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PHYSICAL PROPERTIES OF THE SOIL FORMED AS A RESULT OF RECULTIVATION OF SAND-PITS IN THE BÓBR RIVER VALLEY

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A b s t r a c t. Quite large areas of the alluvial soils in the valley of the river Bóbr were destructed by the sand and gravel exploitation. After the recultivation measures, which consisted of backfilling of the open-cast with waste aggregate, levelling the surface and putting on such prepared surface 50-200 cm of the stripping material, the yield was very low.

The field and laboratory experiments have shown that during the technical operations the soil was compacted to such degree, that the root growth and water permeability was restricted to large extent. The soil compaction was noted in the whole soil profile. The evidences of this process were the high bulk density (often over 1.8 Mg m^{-3}), very low water permeability values and low air capacity. The situation during the 12 years from the finishing of the recultivation has not changed.

K e y w o r d s: sand-pit, recultivation, physical properties, soil formation, the Bóbr river valley.

INTRODUCTION

By the agricultural recultivation of soils the forming of physical, air and water conditions for the plant growth is important as well as the macro and micronutrients supply.

One of the most important physical indicators of soil condition is the bulk density. It depends from the mechanical composition, humidity and the compaction degree of the reclaimed soil.

According to the classification of Święcicki *et al.* [10] in the loose soils the bulk density is about 1 Mg m^{-3}, in the soils of good structure from 1.0 to 1.1 Mg m^{-3}. The bulk density from 1.5 to 1.7 Mg m^{-3} is typical for the illuvial horizons of podzolic soils. On the other hand the density over 1.7 Mg m^{-3} occur in the compacted and very compacted consistencies.

The soils developed from boulder loams are predominantly of high natural density. According to Wojtasik [13] the range of natural bulk density of loamy

soils is fluctuating between 1.5 and 1.6 Mg m^{-3}. The bulk density 1.7–1.8 Mg m^{-3} occurs in the loamy soils medium compacted.

The direct resulst of the soil density changes are the total porosity changes, as well as the distribution of the soil pores [1,4].

The bulk density is determining the air capacity [1,4], the water capacity [1,9], the forms of moisture accessible to plants and used for dry matter production, as well as influences on the resistance during mechanical soil cultivation [4]. In the overconsolidated soils the penetration of plant roots is difficult, what can have the influence on the plant yield [6].

The purpose of the work was to determine the changes of physical properties in the soils formed on the areas transformed by the exploitation of sand and gravel aggregate.

EXPERIMENTAL AREA

The experimental works were done on the area on vicinity of Nowogród Bobrzański in Lubuskie voivodship, which was a field after finishing the sand and gravel aggregate exploitation. Before the aggregate exploitation, the fertile alluvial overlay (brown alluvial soils, sandy and loamy) was scraped off in piles 3–4 m high. After finish of the aggregate exploitation the excavation area was filled up with the refuse material, grains with the diameter of 0.02–1.00 mm.

On the surface with heavy machinery were distributed the previously stored overlay. The depth of this soil cover was from 0.3 to 2.0 m. After the levelling of the soil surface the agricultural measures begun for the restoration of the devastated area for the agriculture. The mineral fertilizers were applied and than a pioneer plant – lupine, was sown. After the ploughing in the green lupine, the field was recognized as recultivated and was handed over to the former land user. The recultivation measures provided this way had anyway very pure effects in the yield of the cultivated plants. The harvests of ray on this area were from 0.6 to 0.7 t ha^{-1}.

The descriptions of soil properties were presented in the former work [5]. The new formed soil material characterised:

- very acid reaction (the majority of soil samples below pH 5.0),
- large differentiation of mechanical composition (the content of the fraction below 0.02 mm varied from 9 to 26 %),
- low content of plant available and total forms of nutrients,
- the organic matter content, determined by the Tiurin method was in the most soil samples near 1.5 %.

METHODS

The field experiment was established in 1986. The aim was to explain the reason of low productivity of the new remediated soils. In the first year of experiment the test plants were: winter rape, winter barley, winter rye and potatoes. In the next years the winter rye in monoculture was cultivated.

The field No. I (Fig. 1) was every year ploughed to the depth of 35 cm, and the field No. II to the depth of 25 cm. The plants were fertilized with variable dozes of mineral fertilizers. In spring 1986, 1987 and 1989 from the soil profiles to the Kopecky cylinders samples for determination of bulk density and water capacity were taken. The places where soil profiles were done are marked on Fig. 1.

Additionally, in the years 1988 and 1989 the water permeability of the soil by Ostromęcki method described by Mocek *et al.* [7] was determined.

RESULTS

The field and laboratory investigations have shown a strong compaction of the soil material distributed on the sand pit surface (Tables 1-3). Especially strong compactions were determined in the soil profile below the ploughing layer (on the depth about 40 cm). The bulk density in the first year of experiment in the most soil profiles was over 1.75 Mg m^{-3}. In the soil profile No. 4 made on a fallow land out of the field experiment area the bulk density in the soil layer below the Ap horizon was 1.84 Mg m^{-3}. There were not stated any distinct influence of the crop species or ploughing depth on the changes of bulk density.

The water capacity in the soil profiles was low. The total water capacity in the year 1986 was from 28 to 35 % vol. From year to year in the soil samples a slight water capacity increase was stated. In comparison with the field ploughed to the depth of 25 cm, the water capacity of the soil on the field No. I, ploughed to the depth of 35 cm, was higher.

The differences between total water capacity and the capillary water capacity were very low, average 1 %. In the layers below the ploughing horizons, very compacted, the differences were even lower. The crop growing and the deeper soil ploughing did not have influence on the air capacity changes.

The soil cultivation measures, on the other hand, had positive influence on the water permeability of soils. The results of the water permeability determination were distinctly higher in the plough layers, than in the deeper ones, especially direct below the plough layers.

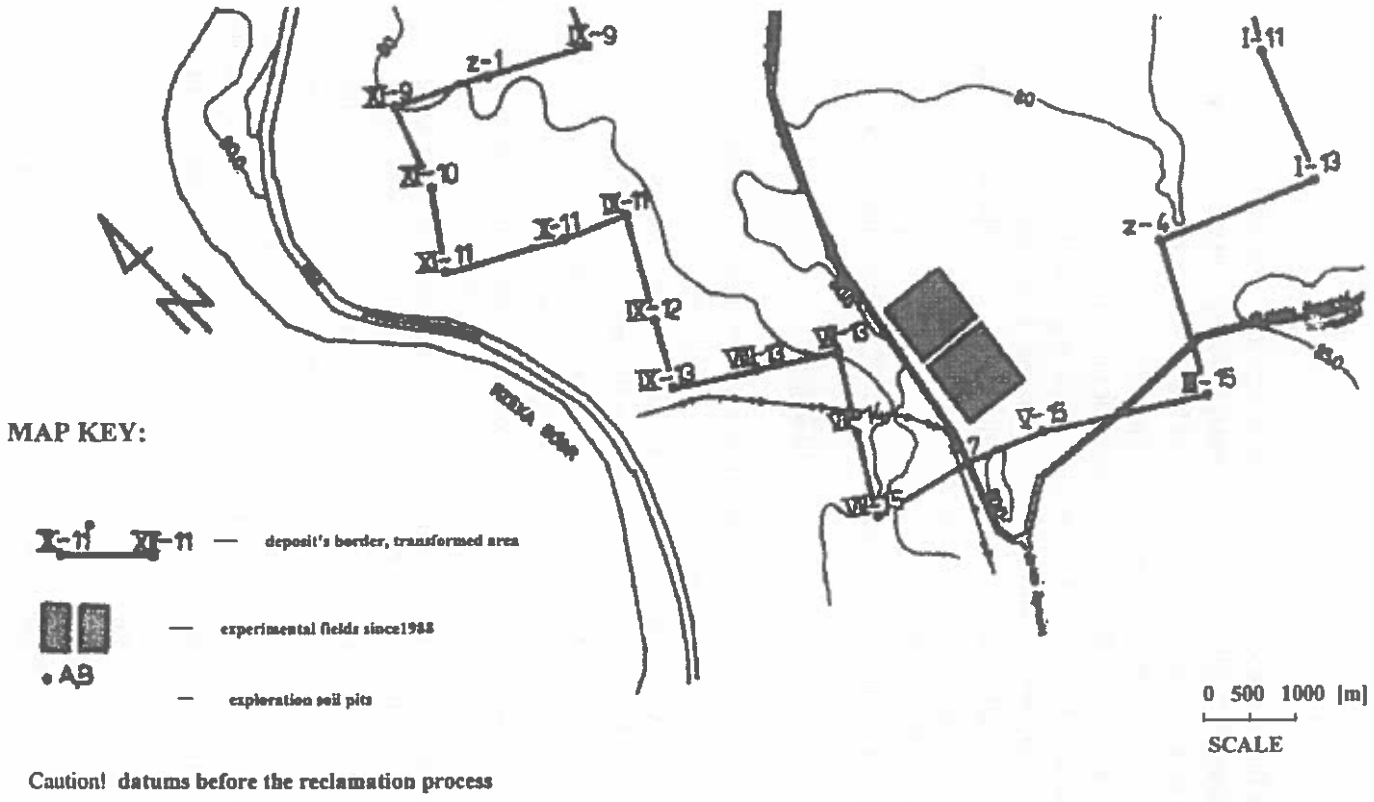

Fig. 1. Basic map of the builder material deposit near Dobroszów Wielki - village. Localization of the experimental fields.

T a b l e 1. The physical properties of soils in the year 1986

Profile	Depth (cm)	Bulk density (Mg m^{-3})	Water capacity (%)				Air capacity (%)
			capillary		total		
			weight	volume	weight	volume	
	0-5	1.63	18.7	30.6	20.0	32.6	2.0
	20-25	1.64	19.2	31.5	20.0	33.3	1.8
1	40-45	1.74	19.1	33.3	20.0	34.9	1.6
	50-60	1.68	18.5	31.2	19.9	33.6	1.4
	75-85	1.69	16.2	27.3	17.1	28.9	1.6
	90-100	1.67	16.2	27.0	17.0	28.4	1.4
	0-5	1.74	16.9	29.4	17.4	30.2	0.8
	10-15	1.75	16.3	28.6	16.4	28.8	0.2
2	25-35	1.78	17.3	30.8	17.3	30.8	0.0
	45-50	1.80	14.6	26.4	16.0	28.9	2.5
	0-10	1.68	17.3	29.0	18.3	30.6	1.6
	15-20	1.72	18.4	31.7	18.6	32.1	0.4
3	35-40	1.76	22.2	34.7	22.4	35.0	0.3
	50-60	1.72	17.0	29.3	17.6	30.3	1.0
	0-10	1.74	19.7	34.3	20.5	35.6	1.3
4	35-40	1.84	15.3	28.1	15.5	28.5	0.4
	60-70	1.62	19.5	31.6	20.3	32.2	0.6
	90-100	1.61	20.2	32.4	20.9	33.7	1.3

Between the bulk density and the water permeability a negative significant correlation was found. The correlation coefficient for the soil samples was in the year 1988 higher than in the year 1989. It indicates on slight positive influence of crop and soil cultivation on the changes of soil physical properties.

DISCUSSION

The soil compactness depends, among others, from the mechanical composition, pressure per unit area of the agricultural machines, soil type [4,11] and the humus content [12]. Between the indicators, which determine the physical state of the soil to the most important belong the bulk density [12], the total porosity and the water permeability [1,12]. The bulk density in the investigated soil profiles was from 1.60 to 1.85 Mg m^{-3} and was distinctly higher than in the literature [1-4, 10-12]. The high density values occur in the soil developed from boulder loams [6,13]. The mechanical composition of the investigated soil is mainly in the range from coarse sandy soil to loamy sand. Therefore mainly the heavy machinery, used for soil recultivation causes the high bulk density. The pressure for unit area

Table 2. The physical properties of soils in the year 1987

Profile	Depth (cm)	Bulk density ($Mg\ m^{-3}$)	Water permeability K_{10} cm s^{-1}	Water capacity (%)				Air capacity %
				capillary		total		
				weight	volume	weight	volume	
	0-5	1.37	0.05148	25.2	34.6	28.0	38.5	3.9
	20-25	1.50	0.00606	20.5	30.8	21.6	32.4	1.6
1	40-45	1.67	0.00085	17.9	30.0	18.3	30.6	0.6
	50-60	1.62	0.00530	19.7	32.0	20.6	33.5	1.5
	75-85	1.68	0.00056	20.7	34.9	21.3	35.8	0.9
	90-100	1.64	0.00120	18.9	31.0	19.3	31.7	0.7
	0-5	1.44	0.00936	26.4	38.2	28.5	41.2	3.0
2	10-15	1.84	0.00017	12.7	23.4	13.4	24.7	1.3
	25-35	1.87	0.00003	12.2	22.9	12.7	23.9	1.0
	45-50	1.80	0.00008	13.6	25.3	14.1	26.2	0.9
	0-10	1.60	0.00294	21.9	35.0	23.2	35.8	0.8
3	30-40	1.80	0.00022	19.3	32.3	19.7	33.1	0.8
	50-60	1.60	0.00086	19.8	30.2	20.2	30.9	0.7
	0-10	1.44	0.00986	26.4	38.2	28.6	41.0	2.8
4	10-15	1.84	0.00017	14.5	26.8	15.2	27.6	0.8
	35-40	1.84	0.00022	15.8	27.3	16.2	28.1	0.8
	70-80	1.60	0.00236	16.6	28.9	17.0	29.7	0.8

during the technical part of recultivation was very high, because heavy bulldozers and heavy trucks were used. The soil tillage scarified slightly the upper layer, therefore the most compacted are the layers below this horizon.

The strong soil compaction distinctly reduced the total porosity and water capacity. In the investigated soils the soil porosity was very low, about 30 %. For normal plant growth the total porosity have to be approximately 50 % [4].

The air porosity was also very low, far below the 10 %, which is a boundary value for normal plant growth [9].

The all above mentioned properties cause difficulties for the plant growth. The strongly compacted soil layers below the plough layers make impossible the deeper root penetration. The water percolation is extremely low, as well as the capillary rise. Even by normal amount of precipitation in winter and early spring the upper soil layers are very wet. The water run-off is forming in the small surface caves and shallow water ponds, to which very soon enter the bog vegetation.

The improving of the soil physical properties is possible by deeper loosing of the upper cultivated layer. For this purposes is useful the deep plough, tiller and rotatiller. The last mentioned machines could be more effective, as active tools.

Table 3. The physical properties of soils in the year 1988

Profile	Depth (cm)	Bulk density (Mg m^{-3})	Water permeability K_{10} cm s^{-1}	Water capacity (%)				Air capacity %
				capillary		total		
				weight	volume	weight	volume	
1	0-10	1.60	0.00298	21.2	34.0	21.9	35.1	1.1
	30-40	1.72	0.00075	17.5	30.3	18.7	32.3	2.0
	50-60	1.59	0.00310	22.9	36.4	23.7	37.7	1.3
	75-85	1.65	0.00120	25.5	39.5	26.1	40.2	0.7
	90-100	1.45	0.02470	29.6	43.0	30.4	44.2	1.2
2	0-10	1.60	0.00240	21.5	34.4	22.5	35.9	1.5
	30-40	1.78	0.00026	16.3	28.9	16.9	29.9	1.0
3	0-10	1.60	0.00149	22.4	34.0	23.0	36.9	2.6
	30-40	1.74	0.00035	14.6	25.3	15.6	27.0	1.7
	80-100	1.55	0.05632	21.9	34.0	22.0	34.8	0.8
4	0-10	1.61	0.00252	19.7	31.9	20.0	33.0	1.1
	30-40	1.79	0.00022	15.1	27.5	15.7	28.0	0.5

After loosen the soil under the plough layer the water percolation and root penetration improves. The air condition in the soil would be improved too.

CONCLUSIONS

The results presented in this work made possible to form the following conclusions:

1. The investigated soils are very compacted. The bulk density corresponds to the values for soils developed from boulder loams. Especially strong compaction had the soil layers below the topsoil.

2. The total porosity and air capacity were very low. In the layers under the surface soil very low water percolation rate was stated.

3. The highly significant correlation between the bulk density and water percolation was found.

4. The influence of cultivated plants and soil tillage on the physical properties of soil was not detectable.

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