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Agricultural compaction of some soil types in eastern Croatia

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Abstract

Frequent use of heavy equipment (mechanisation) lead to soil degradation processes of physical-mechanical properties of soils in agricultural production. Soil compaction, as one of the main causes of soil degradation, reduces pore volume in the soil, which directly influence on water-air relations. A very common problem is the impossibility of infiltration of rainwater and its retention on the surface in a shorter or longer period. In such conditions, plants suffer from lack of oxygen (hypoxic or anoxic stress) which resulted of reduction conditions and may lead to decreasing of pH reaction and availability of plant nutrients. In addition, when the bulk density reaches a critical value, e.g., 1.6 Mg m^{-3} for loam and clay loam, significantly increases resistance to root penetration in soil depth. Research was conducted at 40 locations on three soil types with the aim of recording the current situation and the intensity of soil compaction damage in agricultural area of eastern Croatia (Slavonia and Baranja region) and to determine the soil properties that are in a strong correlation related to the compaction. According to the values of packing density, researched soils can be classified as medium (PD = 1.35 to 1.57 Mg m^{-3}) to very compacted (PD = 1.77 to 1.99 Mg m^{-3}).

Key words: Soil degradation, soil compaction, bulk density, Packing density

Introduction

Modern trends in agricultural production in the last few years more and more imposing use of heavy duty mechanization (mass and power). In addition to the reached of positive financial effect (high yields and profit) in modern agricultural production may occur and some negative effect (Chamen et al., 2000) through the physical and mechanical degradation of soil properties. Soil compaction, according Pagliai et al. (2003), is one of the main causes of degradation of the physical properties of soils. Changes resulting from these processes (Horn, 2000; Czyż, 2004) very unfavourable affect the growth and development of plants in the early growing season, and as such, are becoming an increasing agroecological problem. Due to the large number of passes by heavy mechanization and soil tillage in wet condition, soil pore volume becomes reduces which directly impair on water-air relations. In arable and subarable horizons due to the impossibility of rainwater infiltration comes to waterlogging. In these conditions occurs reduction processes and usually lead to decreasing of pH reaction and availability of plant nutrients. Furthermore, increases resistance of root penetration in soil depth, reducing the yield but also the quality of the crops. According Miloš (2007) on compacted soils average yields can be decreased by 15-20%, but in the same time the fuel consumption can increase by 20-30%.

These changes can be followed in continuity by readings of bulk density and total porosity (Håkansson and Lipiec, 2000) or packing density (van der Akker, 2002). According to Lebert et al. (2007) only five parameters can be used to assess soil compaction in subarable horizons, and one of them is packing density (PD). Based on these values, the soil can be classified into five classes: from 1 (very light structure) to 5 (very heavy structure).

Researches were conducted with the aim: a) recording the current situation and the intensity of soil compaction damages in agricultural area of eastern Croatia; b) identification of soil properties that are in a strong correlation related to the compaction.

Material and methods

Research of compaction of agricultural soils in intensive agricultural production were conducted on 40 locations in eastern Croatia (Slavonija and Baranja region). From the opened profiles at the locations describes the morphological properties and samples from genetic horizons for soil types identification were collected. For the assessment of soil compaction of arable and subarable horizon, samples were collected in disturbed condition (80 samples) and undisturbed conditions in the cylinders of 100 cm^3 in five repetitions at each depth (total 400 samples). According to the Croatian soil classification (Škorić, 1986) was determined are three soil types: Chernozem (10 locations), Luvisol (15 locations) and Pseudogley the other 15 locations. In samples were analysed: soil texture according to HRN ISO 11277:2004, humus content with modified bichromate method, particle density by Albert-Bogs method, bulk density with cylinders of 100 cm^3 volume. Total porosity and packing density of particles were determined by calculation. The results were statistically analysed in Statistica 10.

Results and discussion

On the intensity of agricultural soil compaction directly affects the content of clay and organic matter. The research covered three soil types: chernozem pseudogley and luvic soil. In samples of arable and subarable horizons in addition to texture and humus content and the soil density (bulk and solid phase), overall porosity and packing density.

Humus content

Data from the Table 1 show low humosity agricultural soils. The average humus content in the arable horizons varies between 2.06% of the Pseudogley soils and 2.18% of the Chernozem. The humosity decreasing with the depth (Table 2). So average value of subarable horizons varies betwen 1.17% in Pseudogley to 1.57% in Chernozems. In the upper horizons of chernozems humus content are in highly significant correlation with packing density ($r = 0.874^{**}$) and significant correlation with bulk density ($r = 0.695^{*}$). In Figure 1-4 are shown the influence of humus content on compaction parameters.

Texture and clay content

Analysis of the clay content in the arable horizons (Table 1) shows considerable variability among soil types, but also within the same type. In Chernosems is in the range from 21.05 to 42.64%, and according to the particle size distribution: silty clay (50%), silty clay loam (40%) and silty clay (10%). In pseudogley soils dominated silty loam texture (80% of samples) over silty clay loam (20%). Content of clay particles varies in a range from 15.94 to 31.89%. In Luvisols the clay content vary from 17.13 to 28.64%, and prevailing (53%) silty clay loam over the silty loam (47%). Clay content vary from 15.94 do 31.89%. In luvisol soil clay content ranging from 17.13 to 28.64%, but unlike pseudogley prevalent (53%) silty clay loams over silty loam (47%).

In subarable horizons of chernozem clay content is lower and vary in the range from 20.23 to 44.29%. Prevailing silty loam (60%) (Table 2). This lower clay content in deeper horizons of chernozems is logical. In fact, the forming processes of chernozem are related to semiarid climate in which there is not enough rainfall (Škorić, 1986) for more intensive leaching process of colloidal fraction from surface horizons.

Table 1. Soils physical properties in arable horizon

Soil type		Clay %	Organic matter %	Bulk density Mg m^{-3}	Packing density Mg m^{-3}	Overall porosity %
CHERNOZEM	n	10	10	10	10	10
	x	29.29	2.18	1.42	1.69	41.98
	Sd	7.85	0.40	0.08	0.13	4.01
	Cv	26.78	18.26	5.60	7.93	9.54
	min	21.05	1.70	1.29	1.51	37.08
	max	42.64	2.83	1.52	1.89	48.40
PSEUDOGLEY	n	15	15	15	15	15
	x	21.35	2.06	1.43	1.62	42.15
	Sd	5.01	0.39	0.11	0.14	4.02
	Cv	23.47	18.83	7.78	8.95	9.53
	min	15.94	1.60	1.20	1.35	35.60
	max	31.89	2.89	1.61	1.90	52.00
LUVISOL	n	15	15	15	15	15
	x	24.74	2.08	1.42	1.65	42.23
	Sd	3.25	0.44	0.07	0.09	3.40
	Cv	13.16	21.26	5.08	5.29	8.06
	min	17.13	1.36	1.29	1.44	33.62
	max	28.64	3.10	1.56	1.77	48.40

Note: n - number of analysed samples (locations), x - arithmetic mean value, max - maximal value, min - minimal value, Sd - standard deviation, Cv – variation coefficient (%).

On the other hand, the results in Table 2 show different intensities of eluviation in pseudogley and luvisol soil types. In subarable horizons of pseudogley, clay content are significantly increased in relation to upper layers. The average content was 26.44%, but with a lower coefficient of variation (CV = 18%) than in the upper horizons, where it amounted to 23.47%. Intensive eluviation confirmed the fact of increasing the silty clay loam content to 47%, and silty clay content decreased to 53% compared to the arable horizon. In subarable luvisol soil horizons (Table 2), the clay content in the range from 17.53 to 33.40%. This means an increase of silty clay loam at 80%, and a lower of silty clay content for 27%.

Soil bulk density

To estimate the intensity of compaction of agricultural land one of the most important indicators is the soil bulk density. Higher values indicate increased density, mostly due to low humus content, increased content of clay or tiny pores. The result is greater resistance of plant roots penetration to soil. Critical values are 1.6 Mg m^{-3} for loam and clay loam, 1.4 Mg m^{-3} for clay soils, and for silty clay loams 1.7 Mg m^{-3} (Jones, 1983, quote: Hazelton and Murphy, 2007).

Result in Table 1. According Hart (quote: Hazelton and Murphy, 2007) show low to medium values of bulk density in the upper horizons (1.20 to 1.61 Mg m^{-3}). Highly significant correlation (r = 0.665**) between bulk density and clay content with only the upper horizons of pseudogley soil type. In subarable horizons of pseudogley clay content and bulk density are in significant correlation relationship (r = 0.567*), as in luvisol soils (r = 0.596*).

Table 2. Soils physical properties in subarable horizon

Soil type		Clay %	Humus %	Bulk density Mg m^{-3}	Packing density Mg m^{-3}	Overall porosity %
CHERNOZEM	n	10	10	10	10	10
	x	28.87	1.57	1.38	1.64	45.19
	Sd	7.87	0.35	0.06	0.10	2.50
	Cv	27.27	22.31	4.61	6.38	5.53
	min	20.23	1.17	1.3	1.48	41.96
	max	44.29	2.42	1.48	1.82	49.02
PSEUDOGLEY	n	15	15	15	15	15
	x	26.44	1.17	1.52	1.76	40.49
	Sd	4.76	0.27	0.09	0.12	3.83
	Cv	18.00	22.76	5.79	6.69	9.45
	min	21.25	0.74	1.37	1.57	34.12
	max	37.72	1.59	1.68	1.99	47.91
LUVISOL	n	15	15	15	15	15
	x	27.82	1.42	1.55	1.80	38.93
	Sd	4.03	0.32	0.09	0.12	3.41
	Cv	14.49	22.78	5.90	6.49	8.76
	min	17.53	0.73	1.39	1.55	33.33
	max	33.40	1.97	1.72	1.99	45.49

Note: n - number of analysed samples (locations), x - arithmetic mean value, max - maximal value, min - minimal value, Sd - standard deviation, Cv – variation coefficient (%).

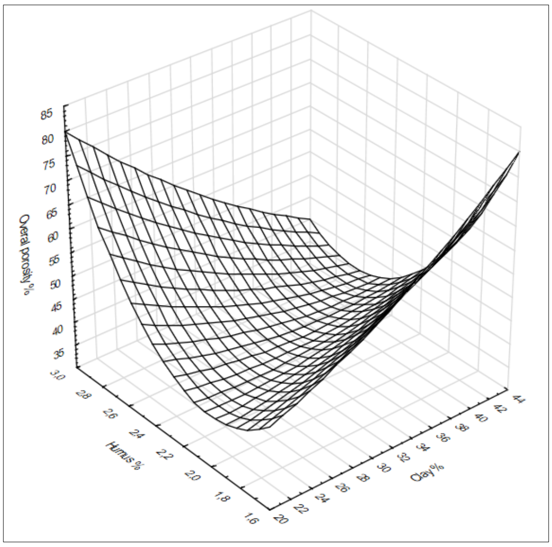

Figure 1. Impact of the clay content and humus to the overall porosity in arable horizons of the Chernozems

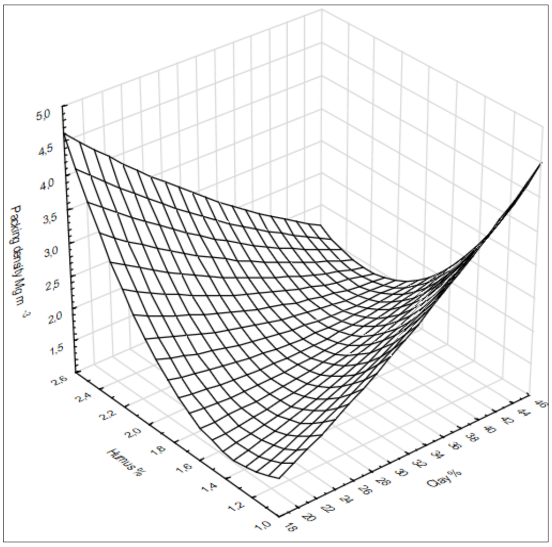

Figure 2. Impact of the clay content and humus to the packing density in subarable horizons of the Chernozem

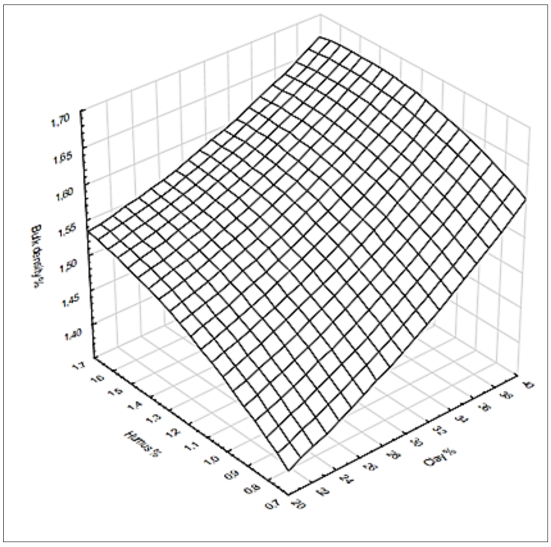

Figure 3. Impact of the clay content and humus to the bulk density in subarable horizons of the Pseudogley soils

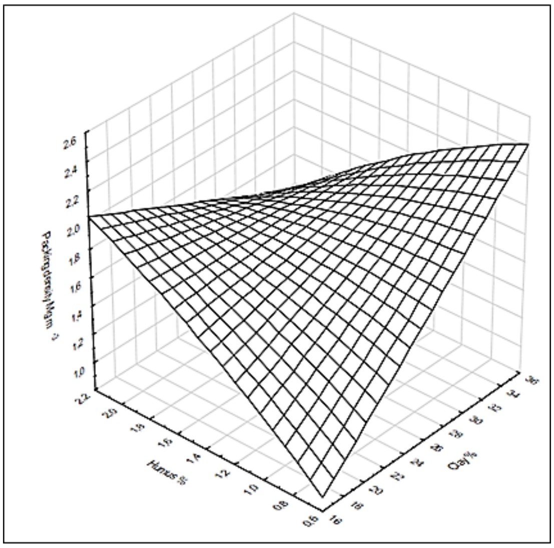

Figure 4. Impact of the clay content and humus to the packing density in subarable horizons of the Luvisols

Effect of humus and clay content on bulk density in subarable pseudogley horizon is shown in Figure 3. Maximum values of bulk density in subarable horizons pseudogley and luvisol soils (Table 2) reaches a critical value after which is very difficult due to penetration of plant roots.

<u>Packing density</u>

According Kämpf et al. (1999) increasing the packing density values significantly influence on mechanical resistance of the soil root penetration. Very heavy compacted soils have very low infiltration, poor aeration and resistance of roots penetration. Reduced growth of plant roots in depth, according to Croucher (2005), occurs with the bulk density of 1.2 Mg m^3. However, the problem is not easy to notice with high content of clay which cracking, because the root grows through the cracks occurred, even if the bulk density increases. As in soils with a high clay content effects of compaction occur at lower values of bulk density, for evaluation of clay component influence on soil compaction need to be used packing density, which is calculated according to the formula: $PD = \rho_v + (0{,}009 \times clay\ \%)$.

Values of packing density are in very strong connections with bulk density and clay content (Table 1 and 2). Minimal values in arable and subarable horizons (1,35-1,57 Mg m^{-3}) indicate the mean density packaging, and maximal values (1,77-1,99 Mg m^{-3}) are indicator of the high compaction. Figure 2 shows the dependence of the packing density to the clay content in chernozem subarable horizons (r = 0,788**), and on the Figure 4 are shown same dependence (relationship) in luvisols (r = 0,777**).

<u>Overall porosity</u>

The process of soils compaction primarily reflects on decrease in the volume of large pores and then on small pores. Therefore, the calculation of the total porosity are an indirect indicator of the compaction of agricultural land, because any increase in clay content, bulk density or density packaging reduces the amount of pores in soils. Figure 1 shows the impact of the clay and humus content on the total amount of pores in the upper horizons of chernozems. Between clay content and porosity is significant negative correlation (r = -0.702*), and between the humus and porosity very significant negative correlation (r = -0.808**).

Conclusions

Based on the results of the research presented in this paper can be concluded that the agricultural land in eastern part of Croatia (Slavonia and Baranja region) present different degrees of degradation of soil physical properties. Soil are, according to the values of density packaging, within the limits from medium to severe compaction in the upper (0-25 cm) and subarable (25-50 cm) horizons. There was a strong and very strong correlation of soil compaction with the clay content, humus content and soil bulk densities. Porosity is in a very strong negative correlation with soil compaction.

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