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Selected physical properties of initial soils on the outside spoil bank of the Bełchatów brown coal mine

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ABSTRACT: The purpose of the study was to assess, in respect of selected physical properties, the reclamation of the northern slope of the outside spoil bank of the Bełchatów brown coal mine by reforestation carried out 20 years ago. Investigations were carried out on 55 permanent research plots. This study confirmed the efficiency of reclamation of strip-mine spoils, and its results allowed to point out the properties of initial soils as the most useful characteristics for the assessment of land reclamation by reforestation.

Keywords: forest reclamation; spoil bank; initial soils

At the present time, the reclamation of lands without soil, including spoil banks of brown coal strip mines, is generally confined to reforestation. In the case of spoil banks, the physicochemical properties of the overburden rocks from which their covering is formed, as well as the proper reclamation procedure, have a decisive influence on the processes of formation of initial soils, and therefore on the quality of forest sites coming into being (Skawina 1958). The purpose of the study presented in this paper was to estimate selected physical properties of initial soils forming on the outside spoil bank of the Bełchatów brown coal mine.

MATERIAL AND METHODS

The field investigations were conducted on 55 permanent research plots located on the northern slope of the outside spoil bank of the Bełchatów brown coal mine in about 20-years-old plantations established during 1978–1981. The investigated spoil bank is built of Quaternary and Tertiary sands (65%), Quaternary loams and mudstones (20%), and Tertiary clays (15%). During 1977–1982, after the formation of the northern fragment of the slope, biological treatments of reclamation were carried out. They included the introduction of herbaceous vegetation, planting of trees, and also basic and supplementary fertilization. In the composition of herbaceous vegetation the grasses (fescue and rye-grass) and legumes (white clover and lupine) dominated, while among trees the pioneer species (*Robusta* poplar, black and gray alders, and European white birch) were dominant.

In each study plot, in its central fragment, a soil pit (1 m in depth) was made. In each soil pit the genetic horizons were determined from which samples were collected for laboratory analyses. In samples, using a hydrometric method of Casagrande modified by Prószyński, the mechanical composition was determined. Then, out of 55 plots, 10 were chosen representing 3 categories distinguished on the basis of the mechanical composition of the soil substrate (according to the content of silt and clay fractions, Ø < 0.02 mm), namely: a – light formations containing up to 10% of silt and clay (loose and coarse sands), b – medium-heavy formations containing 10–20% of silt and clay (medium sands – light and strong), c – heavy formations containing over 20% of silt and clay.

The following properties were determined in soil samples (in four replications):

- particle density – by a pycnometric method,
- bulk density,
- retention capacity of soil as the soil moisture potential in the range of pF* 2.0 – pF 4.2 in the process of drying (*the unit pF was introduced

by Schofield in 1935 and it is the logarithm of the negative pressure exerted by the water column. Also other units are in use: kPa, cm H_2O, J/m^3). Determinations were carried out in the low and high pressure chambers on plates 1 bar, 5 bar, and 15 bar produced by Eijkelkamp. Samples in an intact arrangement were placed in rings, 1 cm in height and 4 cm in diameter.

Next, the field air capacity and categories of water availability to plants (Trzecki et al. 1971) were calculated, assuming values of field water capacity (FWC) according to Trzecki (1967):

– field air capacity (FAC) – the difference between air capacity (AC) and field water capacity (FWC) determined by the amount of free (aeration) pore spaces in the soil at the moisture corresponding to FWC;
– retention of water very easily available (VEA) – the amount of water in the potential range of pF 2.0–2.85;
– retention of water easily available (EA) – the amount of water in the potential range of pF 2.85–3.2;
– retention of water hardly available (HA) – the amount of water in the potential range of pF 3.2–3.7;
– retention of water very hardly available (VHA) – the amount of water in the potential range of pF 3.7–4.2;
– retention of effective water (so called Effective Usable Retention – EUR) – the amount of water in the potential range of pF 2.0–3.2;
– retention of usable water (so called Maximum Usable Retention – MUR) – the amount of water in the potential range of pF 2.0–4.2.

On the basis of the characteristics listed above the porosity structure of formations was determined. In this respect only basic groups of soil pores were taken into account, i.e. aeration pores – macropores (of diameter > 30 μm which corresponds to the potential difference pF 0–2.0), capillary pores – including mesopores (of diameter 0.2–30 μm which corresponds to the potential difference pF 2.0–4.2), and micropores (of diameter < 0.2 μm which corresponds to the potential pF > 4.2) (this classification was taken over according to Trzecki 1967).

RESULTS AND DISCUSSION

Besides the growth dynamics of plants and the succession progress the changes in physical, chemical, and biological properties taking place in reclaimed lands are among the main criteria of the assessment of the efficiency of land reclamation methods used (Skawina 1958; Wysocki 1975; Bender, Wasilewski 1976).

The initial soils, which can be included in the group of soils of industrial and urban areas of an undeveloped profile, have developed in the investigated fragment of the outside spoil bank. The profile of these soils has a simple structure, and lithologically it is not usually continuous: AinCan – Can – IICan (Classification of Forest Soils of Poland 2000). Many authors pointed out that the textural make-up was the main factor determining the efficiency of land reclamation, and therefore his method of the point estimation of suitability of lands for reclamation was based on this characteristic to a great extent (Skawina, Trafas 1971). At the first place the covering of the northern slope of the outside spoil bank of the Bełchatów brown coal mine consisted of the following formations: sands (loose and coarse), medium sands (light and strong), and loams to a lesser extent. The initial humus horizon (AinCan) was identified in all study plots, and its average thickness was 7.7 cm. The greatest mean thickness of this horizon was reached in formations of category "b" (medium-heavy formations), i.e. 8.8 cm. In formations of category "a" (light formations) it was 6.7 cm, and in formations of category "c" (heavy formations) 7.6 cm. The greatest part of the initial humus horizons (AinCan) (60%) was composed of medium sands (light and strong). The loose and coarse sands accounted for 25.5% of these horizons, and loams only for 14.5%. While 50.9% of Can horizons was composed of loose and coarse sands, 20.4% of medium sands, and 12.7% of loams. In 30% of the studied plots the horizon II Can was also identified, which was made up of loams in 52.9%, of loose and coarse sands in 29.4%, and of medium sands in 17.7%. These results showed how great the diversification of the textural make-up of the soil substrate is, distinctly heavier in deeper layers. This will have, or already has, the effect on the growth of introduced trees. These formations make a characteristic mosaic on the spoil bank, as described by Skawina (1970), Strzyszcz (1970), Greszta and Morawski (1972) and Gołda (1993). Such a distribution of overburden rocks on spoil banks is the element differentiating the progress of the soil development processes as well as the growth and development of vegetation.

The processes of weathering and organic matter accumulation considerably affected the physical properties of raw rocks of the overburden forming the covering of the northern slope of the spoil bank. These changes may be observed when analyzing the particle and bulk densities, as well as the total porosity, of arising horizons of investigated soils.

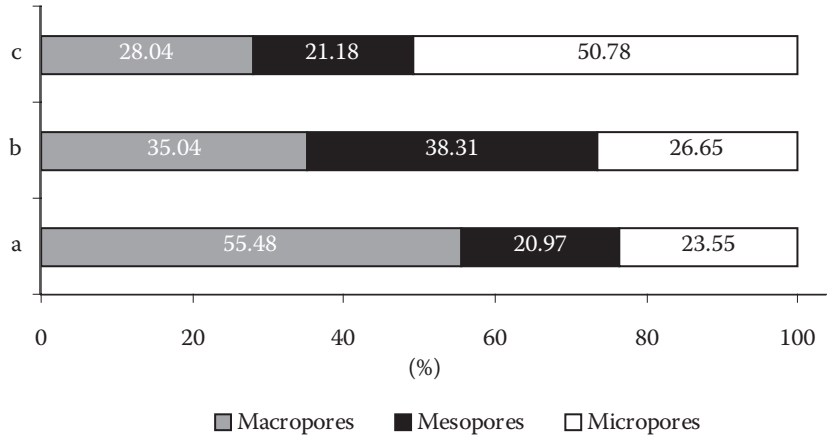

Fig. 1. Mean percentages of pore groups in total porosity of the humus horizon (AinCan) in studied plots according to formation categories and horizons, where: a – horizons composed of light formations, b – horizons composed of medium-heavy formations, c – horizons composed of heavy formations

Mean values of the bulk and particle densities in the initial humus horizon (AinCan) were lower than in the rock horizon (Can). For the initial humus horizon they were 1.32.g/cm^3 and 2.62 g/cm^3, and for the rock horizon 1.44 g/cm^3 and 2.64 g/cm^3, respectively. This pointed unmistakably to the known phenomenon, described also by Wójcik (2000), of the influence of humification and mineralization on loosening the structure of surface soil horizons, and therefore on changes in their physical properties. These results are also in agreement with the results of Bykov's (2003) studies carried out on the outside spoil bank of the Piaseczno sulphur mine.

The structure of porosity can be described not only by giving the overall content of pore space but also by stating the proportions of pores according to their diameter. The distribution of pores (structure) is of great importance in the estimation of soil aeration (percentage of macropores) as well as in the estimation of capillary porosity (percentages of mesopores and micropores), i.e. in the estimation of retention capacity and availability of soil water (Dobrzański, Zawadzki 1995). The more or less even percentages of three categories of pores (micro-, meso-, and macropores) are considered to be their optimum distribution (Dobrzański, Zawadzki 1995). The percentages of the respective pore categories in samples from analyzed horizons were closely connected with the content of the smallest fractions, especially the clay fraction. The least advantageous arrangement occurred in horizons built of light formations (category "a") where macropores dominated. An unfavourable structure was also found in horizons built of heavy formations (category "c") where micropores predominated. Similar relationships were described by Wójcik (2000) in initial soils of the outside spoil bank of the Adamów mine. In all categories ("a", "b", and "c") of the initial humus horizon (AinCan), as compared with the horizon Can, there was an increase in the percentage of macropores, which was favourable for horizons composed of medium heavy and heavy formations contrary to horizons composed of loose formations. The most favourable pore structure in the initial humus horizon (AinCan) was found in medium heavy formations where the percentages of 3 pore categories were the most uniform. In Germany (Katzur et al. 1999) and in the Konin basin in Poland (Bender, Wasilewski 1976)

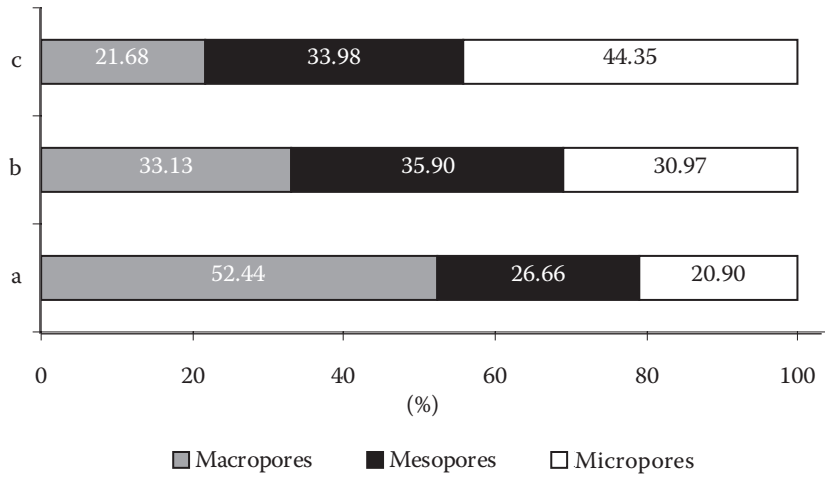

Fig. 2. Mean percentages of pore groups in total porosity of the horizon Can in studied plots according to formation categories and horizons (for designations see Fig. 1)

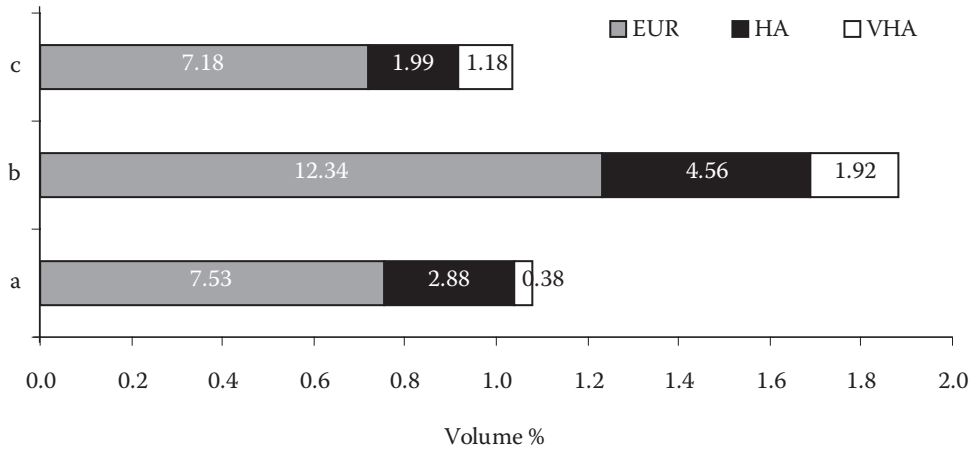

Fig. 3. Mean retention of formations according to distinguished categories of water availability in $cm^3/100\ cm^3$ to plants in the initial humus horizon (AinCan) of studied plots depending on the category of the horizon, where: a – horizons composed of light formations, b – horizons composed of medium-heavy formations, c – horizon composed of heavy formations, (EUR = VEA + EA) – amount of water in the potential range pF 2.0–3.2, retention of effective water, VEA – amount of water in the potential range pF 2.0–2.85, water very easily available, EA – amount of water in the potential range pF 2.85–3.2, water easily available, HA – amount of water in the potential range pF 3.2–3.7, water hardly available, VHA – amount of water in the potential range pF 3.7–4.5, water very hardly available, MUR – maximum usable retention (pF 2.0–4.2)

there were small changes in porosity in the humus horizon after several years of the growing of crops under agricultural reclamation.

The mean percentages of pores according to the category of formation and the horizon are presented in Fig. 1 for the initial humus horizon (AinCan) and in Fig. 2 for the horizon Can.

The retention capacity of initial soils of the outside spoil bank was characterized on the basis of water tension in soil (pF range: 2.0–4.2) and soil hygroscopic water capacity. It is known that an adequate retention of soils is of particular importance on spoil banks where only the precipitation-retention water economy exists. In the studied area the horizons composed of medium heavy formations (category "b") were characterized by the best moisture properties in the initial humus horizon (AinCan) as well as in the horizon Can. Within the maximum usable retention (MUR) three categories were distinguished: EUR (VEA + EA), HA, and VHA. From the aspect of moisture supply to plants the most important role is played by the effective usable retention (EUR) in the potential range of pF 2.0–3.2 (water easily and very easily available – EA and VEA). Above the limit of EUR water is hardly available (HA, the beginning of plant growth impediment) and very hardly available (VHA, the complete check of plant growth). The HA and VHA water may be used, on a limited scale, by trees of the highest capillary potential (Trzecki 1967). All categories ("a", "b", and "c") in the initial humus horizon (AinCan) were characterized by a decrease in the content of easily and very easily available (EUR) water in comparison with the horizon Can. The deterioration of retention conditions could

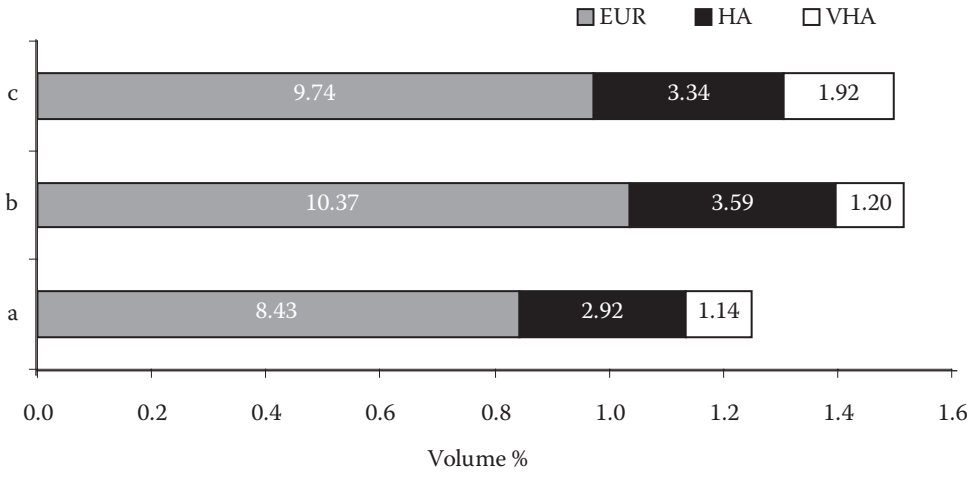

Fig. 4. Mean retention of formations according to distinguished categories of water availability in $cm^3/100\ cm^3$ to plants in the rock horizon (Can) of studied plots depending on the category of the horizon (for designations see Fig. 3)

have been caused by an increase in the percentage of macropores in the initial humus horizon (AinCan) of the investigated soils.

The content of easily and very easily available (EUR) water was the highest in the initial humus horizons (AinCan) composed of medium heavy formations, and it amounted to 12.34% of the volume on average (Fig. 3).

Similarly like in the initial humus horizon (AinCan), also in the rock horizon (Can) the highest mean water content designated as EUR was found in horizons composed of medium heavy formations (medium sands – light and strong) (Fig. 4).

The results of this study showed that during 20 years since the initiation of forest reclamation the initial soils of the northern slope of the investigated spoil bank were exposed to considerable changes which were especially evident in the initial humus horizon (AinCan). The most favourable changes were observed in horizons composed of medium heavy formations (category "b"), and this suggests that these formations were the most favourable ones for land reclamation by reforestation.

CONCLUSIONS

After 20 years since the beginning of reclamation of the northern slopes of the outside spoil bank of the Bełchatów brown coal mine by reforestation there have been formed initial soils with the humus horizon several centimetres deep, which can be included in the group of soils of industrial and urban areas with an undeveloped profile (AinCan – Can – IICan).

The outside spoil bank of the Bełchatów brown coal mine is composed of a mosaic of formations of the overburden of the Bełchatów deposit, with sands as the dominant formation.

The initial soils formed on medium-heavy formations (medium sands) are characterized by the best physical properties (uniform pore structure).

Medium-heavy formations (medium sands) in the horizon AinCan as well as in the horizon Can are also characterized by the best water properties.

The results obtained during this study showed that initial soils of the northern slope of the investigated spoil bank during 20 years since the beginning of reclamation were exposed to considerable changes, especially in the initial humus horizon (AinCan).

Taking into consideration the above conclusions it can be proposed that in the Bełchatów district during reclamation of spoil banks by reforestation the covering of future spoil banks should be built of medium-heavy formations (medium sands) which are characterized by the best moisture-air properties.

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Vybrané fyzikální vlastnosti iniciálních půd výsypek hnědouhelného povrchového dolu Belchatow

ABSTRAKT: Cílem studie bylo vyhodnotit současný stav výsypkových ploch po lesnické rekultivaci povrchového hnědouhelného dolu Belchatow, a to z hlediska charakterizace vybraných fyzikálních půdních vlastností. Dané šetření proběhlo na 55 trvalých výzkumných plochách. Výsledky potvrdily úspěšnost liniového umělého zalesnění. Je zdůrazněno, že byly předloženy podklady o použitelnosti hodnocení půdních vlastností pro celkovou charakterizaci úspěšnosti principů lesnické rekultivace.

Klíčová slova: lesnická rekultivace; výsypky; iniciální půdy

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