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PLOUGH SOLE AS THE RESULT OF THE AGRICULTURAL LAND USE

Abstract: The purpose of this paper was the estimate of the substratum compaction in various soil types and under various conditions of use. The compaction characteristics were performed on the basis of bulk density of soil. It was performed on various types of soil, built of various materials, occurring in the vicinity of Płock. The soils are farming land. The greatest substratum compaction was observed in arable lands, built of light loam, silt and loamy sand. The difference in bulk density between the layer at the depth of 25 – 35 cm and the adjacent horizons reaches 0.3 Mg per cubic metre. In soils used for green crops the substratum layer does not show a large difference between the adjacent layers, but the values of bulk density are equal to about 1.6 – 1.8 Mg per cubic metre already near the surface. Higher values of bulk density at the depth of 25 – 35 cm were observed in 68% of soils under investigation.

Key words: soil compaction, bulk density, arable land, hay-growing meadows, pastures.

The development of land for the agricultural needs influences the changes of the physical and chemical properties of the soils. The greatest changes take place in the plough and humus horizons and in the layer directly underneath. One of the changes which can be observed in soils of arable lands is the compaction of the layer under the plough horizon at the depth of 25 – 50 cm, called plough sole (Marciniak et al., 1995, Miatkowski, 1998, Uggla, 1976). The soil compaction influences many physical properties of the soil, a. o. its overall porosity, air-water conditions, thermal conditions, and as a result it influences also the crop productivity of the plants. The purpose of this paper is the investigation of the regularities; more precisely, an estimate of the magnitude of the compaction of the subarable layer and its influence on soil porosity and vegetation growth in various types of soil and under various conditions of agricultural use. An example of this is a region situated in the vicinity of Płock in central Poland, on lowlands, which remained within the Würm glaciation. The object of the research consisted of all types of soil occurring within the area under investigation: brown soil, grey-brown soil, rusty soil, podzolic soil, black earth soil, alluvial soil and half-bog soil.

Samples of soil were taken after the harvesting of grain and potatoes, and on grasslands, after the autumn haymaking, from the depth of around 10 – 15 cm, 30 – 35 cm, 45 – 50 cm, 70 – 75 cm and sometimes around 140 cm and put into cylinders of capacity 100 cubic metres. Bulk density was the determinant based on which the degree of compaction of the subarable layer was estimated. For mineral soil the determinant of the overall porosity was also estimated, by means of the equation $P = (\rho_s - \rho_v / \rho_s) \times 100\%$, where: P is the overall porosity, ρ_s is the density of the constant phase [?], ρ_v is the bulk density.

RESULTS AND DISCUSSION

Land cultivation in the region of Płock is conducted by classic methods, that is, by means of ploughs. Even though it is energy- and labour-consuming, it ensures the best soil loosening in the layer from 0 to 20 cm.

The actual bulk density in the humus horizon in mineral soils varies within the interval 1.1 – 1.7 Mg per cubic metre (Table 1). Smaller values of bulk density in mineral soils can be observed in the humus horizon, because agrotechnical measures loosen this layer in every vegetation season. Humus occurring in the surface horizon has loosening and structure-forming properties and for that reason it diminishes the compaction of this horizon (Uggla, 1976). Overall porosity in the humus horizon reaches in general maximal values, varying within the interval 32.0 – 49%. The soil under investigation often does not have a homogenous mechanical composition in the entire profile, which is also reflected in the values of bulk density. Lower values of bulk density have been observed at the depth of 35 – 85 cm (in a few cases these are the minimal values, Figs. 1, 2) and at this depth the overall porosity also reaches maximal values in the profile.

In mineral soil at the depth of 30 – 40 cm the observed values of the bulk density are within the interval 1.4 – 1.8 Mg per cubic metre (Table 1), and those of the overall porosity, within the interval 31.2 – 44.5 %. Even though in most profiles the values of the bulk density do not exceed 1.8 Mg per cubic metre, the compaction is sufficiently large compared to the surface horizon so that it may impede the growth of the plant roots and nutrient and water intake and may cause the deterioration of the water-air conditions in the soil. It is accepted that the values of bulk density above 1.8 Mg per cubic metre hinder the growth of the plant roots and disturb the water-air conditions in mineral soil (Uggla, 1976).

Below the depth of 40 cm the values of bulk density vary in the interval 1.5 – 1.9 Mg per cubic metre (Table 1). Below the depth of 60 cm the values of bulk density (between 1.7 and 1.9 Mg per cubic metre) have only small influence on crop plants, since their roots do not develop at such depth.

In mineral soils, used as arable lands, an increase of the subsoil compaction is observed at the depth of 25 – 35 cm by 0.1 – 0.3 Mg per cubic metre compared with the horizons above and below this layer. Particularly large compaction can be observed in soil formed from loamy silty sands (Fig. 1) in which the values of bulk density differ by 0.2 – 0.3 Mg per cubic metre compared with the adjacent horizons. In such soils the plough sole may be formed. This phenomenon may be explained both by the pressing of the earth by

Table 1.
Range of values of the bulk density of the solid phase in soil near Płock

Soil type	Genetic horizons	Depth [cm]	Bulk density [Mg per m^{-3}]
Brown soil	Ap Abbr Bbr C	0-30 25-35 35 (40)-60 60-150	1,4-1,7 1,5-1,8 1,6-1,8 1,5-1,9
Grey-brown soil	Ap AEet Eet Bt C	0-30 25-35 35-55 55-80 80-150	1,5-1,7 1,5-1,7 1,6-1,7 1,7-1,8 1,7-1,9
Rusty soil	Ap ABv Bv C	0-30 25-35 35-60 60-150	1,2-1,7 1,5-1,8 1,6-1,9 1,5-1,7
Podzolic soil	Ap Ees Bfe C	0-25 25-50 50-65 65-150	1,3-1,4 1,4-1,5 1,5 1,5-1,6
Black earth soil	Ap A AC DG	0-30 25-35 35-80 80-140	1,3-1,7 1,5-1,7 1,5-1,6 1,6-1,9
Alluvial soil	A AC C D	0-30 25-35 35-80 80-130	1,1-1,6 1,3-1,6 1,4-1,7 1,6-1,7
Half-bog soil	Mt MtOt Ot D	0-30 25-30 30-75 75-100	0,6-1,2 0,3-1,1 0,3-1,3 1,7-1,8

agricultural machines and by the displacement of the silt and clay fractions into the deeper layers of the profile. In arable soils, formed from the light loam, bulk density at the depth of 25 – 35 cm has the value greater by 0.1 – 0.2 Mg per cubic metre compared with the adjacent horizons (Fig. 2). In soils formed from silt (Fig. 3) an increase of bulk density in the subarable layer by 0.0 – 02. Mg per cubic metre is observed compared with the arable horizon. In lower horizons the values of bulk density increase slowly as the depth increases. In such cases one can state a clear influence of the pressing by agricultural machines. Mechanical cultivation influences also significantly the porosity of arable land. The greatest decrease of porosity in the subarable layer occurred in soils formed from loamy sand and silt. When the values of density and porosity are formed in this way, the air-water conditions may be formed improperly. In wet seasons the plough horizon may become too wet, while in the dry periods the plants may lack water.

In soils left as wasteland one can often notice the compaction of the subarable layer (Fig. 4). After at least two years of not utilising the land for

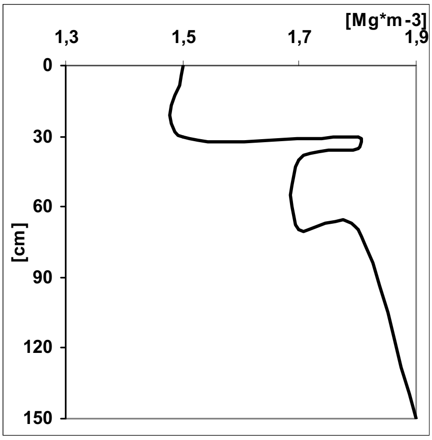

Fig. 1. Bulk density of soil formed from loamy sand

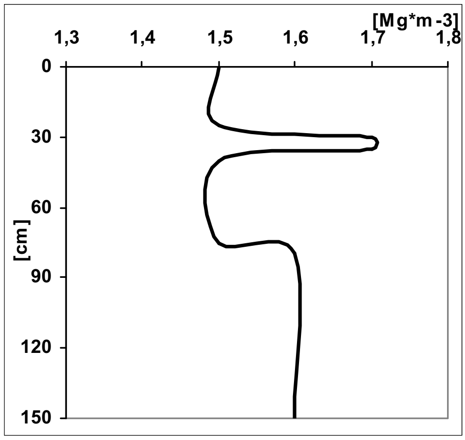

Fig. 2. Bulk density of soil formed from light loam

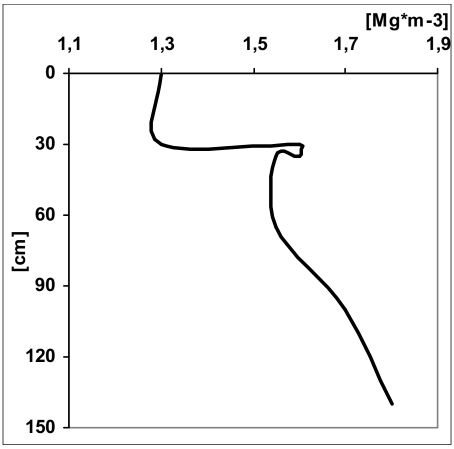

Fig. 3. Bulk density of soil formed from silt

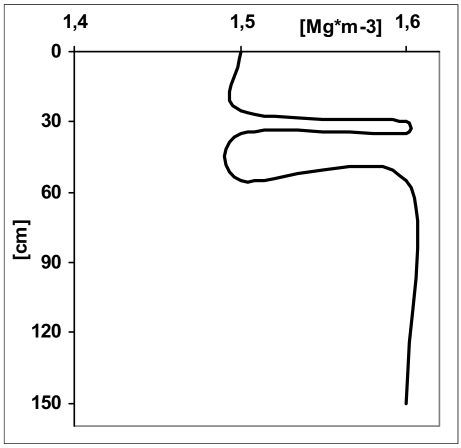

Fig. 4. Bulk density of soil formed from loose sand (wasteland)

farming, the influence of the mechanical agriculture is still clearly visible. It is hard to foresee how bulk density of these soils will be shaped after a longer period of rest. For comparison, in the forest soil previously used for farming no compaction of the layer under the humus horizon has been observed. The values of bulk density grew systematically together with the depth (Fig. 5). Overall porosity, both in forest soils and soils in laying fallow, decrease as the depth increase. In the soils currently lying fallow, formed from loose sands, the decrease of porosity is not observed immediately under the arable horizon, despite of the increase of compaction. In the horizons at up to 60 cm of depth the porosity values are in the interval 44 – 49 %, which ensures very good air conditions, but during the dry seasons shortage of water may occur.

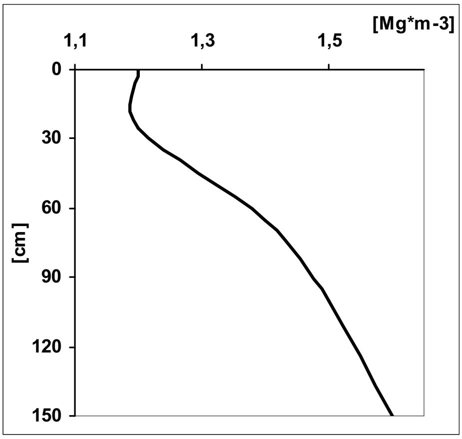

Fig. 5. Bulk density of soil formed from loose sand (forest)

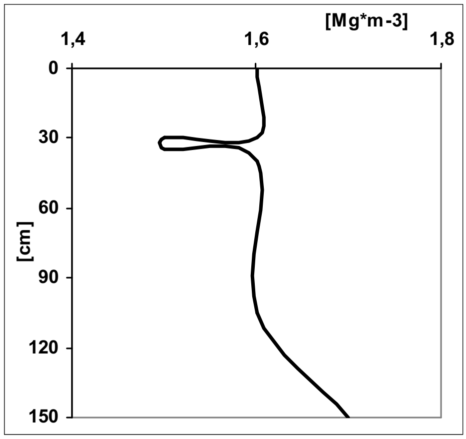

Fig. 6. Bulk density of soil formed from loamy sand

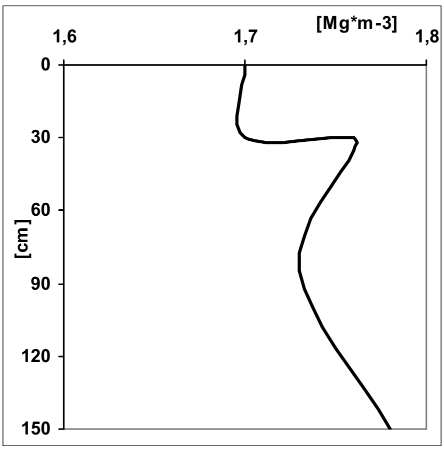

Fig. 7. Bulk density of soil formed loamy sand (meadow)

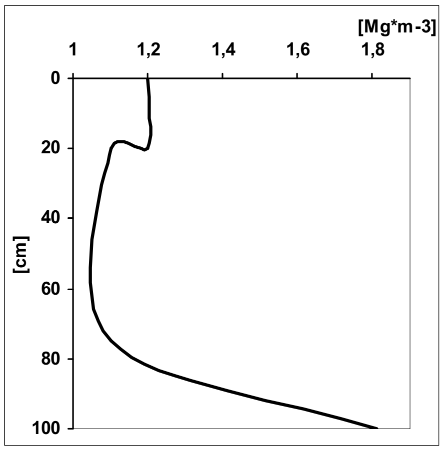

Fig. 8. Bulk density of soil formed from peat on medium-heavy clay

Only in two profiles of arable soils lower values of the bulk density in the subarable layer have been observed. Such soils are built of loamy silt sand and light loam (Fig. 6). Deep ploughing, whose purpose was both the loosening of the compacted layer and the deepening of the humus horizon, has been performed there. After the soil loosening the porosity decidedly improved, increasing by more than 15% in the subarable layer. One can state, however, that loosening of the subarable horizon is not a frequently used agricultural measure.

In mineral soils utilised as hay-growing meadows and pastures a slight increase of bulk density in the 25–35 cm layer is also observed. The values

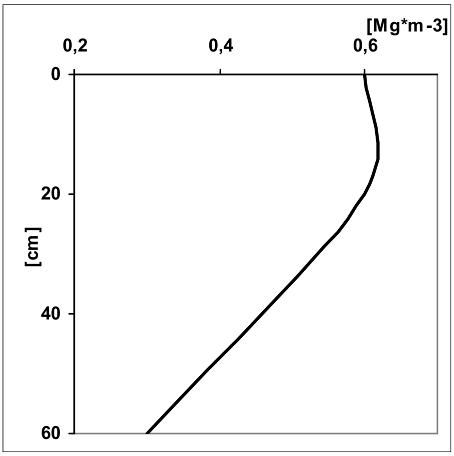

Fig. 9. Bulk density of soil formed on peat (meadow)

of bulk density in soils of hay-growing meadows and pastures at the depth up to 50 cm are 1.5 – 1.7 Mg per cubic metre (Table 1). Values of bulk density between the horizons above and below the 25 – 35 cm layer do not usually exceed 0.1 Mg per cubic metre (Fig. 7). Soils of hay-growing meadows and pastures are built of light loam and loamy silt sand. Such soils contain more than 2% of humus, which has good water-storing capability and influences the increase of compaction from the surface (Tatarkiewicz, Nosalewicz, 1999). Overall porosity in soils of bulk density in the interval 1.7 – 1.8 Mg per cubic metre is equal to around 32 – 34 %, with smallest values observed in the humus horizon. Soils of hay-growing meadows and pastures are not loosened every year, and hay harvest in preformed by means of machines that press the earth and cause a decrease of porosity. According to Uggla (1976) the same kind of soil used for green crops have higher porosity than soil used for farming; one can notice, however, that mechanical hay harvest clearly affects the decrease of porosity in meadow soils.

In half-bog soils slightly higher values of bulk density are observed in the surface layer (Table 1, Figs. 8, 9). If no mineral matter occurs in the substratum, a decrease of bulk density can be observed as the depth increases (Fig. 9). The phenomenon of compaction of the surface horizons in organic soils is connected with the process of peat-earth forming and partial mineralisation of the organic matter (Uggla, 1976). When applying land-improvement measures, the surface was levelled out and pressed, which influenced also the compaction of the surface layer. These soils are covered by wet meadows, which may be utilised as hay-growing meadows.

One should suppose that these observations are typical for soils utilised for farming in central Poland, and perhaps also in other parts of the Central-European Plain. In any case there is no doubt that the plough sole significantly influences porosity, water retention and air conditions in soils, and therefore also plant crops. For that reason loosening of the arable and subarable layers is necessary, in particular in soils enriched in silt and clay fractions, to improve the porosity and the retention capability as well as to cause the decrease of bulk density.

CONCLUSIONS

1. The effect of the compaction of the layer at the depth of 25 – 35 cm occurred in 68% of mineral soils under investigations.

2. Compaction of subsoil and decrease of overall porosity was observed most often in farming soils formed from light loam, silt, and loamy sand. In many cases this is the result of the plough sole formation.

3. Higher values of bulk density in half-bog soils are observed on the surface, which is connected with the peat-earth forming processes and with the mineralisation of the organic matter.

4. Soil utilised as meadows and pastures shows higher values of bulk density from the surface and show small degree of compaction of the subarable layer, while soil utilised for farming shows significant compaction of the subarable layer.

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