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# Utilization of Machines Passages Monitoring Across Plots for Measures Proposal Regarding Soil Protection from Compaction

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**Abstract:** Current farming systems used in agriculture are connected with lots of negative influences to soil. Those factors destroy both productive and non-productive role of soil. One of the most significant effects is soil compaction. Besides its adverse influence on crop yields, the consequences onto the environment as a whole are really relevant. This article describes outcomes from a field experiment evaluating the soil environment in the field where conservation tillage technologies were applied on a long-term basis. This field has been intended for CTF (controlled traffic farming) implementation and therefore it was necessary to monitor starting conditions of the soil there.

Number of passages across the field surface and the area run over by machine's tyres were evaluated during one year. The experiment showed that 71.5 % of the total field area was run over with a machine at least ones during a year. It was calculated that 43.3 % of covered area was run-over repeatedly. Undesired soil compaction was found in the soil profile, in the depths bellow the tillage depth done every year. Soil bulk density measurements of the soil profile bellow the tilled soil layer revealed limits-exceeding values of the soil compaction. Mean value of soil bulk density was around 1.66 $Mg.m^{-3}$ in the depth 0.15 – 0.20 m.

Concentration of blue colour used for infiltration and water flow in soil evaluation decreased remarkably at the depth of 0.20 m, which proves the compacted soil there.

Also tractor tensile force was measured as a crucial factor of energy demands for soil tillage. Tractor tensile force values varied between 21.6 and 56.9 kN.

## INTRODUCTION and LITERATURE REVIEW

The most common cause of subsoil compaction on farms is traffic, particularly the use of heavy equipment with a poor distribution of the total weight to all four wheels on the wet soil (Håkansson et al., 1988; Horn and Fleige, 2003; Chan et al., 2006). Compacting the soil by traffic reduces the soil infiltrability, hydraulic conductivity, porosity, and aeration and increases bulk density and impedance for root exploration (Gan-Mor and Clark, 2001; Chamen et al., 2003; Hamza and Anderson, 2005; Radford et al., 2007).

Until recently, there were not enough available tools to use successfully CT farming in agricultural practice. Particularly it is true when talking about reliable guidance systems which are necessary in the field when using CTF. Nowadays, there are guidance systems for agricultural machinery with the accuracy which enables machines and units to perform precise continuation of the individual passages during different field operations (tillage, seeding, spraying, etc.). The tillage regime that we propose requires techniques that restrict soil compaction onto fixed traffic lanes, giving remaining large zones favourable for crop growth. Because of ongoing processes in precision farming technology, with respect to controlled traffic systems, this regime has realistic opportunities to become widely used in the future (Lamour and Lotz, 2007).

Tractor tensile force is a significant variable influencing energy demands of soil tillage. That is why separation of traffic lanes from remaining productive area of a field without any soil contact with machine´s tyres can save energy and consequently costs for tillage.

Beneficial aspects of CTF concerning energy savings proved McPhee et al. (1995). The authors state that up to 30 % of tractor engine power is absorbed by soil resulting in its compaction. This fact is subsequently the reason for an increase in tensile force by 25 % during tillage. Tullberg (2000) mentions an increase in total energy consumption during tillage, resulting from repeated machine's passages on soil, in the range 25 - 40 %. He further counts that nearly half of the tractor engine power can be wasted in loosening the compacted lines after machines passages – in other words, half of the tractor power participates in soil degradation. By using CTF, time and material input savings can be approximately from10 up to 20 %.

**MATERIAL AND METHODS**

An experimental field with the acreage 15 ha was chosen for the overall evaluation of soil environment when using CTF. Namely, the influence of fixed traffic lines on soil physical properties, soil water infiltration, energy consumption and quality of soil tillage was evaluated. Haplic Cambisol (FAO classification) soil describes the field. Type of soil is mainly sandy loam soil with share of skelet. Minimum tillage was performed for previous 12 years in the field. All machinery passages were monitored during one year in the season 2007/2008 including combine harvesters, trailers, manure spreaders etc.

For machines travelling monitoring across plots the DGPS receivers with recording of points in interval of 2 seconds were utilized. Area covered with tyres was found out and percentage share of soil surface coverage with passages was calculated. The machines passages were expressed in graphical form on plots map cut-out sections.

Soil physical properties were observed and evaluated after harvest of previous crop. Soil sampling by means of Kopecky rings was done in the depths 0.5, 0.15 and 0.25 m – measured from the upper edge of the sampling cylinder, each sample was taken in the same line 0.3 m apart from the previous one. This sampling line was always perpendicularly oriented to machinery passages direction. Length of the sampling line was 9 m, which corresponded with the implements working width. Samples were also taken in the same depths on the field headland.

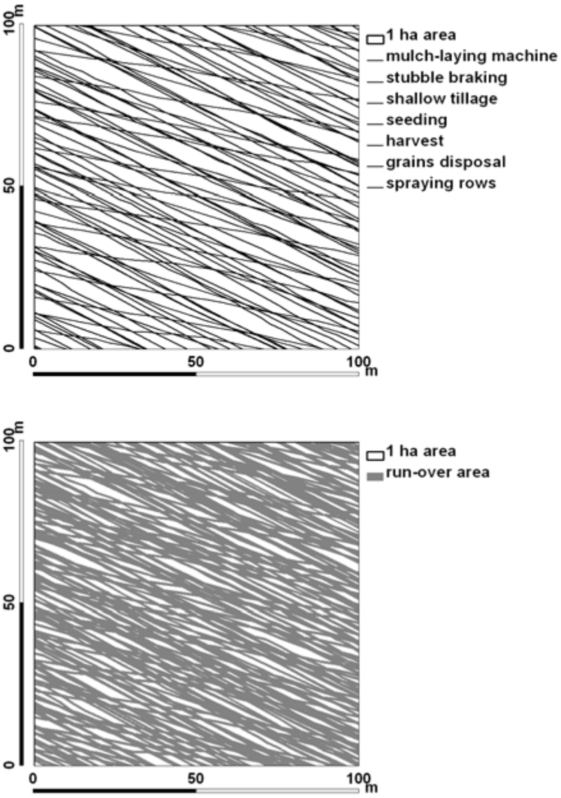
For the water motion visualisation and its quantification in the soil, the method of water infiltration using blue food colouring agent with the consequent image analysis of photographic pictures was used. On the soil surface was applied 0.3% water solution of the colouring agent "E 330 brilliant blue" in the amount of 40 $dm^3m^{-2}$ for the individual variants. The infiltration time was 24 hours. This was followed by uncovering parts of the soil profile (0.60 m width, 0.40 m deep) and their consequent photographing. The digital photograph picture was processed by the program "BMPtool" where the picture is transformed into two colours: blue (soil saturated with coloured water) and red. The analysed picture is stored in tabular form where the blue colour representation in percentual amount for the respective depth is presented for individual layers (0.05 m). The assessment method is described in the work presented by Anken et al. (2004).

On the plots with machines passages' monitoring the tensile force using a electro-hydraulic hitch control of tractors was measured on the selected plot during soil cultivation after crop harvest. The 7.5 m working width tiller Horsch Phantom FG 7.5 was attached to the tractor CASE Magnum 310. The tractors have serial installed power pins of the three-point hitch. The tensile force values, the tension value at the output of the power pins sensors let us say, were recorded in 2 s interval in the measuring exchange. Together with the tensile force value the data about the machine position were registered. The results were worked-up in the tensile force maps and consequently utilized for assessment of soil environment variability.

**RESULTS AND DISCUSSION**

Following field jobs in real sequence were taken into account for the experiment evaluation: harvesting of winter wheat, stubble mulching, shalow tillage (depth 0.12 m), repeated tillage, seeding, plant protection and fertilization (using tramlines). Plant remains were chopped and distributed onto the field surface during harvest. All passages of agriculture machinery across the field were mainly random except chemicals and fertilizer application done using tramlines. No interference into direction of passages were done so the experiment was fully on practice basis. It is possible to presume that the trajectories of passages will be different next year.

Generally speaking, as a result of this fact, the soil is exposed very often to repeated passages and thus irreversible structural changes connected with soil compaction. The results of our measurement, concerning this problem, showed that 71.5 % of the total field area was run over with a machine at least ones during a year (Figure 1). It was calculated that 43.3 % of covered area was run-over repeatedly. Higher number of passages was also spotted at places where machinery turn back – mainly headlands. The results show considerable high number of tyre's contacts with soil.




**Figures 1. Graphic expression of machinery passages record in the selected part of the experimental field upper figure: machine´s movement trajectories in the field figure down: total run-over area**

Repeated machinery passages in the field are connected with the risk of undesired soil compaction. High intensity of machinery passages in the field was found in several fields observed simultaneously with our experiment. Namely, field where ploughing was used and also field with direct seeding technology was evaluated. The results showed that 96 % of the ploughed field area and 42.2 % of the field with direct seeding technology was affected by machinery tyre tracks.

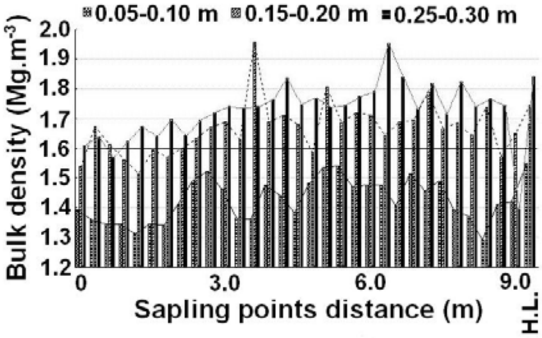



**Figure 2. Soil bulk density diagram. Three sampling depths. Sampling line was perpendicular to machine work direction. (HL- headland)**

Figure 2 shows soil bulk density diagram across working width of the implements used in the field. Also the average values of soil bulk density from the field headlands are displayed in the graph.

Table 1 describes values of soil bulk density in different sampling depths. Lowest values were measured in the upper soil layer. The reason for this fact is shallow tillage done every year and also higher amount of pant remains incorporated into this layer.

**Table 1. Soil bulk density values (Mg m$^{-3}$) measured in three depths - experimental field.**

| | Sampling depth (m) | | |
|---|---|---|---|
| | 0.05-0.10 | 0.15-0.20 | 0.25-0.30 |
| Mean | 1,42 | 1,66 | 1,72 |
| Std. deviation | 0,07 | 0,09 | 0,10 |
| Skew | -0,01 | 1,16 | -0,94 |
| Minimum | 1,29 | 1,52 | 1,40 |
| Maximum | 1,54 | 1,96 | 1,95 |

In figure 2, it is possible to draw the line representing the value 1.6 Mg m$^{-3}$, which is the limit value for loamy-sandy soil (Lhotský, 2000). Except a few measured values of soil bulk density, all others exceeded this mentioned limit value in all depths. The same results were achieved on headlands. From the CTF point of view, Chan et al. (2006) recommend, on the basis of their experiments, to perform deep soil loosening before starting CTF in order to eliminate subsoil layer compaction caused by previous system of tillage.

The results of our measurements proved this statement and showed that it is necessary to do deep soil loosening in the experimental field. The depth of this essential tillage step is limited by the depth of tillage-able soil profile.

The results of infiltration test, done in the field by means of blue experimental colour, showed higher concentration of blue colour in upper part of soil profile and decreasing infiltration rate when going deeper only with higher flow through macro pores and discontinuities. This infiltration behaviour is characteristic for fields with shallow tillage system applied.

The highest concentration of blue colour was found in the upper soil layer till 0.20 m then it was possible to see a remarkable concentration drop. Graphic representation of the measured values is in figure 3. The results just prove the research outcomes presented by many authors. For instance, Hangen et al. (2002) presents as the possible cause of these infiltration differences various methods of soil tillage: the homogeneous layer with horizontal structure is generated in the soil conventional tillage with ploughing and the vertical structure is generated during the soil reduced tillage. Significant for infiltration in this case are the vertical macro pores generated by the earthworms as well as the soil ruptures. The presence of vertical macro pores, ruptures and other discontinuities is visible in figure 4. Figure 4 shows bottom of the hole (in the depth 0.4 m) where soil profile was taken out after infiltration test. White colour in the figure represents the infiltrated dyeing colour flowed down through the mentioned macro pores.

Pulling force measurement during first shallow tillage done by Horsch Phantom FG 7.5 in the experimental field revealed remarkable variability in its values (Figure 5). The values of pulling force were in the range between 21.6 and 56.9 kN.

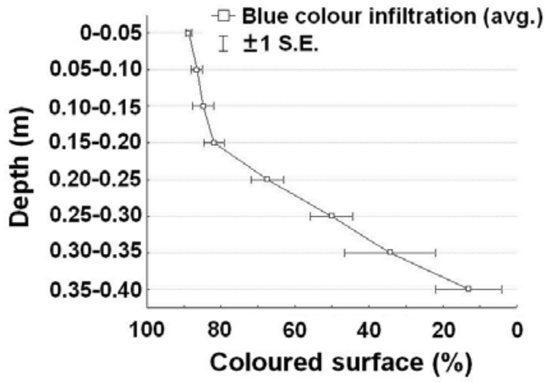



**Figure 3. Flow patterns measured by the determination of the percentage of the blue dyed surface area; error bars indicate ± 1 S.E.**

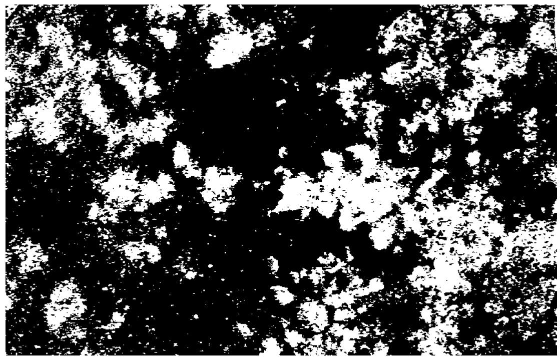


**Figure 4. Soil layer surface in the depth 0.4 m where infiltration rate was monitored. White colour represents soaked-in dyed water, black colour is soil.**

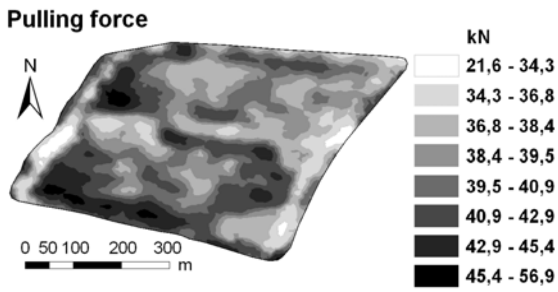



**Figure 5. Recorded map of pulling force during tillage done by Horsch Phantom FG 7.5 tiller after winter wheat harvest.**

The tractor pulling force is affected generally by many factors including degree of soil compaction. The values measured in the experimental field constitute starting conditions of soil in the field where CTF is intended to be introduced into a common agriculture practice. Energy demands of tillage, their possible changes and also soil profile characteristics will be observed during following years in this field.

## CONCLUSIONS

The measurements and evaluation of soil profile characteristics in the chosen experimental field showed undesired soil compaction below the tilled depth. The field is intended for further observation concerning changes in soil profile parameters and consequently energy demands of soil tillage when introducing CTF. Bad physical soil properties in the soil profile deeper than 0.20 m caused decreasing infiltration rate in this soil layer.

Intensity, namely number of machinery passages across the field was monitored during one season. The analysis revealed excessive number of machinery passages on the field surface and therefore the risk of soil structure damage when using conventional plant production technologies.

Further, observation of the field will be focused on the CTF implementation into common agricultural practice and the consecutive benefits for soil physical properties and anticipated energy savings necessary for tillage.

This issue will be solved under a new research project concerning interactions between water soil and the environment. The results should broaden the information basis relating to tillage systems, effect of tillage on the environment, soil conservation and its rational and sustainable utilisation.

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