Soil compaction survey in Estonia

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Abstract
The aim of the study was to detect the current conditions of Estonian soils in case of compaction and to test the indicators recommended in the result of the Environmental Assessment of Soil for Monitoring (ENVASSO) project final report in 2008. The soil compaction survey on Estonian fields was conducted in the fall of 2008 in a collaboration of Estonian University of Life Sciences and Agricultural Research Centre. Fifteen annual crop fields and 3 grasslands were under survey on different soils. Current study results for 4 study areas are presented as for those areas the data are for the last survey (1987) available. The parameters measured were soil bulk density, total and air filled porosity at 6 kPa suction, soil texture and content of organic carbon. Samples were collected from 5 randomly selected places from each field from 5-10 cm and 20-25 cm depth in two replications. One sampling place was selected at the field edge or tyre track. In three places under investigation the bulk density measured in 2008 was higher than in 1987 by 0.15 to 0.39 g/cm^3 and in one area remained the same at both depths. In all investigated places soil bulk density exceeded 1.55 g/cm^3, which is over the suggested limit of those soils. Soils total porosity was around 40%, but air filled porosity exceeded 10% only in two places in the top 5-10 cm soil. In field edges or tyre tracks statistically significant lower aeration porosity and higher bulk density were measured compared to the rest of field. However, even if the soil bulk density values in some places were over the recommended limit, the aeration porosity showed the good condition of these soils.

Key Words
Soil compaction, bulk density, aeration porosity, survey.

Introduction
Soil is definitely one of the most important environmental components but also one of the most underestimated, abused and ill-treated resource on Earth. Systematic soil surveys were started in the 1950s in most countries against the background of an urgent need for increased agricultural productivity. In Estonia, systematic large-scale soil mapping was initiated in 1949 and from 1954 special survey was carried out under supervision of the Ministry of Agriculture (Reintam *et al*. 2003). However, from EU 25 countries only 9 lave some direct legislation for soil protection (Thematic Strategy 2006) and in other countries no direct legislation for soil protections are implemented, including Estonia. In Estonia systematic survey of agricultural area started in year 1983 and extended to the year 1994. During that survey the main attention was paid to macronutrients in soils. In the beginning of that period also the special survey of soil compaction was carried out, during which the bulk density in the plough layer and under it were measured. Soil survey was restarted by order of Ministry of Environment by Agricultural Research Centre in 2001. No soil compaction studies were included in this survey. As it is now more than 20 years from the last soil compaction survey, an application was presented to the Ministry of Agriculture in cooperation with the Agricultural Research Centre and Estonian University of Life Sciences. In spring of 2008 funding was received and the work could start in the fall of this year. The aim of the current study is to present some results of the soil compaction study carried out in 2008 in Estonia. Innovative during that survey was that first in time that air filled porosity as an indicator was included in to the survey.

Methods
The soil compaction survey on Estonian fields was conducted in the fall of 2008 in collaboration of Estonian University of Life Sciences (EULS) and Agricultural Research Centre (ARC) and funded by Estonian Ministry of Agriculture. Fifteen annual crop fields and 3 grasslands were under survey on different soils. In current study results of 4 study areas are presented as for those areas the data of last survey (published in 1987) are available. The places selected for this study were Kiislimõisa and Tuuleveski on sandy clay loam soil, Laiuse and Avispea on sandy clay soil. By World Reference Base for Soil Resources WRB (2006) classification of the soils of experimental areas are the follow: Kiislimõisa and Laiuse – Stagnosol, Tuuleveski and Avispea – Calcaric Phaeozem.

The parameters measured were soil bulk density, total porosity, air filled porosity at 6 kPa suction, soil texture and content of organic carbon. Organic carbon measurement was needed for calculation of soil porosity.

Field measurements
Samples were collected from 5 randomly selected places from each field from 5-10 cm and 20-25 cm depths in two replications. One sampling place was selected from the field edge or tyre track. Sampling was done by 100 cm^3 steel cylinders in September and October after harvest and before ploughing. Special soil samples were taken to measure soil texture and organic carbon content. Sampling was done by ARC.

Laboratory measurements
Soil texture, bulk density and porosity analyses were carried out at in the laboratories of the Department of Soil Science and Agrochemistry of EULS and organic carbon measurements in laboratories of ARC.
To find out the air filled porosity, the soil samples taken from the field were weighed and saturated with water. After saturation the soils with the cylinders were placed on ecoTech plastic suction plates at 6 kPa suction for approximately 10 days (to equilibrium water content). After that, to find out the water content, porosity and dry bulk density, the soil samples taken from the apparatus were weighed and dried at 105°C to constant weight and weighed again. After that the water content, total porosity, air filled porosity and dry bulk density were calculated. Samples for the determination of particle size were treated with sodium pyrophosphate to break down aggregates. Sands were sieved and fractions finer than 0.063 mm were determined by pipette analysis (van Reeuwijk 2002). Air–dried soil samples were sieved through a 2-mm sieve and used to determine soil carbon (Corg) (Vorobyova 1998).

Statistical analysis
The statistical analyses were used the software Statistica 8.0 and analysis of variance (ANOVA) was implemented to find out the least significant differences (LSD) at $P<0.05$.

Results
Results of the survey on four fields in Estonia indicated that soil bulk density at a depth of 5-10 cm has been increased the most being in the Avispea experimental area, where the bulk density ranges to 1.65 g/cm^3 in 2008 compared to 1.35 g/cm^3 in1987 (Figure 1a). In general terms the bulk density is the lowest on Tuuleveski experimental area (about 1.45 g/cm^3 in 2008). Bulk density has remained on the same level on Laiuse experimental area. At a depth of 20-25 cm the soil bulk density has significantly increased on Tuuleveski experimental area (Figure 1b) compared to 1987. The highest values of bulk density were measured on the Avispea experimental area. Bulk density has remained at the same level on the Kiislimõisa experimental area. On the Laiuse experimental area the bulk density had decreased by 2008 (1.54 g/cm^3) compared to earlier measurements (1.67 g/cm^3).

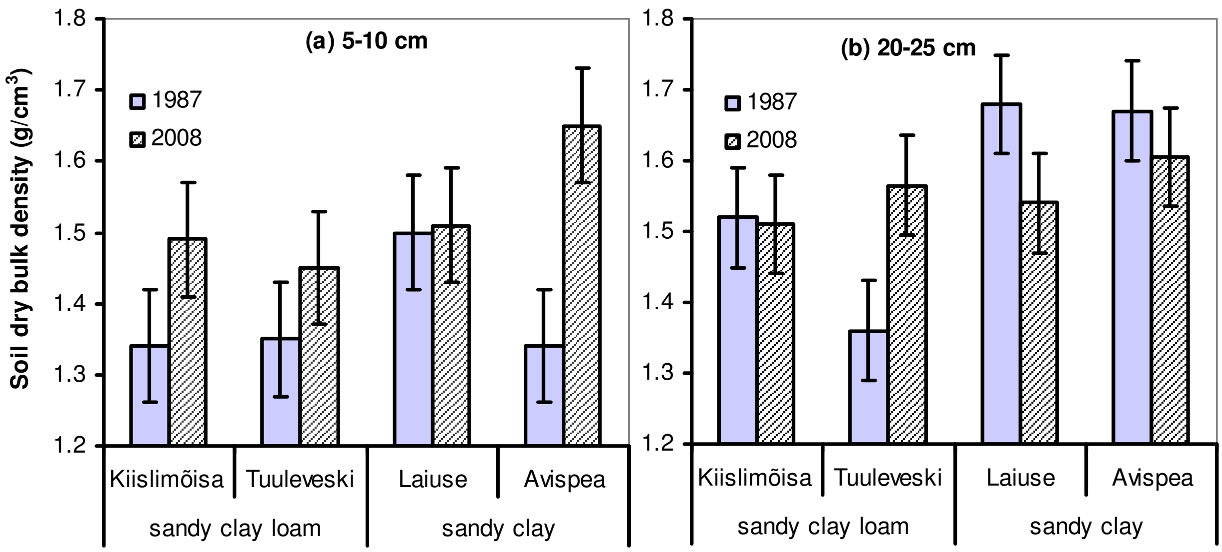

Figure 1. Soil dry bulk density of four survey sites in 1987 and 2008 in 5-10 cm (a) and 20-25 cm (b) depth in Estonia. Vertical bars denote least significant difference at *P*<0.05.

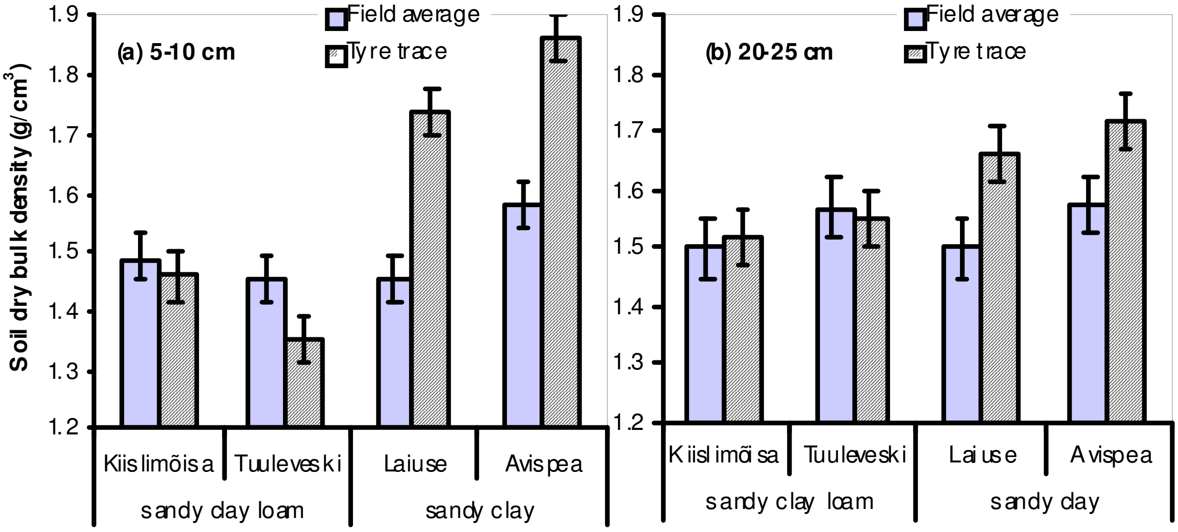

Figure 2. Soil dry bulk density of four survey sites as average of study field and in tyre track in 5-10 cm (a) and 20-25 cm (b) depth in Estonia in year 2008. Vertical bars denote least significant difference at *P*<0.05.

Highest values of soil dry bulk density were measured on sandy clay loam soil on Laiuse and Avispea in tyre tracks in 5-10 cm depth where it exceeded 1.7 g/cm^3 (Figure 2a). No significant differences were detected in soil of Kiislimõisa and Tuuleveski. Under the plough layer the bulk density was higher than in the plough layer (Figure 2b). As for topsoil also in deeper soil significantly higher bulk density values exist in tyre tracks for Laiuse and Avispea. On Tuuleveski experimental area bulk density at field edge was lower than the average of the field.

The aeration porosity in wheel tracks at a depth of 5-10 cm was lower in two experimental sites– in Laiuse and Avispea (Figure 3a). In other two places there was more air filled pores in track line. But probably it was not the real track line. In wheel tracks at a depth of 20-25 cm the aeration porosity was also higher or on a same level with the average of variables (Figure 3b). Generally the aeration porosity was less than 10% therefore the soil is suffering shortness of air. Lowest aeration porosity was measured at Avispea in tracks at 5–10 cm depth, where it was significantly lower from the average value of the field. In deeper soil no statistically significant differences between study sites were detected. The highest moisture content was measured on Laiuse 2 experimental area (about 33%) and the lowest on Avispea experimental area (about 25%). In general the moisture content at depth was slightly lower but on the Avispea experimental area it was higher than at a depth 5-10 cm.

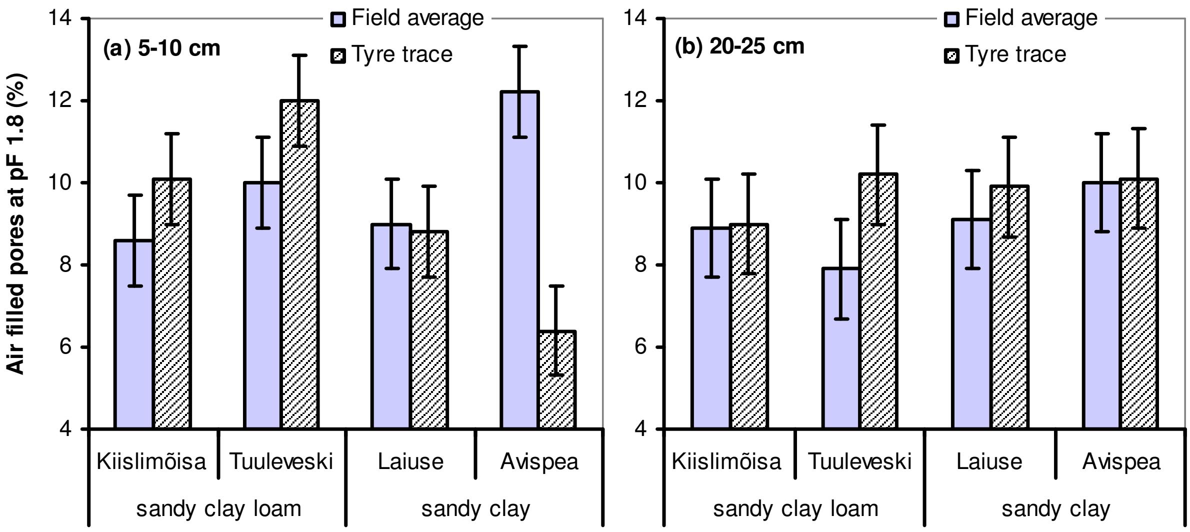

Figure 3. Soil air filled pores at pF 1.8 (6 kPa) of four survey sites in 2008 in 5-10 cm (a) and 20-25 cm (b) depth in Estonia. Vertical bars denote least significant difference at *P*<0.05.

In soil of all investigated sites the bulk density exceeded recommended values for plant growing. For most of the cultivated plants the suitable soil bulk density is 1.0–1.35 g/cm^3 and acceptable limit is 1.5 g/cm^3 (Lehtveer and Nugis 1987). In our earlier studies the plant growth limiting bulk density in sandy loam soil was 1.6 g/cm^3 (Reintam *et al.* 2008). In studies of Daddow and Warrington (1983) (in Gray 2002) the plant growth limiting value of dry bulk density for sandy clay soils is between 1.55 and 1.65 g/cm^3 and for sandy clay loam soils between 1.55 and 1.75 g/cm^3. Those critical values were exceeded only in track tracks in the soils of investigated areas. However, average aeration porosity remained below 10% in soils of investigated areas. Some researchers found that if aeration porosity is below 10%, there is not enough air in the soil, 10–25% is moderately aerated and over 25% is a well aerated soil (Conlin and Driessche 2000). In the conclusions of ENVASSO project they found that 10% is required for a satisfactory medium for plant growth and at least 5% air filled pores in subsoil are needed in well structured soil at 5kPa suction (ENVASSO 2008). Soil aeration in Kiislimõisa, Tuuleveski and Laiuse in plough layer was, but in the subsoil the aeration was over 5%.

Conclusion

Soil compaction in Estonia is a problem. Bulk density and porosity is in a poor state, so it would be necessary to continue the investigation of soil compaction and thus to identify the best methods to improve the situation of our soils. To evaluate the soil conditions, the air filled porosity at 6 kPa indicates the conditions better than just measurement of soil bulk density.

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