Soil physical properties and earthworms as affected by soil tillage systems, straw and green manure management

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Abstract

Conventional tillage is not only high energy and labour consuming process, but it can also have a negative impact on soil properties. The objective of this study was to determine the influence of different tillage systems: deep conventional ploughing (CP) at 23–25 cm depth, shallow ploughing (SP) at 10–12 cm depth, shallow loosening with a chisel cultivator and disc harrows (SL) at 8–10 cm depth, shallow loosening with a rotary cultivator (SR) at 5–6 cm depth, shallow green manure (red clover and timothy catch crop) incorporation with a rotary cultivator (GMR) at 5–6 cm depth and no-tillage (NT) on soil bulk density, penetration resistance, aggregate size distribution and earthworms. The experiment was carried out in two backgrounds: straw removed (N) or straw chopped and spread at harvesting (S). A long-term two-factorial field experiment was carried out at the experimental station of the Lithuanian University of Agriculture at 54º52′50 N latitude and 23º49′41 E longitude. The soil of the trial site was an *Calc(ar)i-Endohypogleyic Luvisol* (*LVg-n-w-cc*), clay loam on sandy light loam, with a pH_{KCl} of 7.6, humus content of 28.6 g kg^{-1}, K_2O – 134 mg kg^{-1}, and P_2O_5 – 266 mg kg^{-1}. Straw incorporation had no significant influence on bulk density, penetration resistance and quantity of earthworms, but significantly reduced the amount of the smallest <0.25 mm aggregates. No significant differences of bulk density vs. CP were obtained in reduced autumn tillage – SP, and SL, while in reduced spring tillage systems – SR, GMR and NT significant changes were observed only in the first year of experiment at 3–13 cm depth. Soil penetration resistance increased in undisturbed soil layers. In SP it increased from 12 cm depth, in SL from 9 cm depth and in SR and GMR from 6 cm depth, while in NT it became higher from the very soil surface. SR, GMR and NT increased the number and biomass of earthworms and decreased the amount of the smallest <0.25 mm soil aggregates. Significant differences in soil aggregate size distribution and stability were found already in the first year. Reduced and no-tillage significantly increased the amount of water stable aggregates in both 0–15 cm and 15–25 cm soil layers compared to deep ploughing.

Key words: bulk density, penetration resistance, aggregation, earthworms, tillage systems, straw, green manure.

Introduction

Conventional tillage is not only high energy and labour consuming process, but it can also exert a negative impact on soil properties. Continuous mixing of plough layer accelerates decomposition of organic matter and nutrient leaching and therefore it becomes difficult to conserve soil fertility without high fertilizer input (Boguzas, Stancevicius, 1993; Balesdent et al., 2000). Numerous research findings suggest that deep or shallow autumn ploughing decreases bulk density and increases porosity of soil top-layer therefore providing better conditions for plant root growth (Børresen, Njos, 1994). However, other experiments gave controversial results showing that conventionally ploughed soil settles down until sowing time leaving no significant differences between tillage systems (Franzluebbers et al., 1995; Jodaugienė, 2002). As a result, intensive tillage system seems not always reasonable.

Favourable conditions for plant germination occur in loose soils with a proper air to water ratio, sufficient amount of organic matter and high microbiological activity. Conventional deep tillage

has long been stated as the best operation to ensure these properties. However, the experience of the research carried out over the recent decades showed that continuous ploughing increases soil density, worsens air-water relations, decreases the amount of organic matter, enhances nutrient leaching, and lower soil aggregation leads to soil erosion.

In the first year of no-tillage, bulk density may increase as no soil loosening is performed afterwards. Therefore appropriate crop rotation, catch crop and straw incorporation increases soil bioactivity, amount of organic matter (Marcinkevičienė, Bogužas, 2006) and improves soil aggregation, which leads to lower soil density. Many researchers in different countries concluded that no-tillage increases bulk density in 5–10 cm layer (Franzluebbers et al., 1995; Unger, Jones, 1998; Tebrügge, Düring, 1999), while others found that sowing into no-tilled soil significantly reduced bulk density, especially when increasing organic matter amount (Crovetto, 1998).

One of the main indicators of soil quality is soil aggregation (Karlen, Stott, 1994). Soil aggregation and aggregate stability is closely related with the amount and quality of organic matter, microbiological activity, water infiltration (Pierson et al., 1994) and resistance to soil erosion (Blackburn, Pierson, 1994). Some trials showed that reduced tillage, incorporation of plant residue and green manure of catch crops causes significant changes in these soil properties (Karlen, Stott, 1994; Franco-Vizicano, 1997; Staben et al., 1997; Kairytė, 2005).

Research evidence obtained in Lithuania and other countries indicates that soil aggregation highly depends on tillage intensity (Feiza et al., 2008; Feiza et al., 2010). Soil tillage mechanically destroys and reduces the amount of water stable soil aggregates (>0.25 mm), changes soil climate conditions (temperature, moisture, aeration) and enhances organic matter decomposition (Six et al., 1999; Balesdent et al., 2000).

Reduced tillage and no-tillage increases the amount of water stable aggregates and organic matter, while ploughing changes natural soil features and enhances organic matter decomposition (Balesdent et al., 2000). Therefore it was found that increased amount of organic C in reduced tillage systems enhances formation of water stable aggregates (Campbell et al., 1993).

Reduced tillage systems provide more favourable conditions for earthworms because of higher amount of residue remaining in upper soil layer. The earthworms improve decomposition of straw, green manure and other plant residue and nu-trient balance in the soil, by taking part of the residue in their burrows (Mackay, Kladivko, 1985). Some authors found that straw had no influence on soil bulk density and porosity (Børresen, 1999). While others stated that annual use of straw increased soil porosity and it is highly related to earthworm activity (Ehlers, 1975).

The aim of the research was to evaluate and compare the influence of no-tillage, reduced tillage, straw and green manure management on soil bulk density, penetration resistance, soil stability of soil aggregates, and quantity of earthworms.

Materials and methods

Site and soil of the experiment. A long-term field experiment was carried out at the experimental station of the Lithuanian University of Agriculture at 54º52′50 N latitude and 23º49′41 E longitude over the period 2000–2004. The climate is humid, with mean annual precipitation of 627.8 mm and average temperature of 6.6ºC. The soil of the trial site was as an *Calc(ar)i-Endohypogleyic Luvisol* (*LVg-n-w-cc*), clay loam on sandy light loam (according to World reference base for soil resources, 2006). Chemical properties of the soil were investigated at the beginning of the experiment. The soil pH_{KCl} was 7.6 (measured with a potentiometer), humus content was 28.6 g kg^{-1} (Heraeus), K_2O was 134 mg kg^{-1}, and P_2O_5 was 266 mg kg^{-1} (A-L – Egner-Riehm-Domingo).

Characteristics of the trial. Two factors were tested. The straw (Factor A) was removed (R) from one part of the experimental field and at the other part it was chopped and spread (S) at harvesting. As a sub-plot factor, 6 different tillage systems (Factor B) were investigated:

CP – conventional deep ploughing (control, 23–25 cm) in autumn,

SP – shallow ploughing (10–12 cm) in autumn,

SL – shallow loosening with a chisel cultivator and disc harrows (8–10 cm) in autumn,

SR – shallow loosening with a rotary cultivator (5–6 cm) in spring,

GMR – green manure incorporation with a rotary cultivator (5–6 cm) in spring,

NT – no-tillage, direct drilling.

The stubble of the fourth and fifth treatment was incorporated only in spring before barley sowing. Red clover (*Trifolium pratence* L.) and timothy (*Phleum pratence* L.) mixture was undersown in GMR treatment. This catch crop emerged after barley harvesting and was incorporated as green manure next spring. No autumn or spring tillage was

performed in NT treatment. White mustard (*Sinapis alba* L.) for the green manure was undersown only in plots of this treatment with chopped straw after barley harvesting. Seedbed preparation – harrowing in spring was performed in CP, SP and SL treatments. Only the stubble of CP was deeply ploughed later in autumn.

Spring barley (*Hordeum vulgare* L. cultivar 'Ula') was sown in the field each year starting with 1999, at rates ranging from 4.5 to 5.0 million seeds ha^{-1} and was continuously grown until 2004. Spring rape (*Brassica napus* L. var. *oleifera*, cultivar 'Heros' 10 kg ha^{-1} seeds) was sown in 2004. A no-till seeding drill was used in all plots. Barley was fertilized with complex fertilizer (50 kg N ha^{-1}, 50 kg P_2O_5 ha^{-1}, 50 kg K_2O ha^{-1}) and ammonium nitrate (30 kg N ha^{-1}) was added since 2001. Spring rape was fertilized with 400 kg ha^{-1} of complex fertilizer before sowing (N – 44 kg ha^{-1}, P_2O_5 – 52 kg ha^{-1} and K_2O ha^{-1} – 120 kg ha^{-1}) and 60 kg N ha^{-1} as ammonium nitrate was applied after emergence. Weeds and fungi in crops were controlled using appropriate herbicides and fungicides in all treatments. In addition, the stubble of treatment GMR in 2000 and that of treatments SR, GMR and NT in 2001–2002 were sprayed with Roundup (glyphosate) 4 l ha^{-1} before barley sowing, while in 2003 the herbicide was applied after barley sowing and after harvesting.

The trials were replicated four times. The treatments were arranged using a split-plot design. The total size of each plot was 102 m^2 (6 × 17) and net size was 34.5 m^2 (2.3 × 15).

Measurements and analyses. Soil bulk density was investigated according to cylinder method one week after barley sowing. 'Undisturbed' soil cores were obtained in 200 cm^3 cylinders with a Nekrasov soil borer at two locations within each plot from 3–13 cm and 15–25 cm depths with a double-cylinder coring device. Samples were oven-dried at a temperature of 105°C (Vadiunina, Korchagina, 1983).

Soil penetration resistance was determined in the fifth experimental year (in 2004) with a manually operated recording electronic penetrometer. Penetrations were made at 5 randomly selected locations per plot. The penetrometer was preset to measure and record at 1.5 cm increments to a maximum depth of 30 cm.

Soil aggregation and stability was investigated at barley second node stage (GS 32, Zadoks et al., 1974). Samples were taken from 0–15 cm and 15–25 cm soil layers. Air-dry soil samples were shaken through the nest of sieves having rectangular holes with equivalent diameter of 10, 7, 5, 3, 2,

1, 0.5 and 0.25 mm and a pan underneath. The aggregate fraction retained on each sieve and pan was weighed and expressed as a percentage of total soil mass. Results were expressed as percent aggregate size distribution. Water stable aggregates were determined by shaking soil samples through a nest of 5, 3, 2, 1, 0.5 and 0.25 mm sieves in water according to method of Savinov (Vadiunina, Korchagina, 1983).

The number and biomass of earthworms was investigated after barley harvesting by the method of chemical repellents (with 0.55% formalin solution) within 0.25 m^2 metallic frames. The frames were hammered in three places of each plot and filled with solution. After solution had infiltrated into the soil, all earthworms from top layer were collected, weighed and expressed in number and grams per square meter (Carter, 1983).

Experimental data was evaluated using analysis of variance ($P < 0.05$) based on two-factorial split-plot design model (*Systat 10* statistical package, procedure GLM). Comparisons of means vs. control were undertaken with Fisher LSD test. No factorial interaction was found, therefore we presented the results as average for each factor.

Results and discussion

Soil bulk density. Soil moisture and temperature regime, biological activity, seed germination, growth and distribution of plant roots and therefore crop yield highly depends on soil bulk density. Many trials showed the increase of bulk density and compaction on conventionally ploughed soils with intensive traffic, which occurs due to many tillage operations (Wiermann, Horn, 2000; Lampurlanes, Cantero-Martinez, 2003).

The results of our field experiment showed that incorporation of chopped straw had no significant influence on bulk density in upper 3–13 cm and lower 15–25 cm soil layers (Fig. 1). Bulk density in upper soil layer totalled 1.25–1.49 Mg m^{-3} in the plots without straw and 1.29–1.47 Mg m^{-3} in the plots with straw. These results confirmed the conclusion of Børresen (1999), who stated that there is no significant effect of straw on bulk density even after 8 years of straw incorporation.

In the first year of the experiment, when conventional deep ploughing was replaced by SR, GMR and NT, bulk density significantly (10–11%) increased in upper soil layer. Meanwhile, there were no significant differences in lower 15–25 cm soil layer. Some other authors also found that reduced tillage and especially no-tillage increases soil density of upper soil layer (Tebrügge, Düring, 1999).
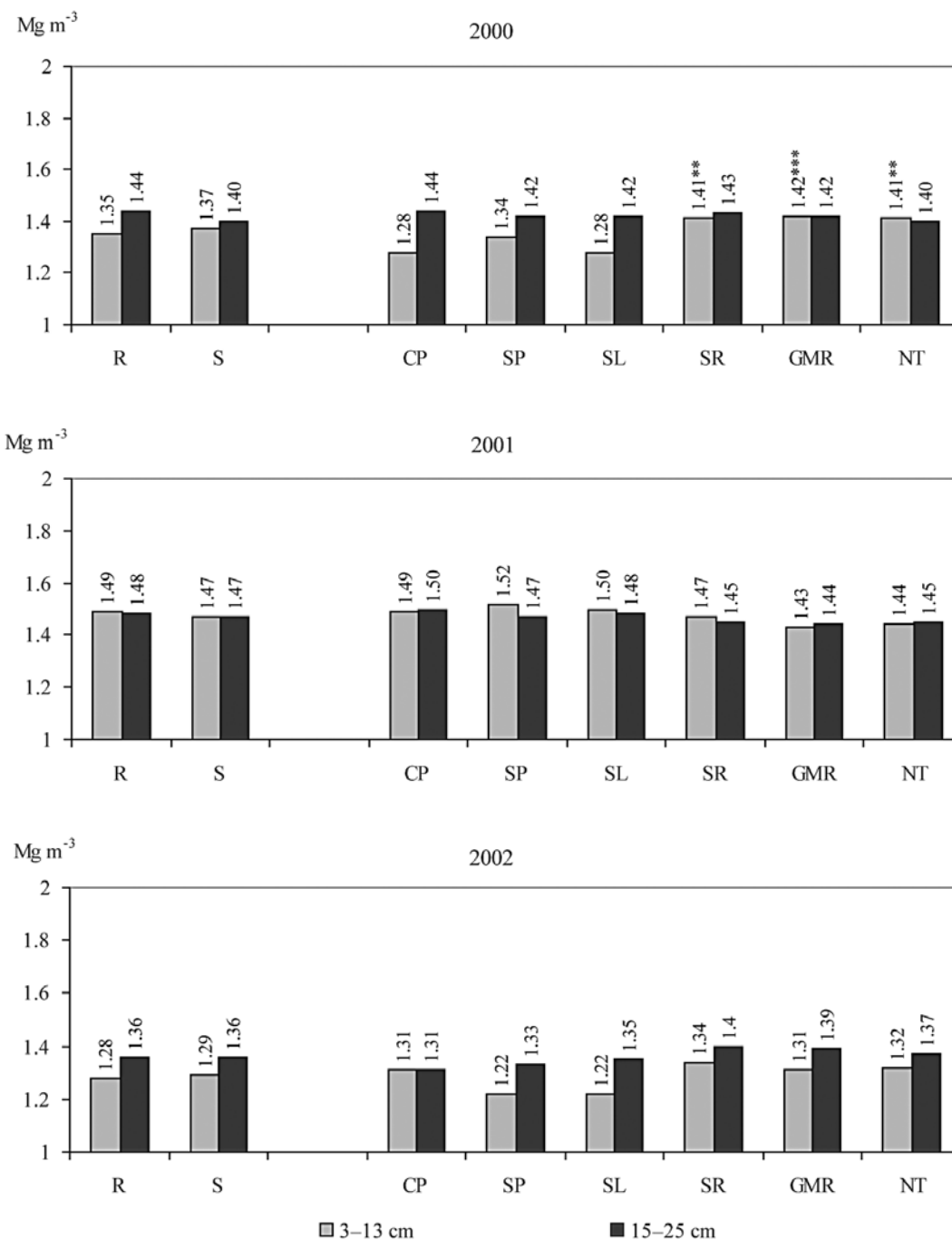
Notes. Significant differences at [*] $P \leq 0.05 > 0.01$, [**] $P \leq 0.01 > 0.001$, [***] $P \leq 0.001$; Fisher LSD test vs. control. R – straw removed, S – straw chopped and spread, CP – conventional deep ploughing, SP – shallow ploughing, SL – shallow loosening with a chisel cultivator and disc harrows, SR – shallow rotary cultivation, GMR – shallow green manure incorporation with a rotary cultivator, NT – no-tillage, direct drilling.

Figure 1. The effect of tillage systems, straw and green manure management on soil bulk density at the 3–13 cm and 15–25 cm depth in 2000–2002

In the second year of the experiment, higher bulk density was observed both in R and S treatments and in all tillage systems, compared to the first year. The bulk density of upper soil layer in R plots increased by 10% (from 1.35 to 1.49 Mg m^{-3}) in S by 7% (from 1.37 to 1.47 Mg m^{-3}), in CP, SP and SL by 13–17%, while in SR, GMR and NT bulk density was only 1–4% higher, than in the first year. Inconsiderably higher bulk density was also found in lower soil layer: in R – 3%, S – 3% and in tillage systems it ranged between 1–4%. In fact, soil bulk density in separate years was more dependent on pressure

of no-till seed drill used in the trial. This shows that the more soil is loosened, the more it is compacted in pre-sowing tillage process and sowing. Some authors indicate that after ploughing is withdrawn bulk density increases in lower soil layer. Therefore 30–35 cm soil layer is less dense than in deep ploughing, because when upper soil layer is lighter, deeper layers are more compacted (Ehlers, 1996).

Reduced tillage systems and straw incorporation had no significant influence on bulk density in the third year of experiment and it was found lower, compared to the second year. Similar results, showing that reduced tillage causes no changes in soil bulk density were reported by other researchers (Logsdon et al., 1999; Šimanskaitė, 2000; Jodaugienė et al., 2005).

Penetration resistance. Our research showed that straw incorporation had no significant influence on soil penetration resistance (Fig. 2). The highest changes in soil penetration resistance were found at 1.5–9.0 cm depth: penetration resistance increased from 223 to1115 kPa (5 times) in R and from 208 to 1053 kPa (also 5 times) in S. Therefore at 9.0–22.5 cm depth soil penetration resistance changed inconsiderably: from 1115 to 1175 kPa in R plots (increased 5%), and form 1053 to 1211 kPa (increased 15%) in S. Higher increase of soil penetration resistance was also found from 22.5 cm depth. Soil penetration resistance in 22.5–30.0 cm soil layer increased: from 1176 to 1615 kPa in R plots (increased 37%), and from 1211 to 1544 kPa (increased 28%) in S plots. However, no effect of straw was found in this soil layer, because the deepest tillage treatment CP reached only 23–25 cm depth. According to Singh and Malhi (2006), straw in untilled soil significantly reduces penetration resistance at 0–10 cm depth, but does not result in any significant differences in cultivated soil.
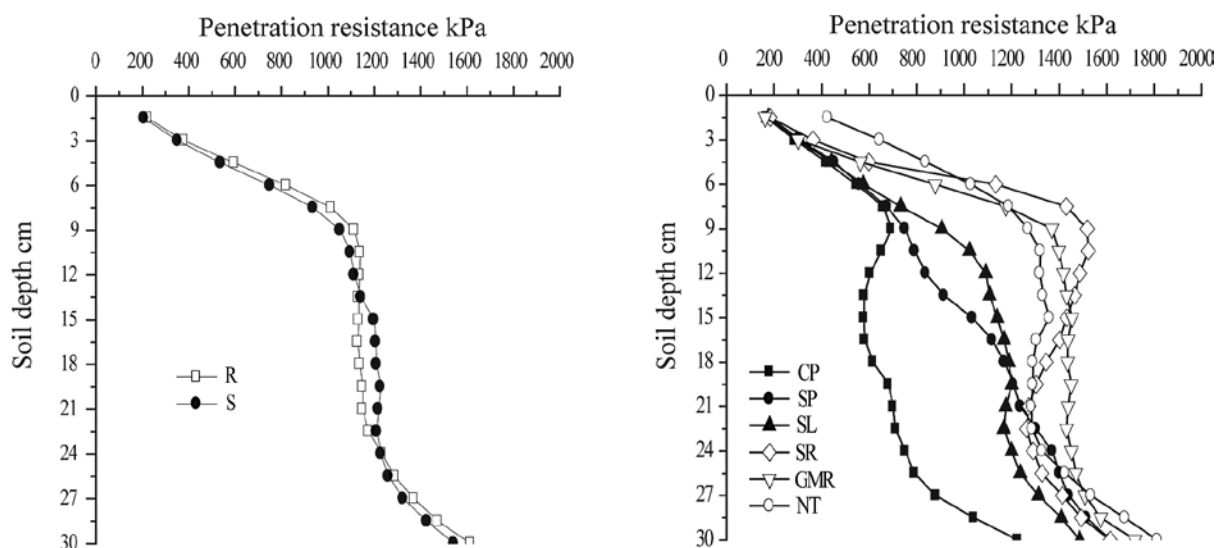
Note. R – straw removed, S – straw chopped and spread, CP – conventional deep ploughing, SP – shallow ploughing, SL – shallow loosening with a chisel cultivator and disc harrows, SR – shallow rotary cultivation, GMR – shallow green manure incorporation with a rotary cultivator, NT – no-tillage, direct drilling.

Figure 2. The effect of tillage systems, straw and green manure management on soil penetration resistance after sowing in 2004

Soil tillage systems affected soil penetration resistance more than straw incorporation. There were no significant differences at tillage depth in all investigated tillage systems. Soil penetration resistance, compared with conventional deep plowing, significantly increased in lower than tillage depth soil layers, respectively: in SP – from 12 cm, in SL – from 9 cm, in SR and GMR from 6 cm depth. Therefore in NT penetration resistance was significantly higher from the topsoil to 30 cm depth ($P < 0.001$).

Hardened and dense soil is more passable and more resistant to compaction, however it becomes hard for tillage operations and plant root growth is more inhibited, than in loose soil. Increased penetration resistance at 0–15 cm depth of no-tilled soil may reduce root elongation (Dexter et al., 1988). Ehlers et al. (1983) reported root limitation of oat at 3.6 MPa in a tilled Ap horizon, but 4.6–5.1 MPa in untilled soil on a Gray Brown Podzol. They attributed differences to development of a continuous pore system in untilled soil, created by earthworms and

roots from preceding crops. These biopores of low strength soil can act as pathways and space for root growth as well as for water movement. Munkholm et al. (2008) state that critical strength for plants is 1.5–2.0 MPa.

Our research evidence suggests that soil penetration resistance at 0–27 cm depth under reduced tillage systems totalled 1509 kPa, in NT – 1534 kPa and considerable increase was found only at 28.0–30.0 cm depth, but still did not reach critical soil strength. We can state that despite significantly increased soil strength in SP, SL, SR, GMR and NT, root restriction did not occur.

Earthworms. Quantity of earthworms in soil depends on many factors. Some authors indicated that the number of earthworms in the soil depends mostly on the amount, quality and incorporation depth of plant residue, soil moisture content (Edwards, Shipitalo, 1998; Trojan, Linden, 1998) and tillage intensity (Marinissen, Hillenaar, 1997; Bardgett, Cook, 1998, Jodaugienė, 2002).

Our research showed that straw had no significant influence on the amount of earthworms (Fig. 3). The number of earthworms in R plots to-

talled 111 and in S 102 individuals m⁻² after barley harvesting in 2003 and respectively 147 in R and 148 worms m⁻² in S plots after sprig rape harvesting in 2004. Meanwhile tillage systems significantly changed the density of earthworms in the soil. The summer of 2003 was comparatively dry, thus the number of earthworms was observed after primary tillage (CP, SP, SL) in autumn. The obtained data showed that number of earthworms both in mouldboard tillage (in CP – 2, in SP – 4 individuals m⁻²) and in non-inversion tillage (in SL – 11 worms m⁻²) treatments was comparatively low. Therefore in soil without autumn tillage the density of earthworms was significantly higher: in SR – 202, in GMR – 208, and in NT – 218 worms m⁻². Higher precipitation in the summer of 2004 gave a possibility to investigate the quantity of earthworm shortly after spring rape harvesting before primary autumn tillage. Also the number of earthworms was significantly higher, the differences between tillage systems remained similar to those in 2003. SR, GMR and NT increased the number of earthworms abundantly (51%, 15% and 70% respectively) compared with CP.
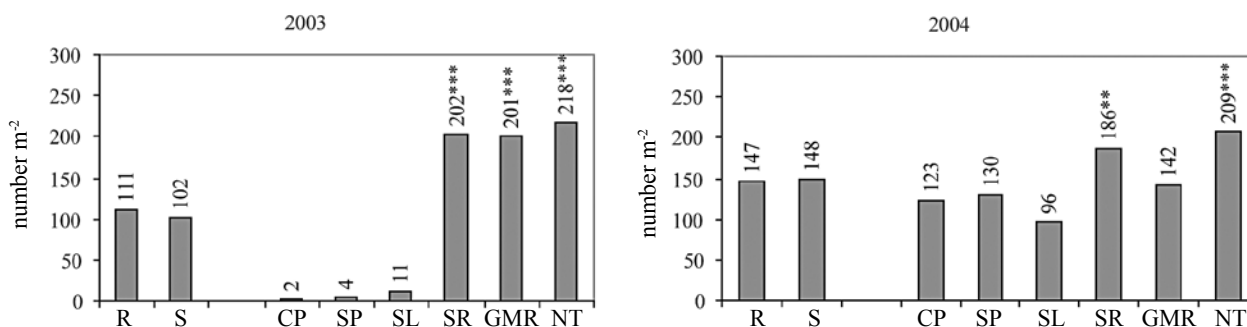
Notes. Significant differences at * $P \leq 0.05 > 0.01$, ** $P \leq 0.01 > 0.001$, *** $P \leq 0.001$; Fisher LSD test vs. control. R – straw removed, S – straw chopped and spread, CP – conventional deep ploughing, SP – shallow ploughing, SL – shallow loosening with a chisel cultivator and disc harrows, SR – shallow rotary cultivation, GMR – shallow green manure incorporation with a rotary cultivator, NT – no-tillage, direct drilling.

***Figure 3.*** The effect of tillage systems, straw and green manure management on the number of earthworms

Straw and plant residue incorporation had no significant influence on earthworm biomass (Fig. 4). The biomass of earthworms in 2003 totalled 70 g m⁻² in R and 74 g m⁻² in S, and in 2004 it was 92 g m⁻² in R and 96 g m⁻² in S. The biomass of earthworms highly depended on tillage systems. No significant differences of the earthworm biomass were found in SP and SL compared with CP. Therefore under SR, GMR and NT the biomass changed significantly. In one square meter of soil in

2003 it totalled 132 g in SR, 150 g in GMR, 141 g in NT, and in 2004 it was 149 g in SR plots, 122 g in GMR and even 177 g in NT. One of the reasons is increased earthworm population as lower intensity tillage determined more favourable conditions for their activity.

Similar results have been obtained by other researchers. Joschko and Höflich (1996) stated that earthworm biomass increases in reduced and no-tillage. Some authors also found changes in diver-

sity of earthworm population – a higher number of deep burrowing earthworms *Lumbricus terrestris*. Others found that the biopores made by earthworms improve air balance (Potthoff, 1999), water infiltration and herewith create favourable conditions for deeper penetration of plant roots in hardened soil (Ehlers et al., 1983). This could explain our results, because bulk density did not significantly change under different tillage systems, but soil penetration

resistance was found significantly higher in SP, SL, SR, GMR and NT, than in CP. These tillage systems increases cohesion of soil particles and therefore soil strength. However, when the number of earthworms and their burrows – biopores is large, bulk density does not increase. Earthworm excreta stabilize soil aggregation and so middle size pores are protected from mechanic soil load and hardening (Edwards, Shipitalo, 1998).
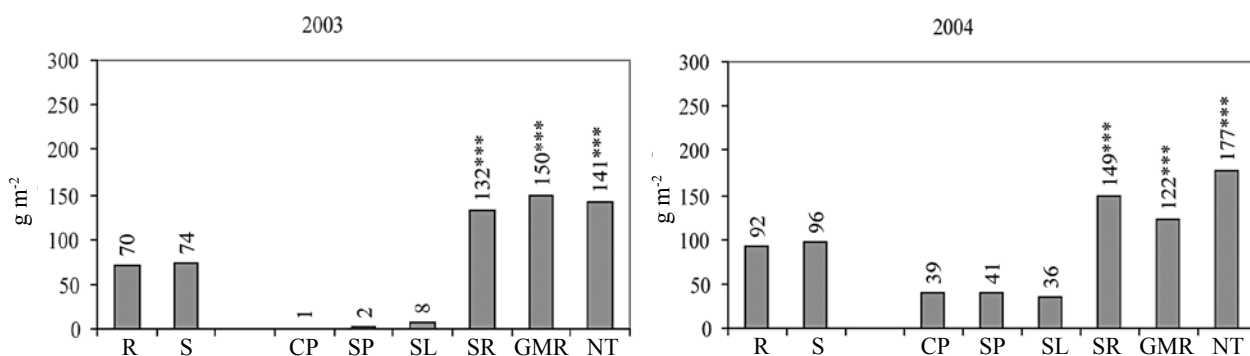
Notes. Significant differences at * $P \leq 0.05 > 0.01$, ** $P \leq 0.01 > 0.001$, *** $P \leq 0.001$; Fisher LSD test vs. control. R – straw removed, S – straw chopped and spread, CP – conventional deep ploughing, SP – shallow ploughing, SL – shallow loosening with a chisel cultivator and disc harrows, SR – shallow rotary cultivation, GMR – shallow green manure incorporation with a rotary cultivator, NT – no-tillage, direct drilling.

Figure 4. The effect of tillage systems, straw and green manure management on biomass of earthworms

Aggregate size distribution and structure stability. Data showed, that retention of straw significantly (7–23%) reduced the amount of the smallest <0.25 mm aggregates in upper (0–15 cm) soil layer and lower (15–25 cm) soil layer (6–26%) (Fig. 5). However, there were no significant changes in 0.25–10 mm and >10 mm size aggregate fraction.

Tillage systems had different impact on aggregate size distribution. In upper layer <0.25 mm aggregates tended to decrease in all three experimental years. Significantly lower amount of these aggregates in 2001 was found in SR (28%), GMR (37%) and NT (28%). In lower soil layer significantly less of <0.25 mm aggregates were found in 2002: in SR (54%), GMR (54%) and NT (48%), while in 2003 significant reduction of these aggregates was found only in NT (22%).

The amount of 0.25–10 mm aggregates did not depend on straw management. Tillage systems caused slight changes in this aggregate fraction. Significantly higher (8%) amount of this aggregate fraction was obtained only in NT in 2001. The 0.25–10 mm aggregates tended to increase in lower soil layer in the second and third year.

Straw management and tillage systems had no significant influence on the amount of >10 mm aggregates both in upper and lower soil layers.

Tillage systems and straw had higher influence on water stable aggregates. Straw incorporation significantly decreased aggregate stability (Fig. 6). Significant difference was found in 2001 in upper layer. Reduced intensity of soil tillage changed stability of soil aggregates both in upper and lower soil layers. In the first year of experiment, significantly higher stability of soil aggregates was found in SL (6.0 percent units), SR (5.0 percent units), GMR (7.6 percent units), NT (8.6 percent units). No significant differences in soil aggregate stability were found in lower soil layer. But the effect of tillage was found in later years of the experiment. The following year, significant differences were observed not only in upper, but also in lower soil layer. Significantly higher soil aggregate stability in upper soil layer was found in SR (5.9 percent units), GMR (8.7 percent units), NT (6.5 percent units), and in lower layer – in SR (5.8 percent units), GMR (1.2 percent units), NT (3.5 percent units).
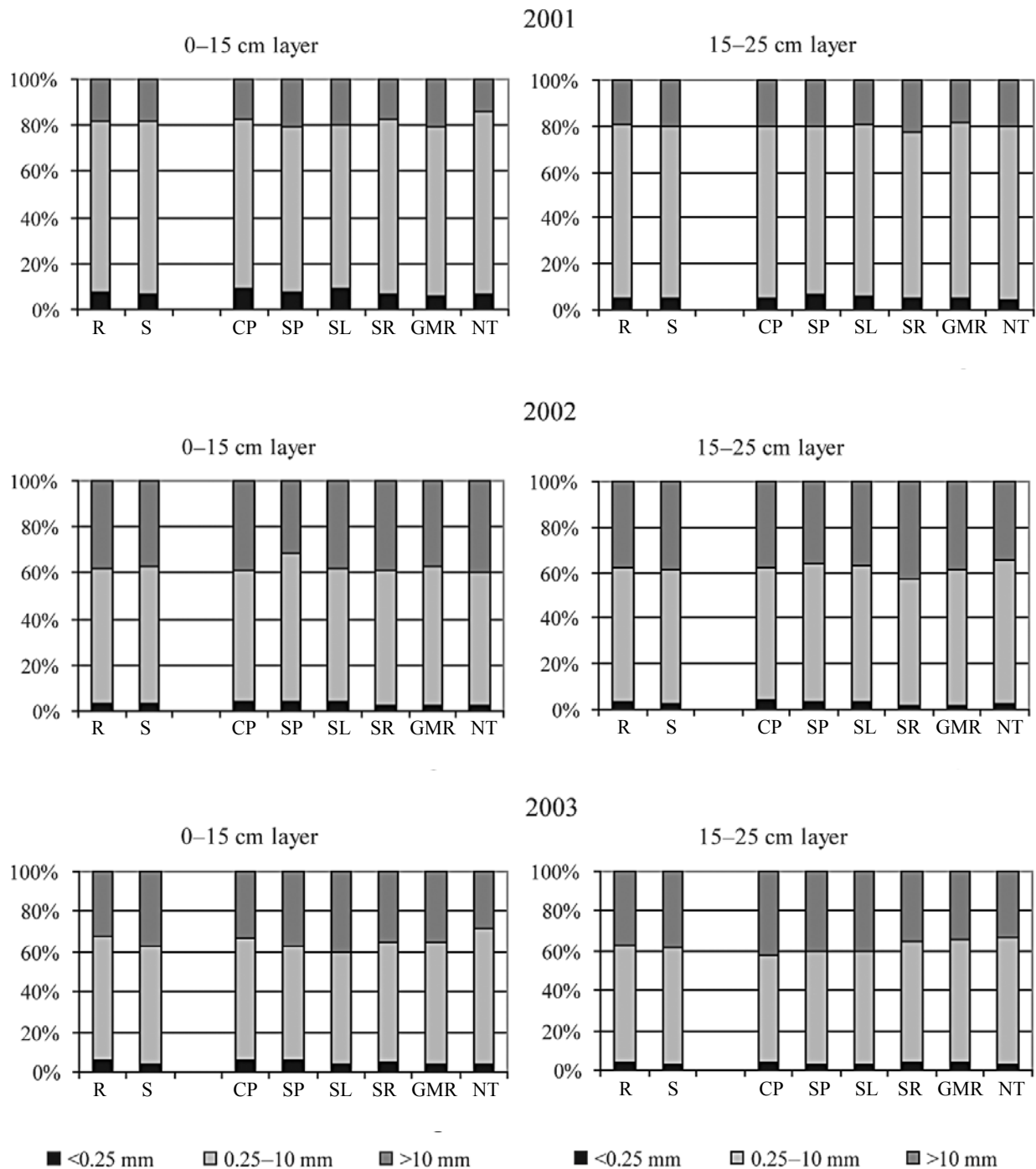
Note. R – straw removed, S – straw chopped and spread, CP – conventional deep ploughing, SP – shallow ploughing, SL – shallow loosening with a chisel cultivator and disc harrows, SR – shallow rotary cultivation, GMR – shallow green manure incorporation with a rotary cultivator, NT – no-tillage, direct drilling.

Figure 5. The effect of tillage systems, straw and green manure management on soil aggregate size distribution

Higher influence of reduced tillage systems was found in the third year of investigation. The lowest amount of stable aggregation formed in upper soil layer of mouldboard ploughed plots (CP and SP). Reduction of soil tillage intensity increased stability of soil aggregates, both in upper and lower soil layers. Significantly higher amount of stable aggregates was found in upper layer of SL (6.9 percent units), SR (11.5 percent units), GMR (14 percent units), NT (14.3 percent units). Therefore in lower soil layer it was higher not only in SL (6.5 percent units), SR (8.4 percent units), GMR (8.7 percent units) and NT (8.1 percent units), but also SP (4 percent units), while this layer was not

disturbed. The increase of soil structure stability could be caused by accumulation of organic matter in upper soil layer and the increased number and biomass of earthworms. Similar results indicating that reduced tillage increased stability of soil aggregates were earlier reported by Jodaugienė (2002), Jodaugienė et al. (2005).
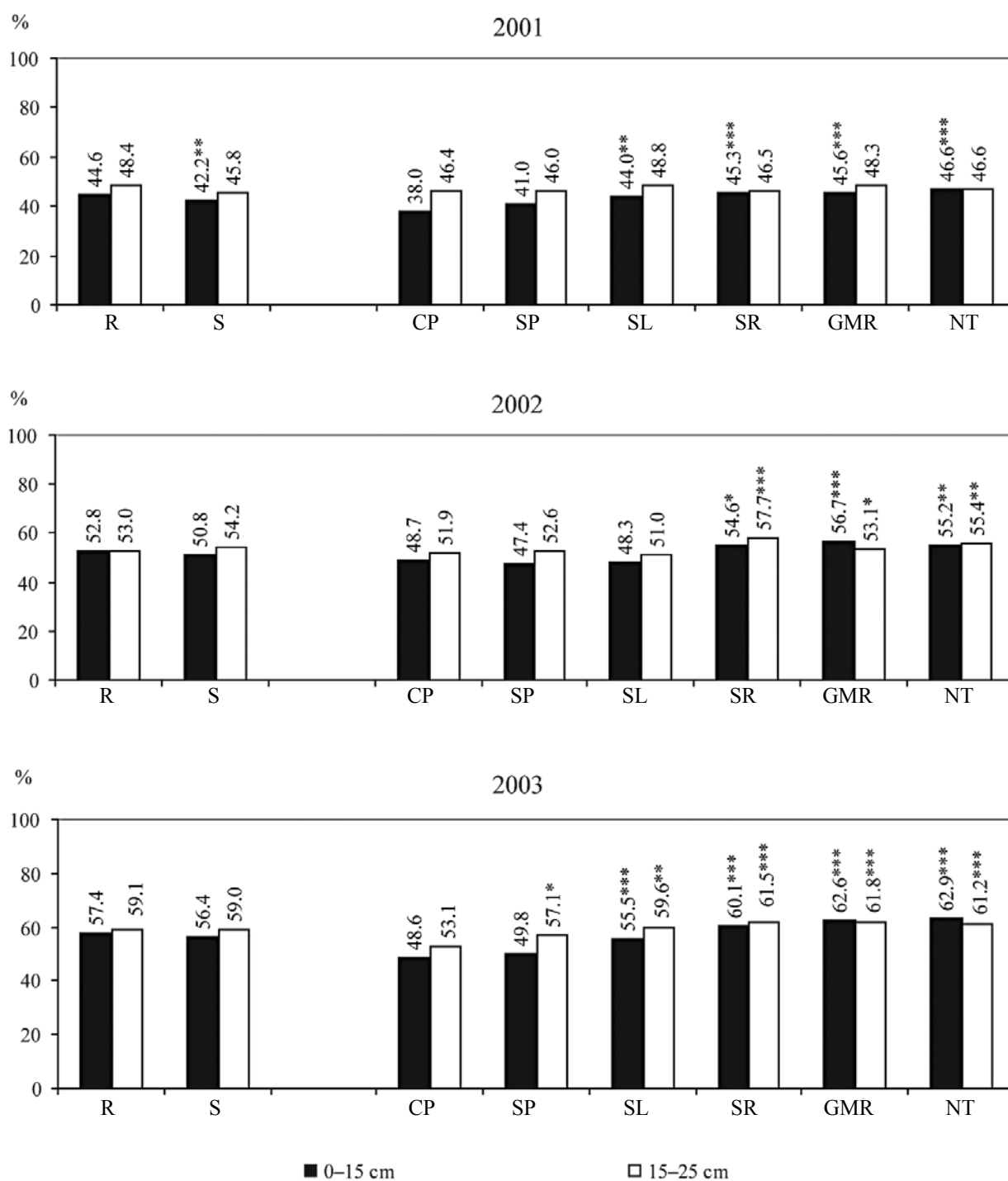
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Figure 6. The effect of tillage systems, straw and green manure management on water stable aggregates

Conclusions

1. Straw incorporation had no significant effect on bulk density, penetration resistance and the number and biomass of earthworms, but significantly reduced the amount of the smallest <0.25mm aggregates.

2. No significant differences in bulk density vs. CP were obtained in reduced autumn tillage SP, and SL, while in reduced spring tillage systems SR, GMR and NT significant changes were observed only in the first year of the experiment at 3–13 cm depth. Soil penetration resistance increased in undisturbed soil layers. In SP, it increased from 12 cm depth, in SL from 9 cm depth and in SR and GMR from 6 cm depth, while in NT it became higher from the very soil surface.

3. The SR, GMR and NT soil tillage treatments increased the number and biomass of earthworms and decreased the amount of the smallest <0.25 mm soil aggregates. Significant differences in soil aggregate size distribution and stability were found already in the first year. Non-inversion tillage increased water stable aggregates in the whole plough layer.

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Žemės dirbimo sistemų įtaka dirvožemio fizikinėms savybėms ir sliekų kiekiui panaudojus šiaudus bei žaliąją trąšą

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Santrauka

Taikant tradicinę žemės dirbimo sistemą reikia didelių energijos ir darbo sąnaudų, prastėja dirvožemio savybės. Tyrimų tikslas – nustatyti įvairių žemės dirbimo sistemų: gilaus tradicinio arimo (CP) 23–25 cm gyliu, seklaus arimo (SP) 10–12 cm gyliu, seklaus purenimo su sunkiuoju kultivatoriumi ir diskinėmis akėčiomis (SL) 8–10 cm gyliu, seklaus purenimo rotoriniu kultivatoriumi (SR) 5–6 cm gyliu, seklaus žaliosios trąšos įterpimo rotoriniu kultivatoriumi (GMR) 5–6 cm gyliu ir tiesioginės sėjos (NT) į neįdirbtą dirvą, poveikį dirvožemio tankiui, kietumui, struktūrai ir jos patvarumui bei sliekų kiekiui. Tyrimai vykdyti dviejuose fonuose: šiaudai pašalinti (N) arba susmulkinti ir paskleisti (S) derliaus nuėmimo metu. Stacionarus dviejų veiksnių lauko bandymas įrengtas Lietuvos žemės ūkio universiteto bandymų stotyje. Bandymų vietos dirvožemis – karbonatingas giliau glėjiškas išplautžemis (IDg4-k), *Calc(ar)i-Endohypogleyic Luvisol* (*LVg-n-w-cc*), vidutinio sunkumo priemolis ant smėlingo lengvo priemolio. Dirvožemis silpnai šarminis, pH – 7,6, humuso kiekis vidutinis – 2,86 %, vidutinio kalingumo – 134 mg kg^{-1} ir didelio fosforingumo – 266 mg kg^{-1}. Šiaudų įterpimas neturėjo esminės įtakos dirvožemio tankiui, kietumui, sliekų kiekiui ir jų biomasei, tačiau esmingai mažino dirvožemio smulkiųjų (<0,25 mm) trupinėlių kiekį ir struktūros patvarumą. Gilų arimą pakeitus supaprastintu rudeniniu žemės dirbimu (SP, SL), dirvožemio tankio esminių skirtumų nenustatyta, o pakeitus SR, GMR ir NT esminiai skirtumai nustatyti tik pirmaisiais tyrimų metais armens viršutiniame 3–13 cm sluoksnyje. Supaprastinus žemės dirbimą, dirvožemio kietumas esmingai padidėjo nejudintuose dirvos sluoksniuose (SP – nuo 120 mm gylio, SL – nuo 90 mm, SR ir GMR – nuo 60 mm), o NT – nuo pat dirvos paviršiaus. SR, GMR ir NT esmingai didino sliekų kiekį bei jų biomasę ir mažino dirvožemio smulkiųjų (<0,25 mm) trupinėlių kiekį. Į pakitusias dirvos sąlygas greičiausiai reagavo armens viršutinis sluoksnis. Šiame sluoksnyje esminiai struktūros patvarumo skirtumai nustatyti jau pirmaisiais tyrimų metais (antraisiais po bandymo įrengimo). Nevartant armens, dirvos struktūros patvarumas didėjo per visą armenį. Viena iš priežasčių gali būti sliekų pagausėjimas, jiems palankesnių vystymosi sąlygų sudarymas ir kartu aktyvesnė jų veikla, atsisakius intensyvaus žemės dirbimo.

Reikšminiai žodžiai: dirvožemio tankis, dirvožemio kietumas, dirvožemio struktūra ir patvarumas, sliekai, žemės dirbimo sistemos, šiaudai.