, Fig. 3).

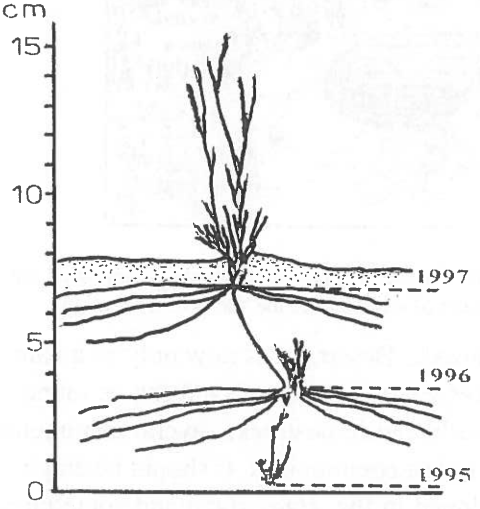

Fig. 3. Development of *Koeleria glauca* in the area with running sands.

During the period of reduced sand migration, a new convex form stabilised and a thick humus horizon developed. The adjacent sand which was not covered with vegetation was subjected to reduced wash down processes. As a result, the surface around the hillock was lowered both during deflation and in the periods when deflation was reduced.

The renewed aeolian processes delivered additional sand masses to the whole neighbouring area. Due to the survival of vegetation on the forming hill, sand accumulation continued there. An alternating cycle of sand accumulation and hill stabilisation due to the vegetation cover caused hill development (Fig. 4).

An uneven distribution of vegetation (in patches) in the early stages of the period when the desert started to become overgrown, is reflected therefore in the distribution of convex (aeolian hillocks) and concave (deflation depressions) forms of a modern relief of the "Błędów Desert".

CONCLUSIONS

The Olkusz area remained as an area of running sand for about 100 years due to the human impact. Once this impact finished, this area was quickly overgrown by plants. This change resulted from the desistance from the activities which hamper vegetation, such as planting the selected species (mainly willows) and then from the natural plant succession. The natural original and secondary successions stimulated relief, which developed during 50 years only. During this time, sands became totally

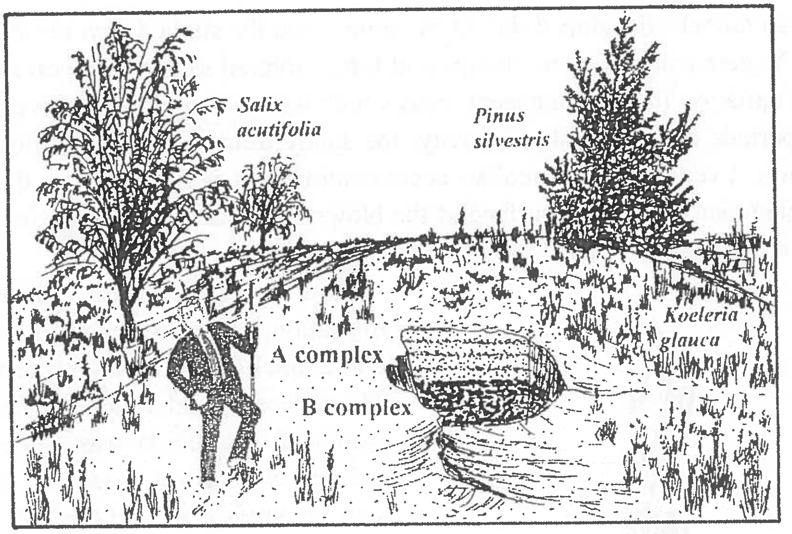

Fig. 4. Structure of the aeolian hillocks in the Błędów Desert. A complex horizontally laminated sand and initial humus horizons; B complex fossil soil (relict of relief before the "dessert" formation.

overgrown by grass and shrubs. The Błędowska Desert exists now only as a name on the map. Now there are hardly any places where uncovered sand can be found.

In this short time and on not particularly fertile hostrock, several-centimetre thick humus horizon developed under the oldest communities. It should be emphasised that the initial humus horizon developed in the *Algae* stage and sometimes under the washed plant detritus. The possibility of such fast development of epipedons in the sandy areas should always be considered in the case of palageographic interpretations of the initial fossil soils which are commonly determined in the late Pleistocene aeolian sands.

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