ALEKSANDRAS STULGINSKIS UNIVERSITY

Sidona Buragienė

IMPACT OF DIFFERENT SOIL TILLAGE TECHNOLOGIES ON THE ENVIRONMENT

Summary of Doctoral Dissertation

Technological Sciences (T 000)
Environmental Engineering (04 T)

Akademija, 2013

The dissertation has been prepared in 2008–2013 in Aleksandras Stulginskis University

Scientific Supervisor:

Prof. dr. Egidijus ŠARAUSKIS (Aleksandras Stulginskis University, Technological Sciences, Environmental Engineering – 04 T)

Consultant:

Prof. dr. Kęstutis ROMANECKAS (Aleksandras Stulginskis University, Agricultural Sciences, Agronomy – 01 A)

Doc. dr. Antanas SAKALAUSKAS (Aleksandras Stulginskis University, Technological Sciences, Environmental Engineering – 04 T)

The dissertation will be defended at Aleksandras Stulginskis University's Environmental Engineering Science Board:

Chairman:

Prof. dr. habil. Algirdas RAILA (Aleksandras Stulginskis University, Technological Sciences, Environmental Engineering – 04 T)

Members:

Prof. dr. Gintaras DENAFAS (Kaunas University of Technology, Technological Sciences, Environmental Engineering – 04 T)

Assoc. prof. dr. Aušra MARCINKEVIČIENĖ (Aleksandras Stulginskis University, Agricultural Sciences, Agronomy – 01 A)

Prof. dr. Juozas PADGURSKAS (Aleksandras Stulginskis University, Technological Sciences, Environmental Engineering – 04 T)

Prof. dr. Valentinas ŠAULYS (Vilnius Gediminas Technical University, Technological Sciences, Environmental Engineering – 04 T)

Opponents:

Prof. dr. Dainius STEPONAVIČIUS (Aleksandras Stulginskis University, Technological Sciences, Environmental Engineering – 04 T)

Prof. habil. dr. Vida STRAVINSKIENĖ (Vytautas Magnus University, Biomedical Sciences, Ecology and Environment – 03 B)

The official defence of the diseertation will be held at the open meeting of the doctoral council at 2 p.m on December 13, 2013 in the 211 room, IV building of the Aleksandras Stulginskis University.
Adress: Aleksandras Stulginskis University,
Universiteto str. 8 A, Akademija,
LT – 53361, Kauno distr. Lithuania

Summary of doctoral dissertation was distributed on November 13, 2013.
The doctoral dissertation is available in the libraries of the Aleksandras Stulginskis University (Studentų str. 11, Akademija, LT–53361 Kauno distr.), Kaunas University of Technology (K. Donelaičio str. 20, LT–44239 Kaunas) and Lithuanian Energy Institute (Breslaujos str. 3, LT–44403 Kaunas).

ALEKSANDRO STULGINSKIO UNIVERSITETAS

Sidona Buragienė

SKIRTINGŲ ŽEMĖS DIRBIMO TECHNOLOGIJŲ POVEIKIS APLINKAI

Daktaro disertacijos santrauka

Technologijos mokslai (T 000)
Aplinkos inžinerija (04 T)

Akademija, 2013

Disertacija rengta 2008–2013 metais Aleksandro Stulginskio universitete.

Mokslinis vadovas:

Prof. dr. Egidijus ŠARAUSKIS (Aleksandro Stulginskio universitetas, technologijos mokslai, aplinkos inžinerija – 04 T)

Konsultantai:

Prof. dr. Kęstutis ROMANECKAS (Aleksandro Stulginskio universitetas, žemės ūkio mokslai, agronomija – 01 A)

Doc. dr. Antanas SAKALAUSKAS (Aleksandro Stulginskio universitetas, technologijos mokslai, aplinkos inžinerija – 04 T)

Disertacija ginama Aleksandro Stulginskio universitete Aplinkos inžinerijos mokslo krypties taryboje.

Pirmininkas:

Prof. habil. dr. Algirdas RAILA (Aleksandro Stulginskio universitetas, technologijos mokslai, aplinkos inžinerija – 04 T)

Nariai:

Prof dr. Gintaras DENAFAS (Kauno technologijos universitetas, technologijos mokslai, aplinkos inžinerija – 04 T).

Doc. dr. Aušra MARCINKEVIČIENĖ (Aleksandro Stulginskio universitetas, žemės ūkio mokslai, agronomija 01 A)

Prof. dr. Juozas PADGURSKAS (Aleksandro Stulginskio universitetas, technologijos mokslai, aplinkos inžinerija – 04 T)

Prof. dr. Valentinas ŠAULYS (Vilniaus Gedimino technikos universitetas, technologijos mokslai, aplinkos inžinerija – 04 T)

Oponentai:

Prof. dr. Dainius STEPONAVIČIUS (Aleksandro Stulginskio universitetas, technologijos mokslai, aplinkos inžinerija – 04 T)

Prof. habil. dr. Vida STRAVINSKIENĖ (Vytauto Didžiojo universitetas, biomedicinos mokslai, ekologija ir aplinkotyra 03 B)

Disertacija bus ginama viešajame Aplinkos inžinerijos mokslo krypties tarybos posėdyje 2013 m. gruodžio 13 d., 14 val. Aleksandro Stulginskio universiteto IV rūmų posėdžių salėje (211 kab.).
Adresas: Aleksandro Stulginskio universitetas,
Universiteto g. 8 A, Akademijos mstl.,
53361 Kauno r., Lietuva

Daktaro disertacijos santrauka išsiuntinėta 2013 m. lapkričio 13 d.

Disertaciją galima peržiūrėti Aleksandro Stulginskio universiteto (Studentų g. 11, Akademijos mstl., 53361 Kauno r.), Kauno technologijos universiteto (K. Donelaičio g. 20, 44239 Kaunas) ir Lietuvos energetikos instituto (Breslaujos g. 3, 44403 Kaunas) bibliotekose.

INTRODUCTION

Relevance of subject. Soil tillage is one of the most important agrotechnological processes having huge influence on the sowing, germination, growing, yield and quality of cultivated plants. At the same time soil tillage is one of the most expensive and energy consuming agrotechnological processes of plant cultivation. The conventional tillage technologies using mouldboard and intensive cultivation machinery have both a positive impact on the preparation of the seedbed for plants and a negative impact as they are rather detrimental to the environment, soil, its properties, biodiversity, pollution of water bodies, etc. During the conventional soil tillage the crop residues of the last yield are incorporated into the deeper layers of the soil and the soil surface is not covered. Such soils are much susceptible to the environmental forces and are easier disturbed by wind and water erosion. Every year around 6 mio ha of fertile soil areas are lost due to inappropriate agricultural activities and changing environmental conditions. Another very important factor is that deep ploughing is an unproductive soil tillage method pertaining to huge time and energy consumption. At the same time multiplex driving of heavy weight agricultural machinery over the soil results in negative influence on its peoperties as well as consuming of huge amounts of diesel fuel results in high pollution of the environment with the greenhouse gas. Therefore, in order to reduce the negative influence of agricultural activities on soil degradation, biological diversity, humus decay, the leaching of organic and chemical nutrients, the activities of natural biological processes taking place in soil the environment and energy sustaining soil tillage technologies are becoming more popular all over the world. The main tasks of such technologies are limiting the intensive technological mechanical, chemical and biological impact on the soil, environment and plants, reducing the invasion into the natural natural biological processes present in soil, ensuring continual rejuvenation of soil productivity, sustaining biosphere and maintaining economically efficient and competitive agricultural production.

Though the area of sustainable soils inceases by 4–5 mio ha all over the word every year, the soil tillage technologies involved are far from being simple or easily implemented. The research of sustainable tillage technologies carried out in different countries shows different influence of the technologies on the physico-mechanical properties of soil and CO_2 emissions from soil to the environment. The research results achieved are very diverse and controversial and it is credible that the related application of sustainable tillage technologies could imply lower yields of crops and lower energy efficiency compared with conventional agricultural technologies. The issues of the influence of tillage technologies on the soils of different composition and the environment are insufficiently investigated and poorly substantiated on research, which does not stimulate the introduction of new sustainable soil tillage technologies both in Lithuania and in the entire Baltic Region.

Research hypothesis. Substitution of the deep ploughing technology with the technologies of shallow ploughing, deep or shallow cultivation or no-tillage allows the reduction of the negative impact on the environment, the decrease of labour and energy

costs while maintaining the main physico-mechanical properties of soil and good maize yield and energy activity.

Research objective – the analysis of the impact of tillage technologies of different intensity on the main physico-mechanical properties of soil, CO_2 emmissions from soil to the environment and the complex assessment of the technologies in terms of environmental protection, energy and economy.

Research tasks. To reach the objective of the research the following tasks have been planned:

1. Perform the analysis of the need for sustainable tillage technologies in terms of soil protection, environmental protection, energy and economical aspects, to analyse the impact of tillage on the main physico-mechanical properties of soil.
2. Investigate the influence of deep and shallow cultivation, deep and shallow ploughing and no-tillage on the hardness, density, moisture, temperature, porousness, structure and resistance to water of soil in different layers.
3. Investigate the influence of autumn and spring soil tillage influence on the variation of CO_2 emissions from soil. Establish the influence of various tillage technologies on CO_2 emissions from soil during maize vegetation.
4. Assess the technologies of deep and shallow ploughing, deep and shallow cultivation and no-tillage in terms of the environmental, energy and economical aspects and establish the energy efficiency of all mentioned technologies.

Propositions to be defended:

1. The application of sustainable soil tillage technologies (shallow ploughing, deep and shallow cultivation and no-tillage) while cultivating maize in *Endohypogleyic-Eutric Planosols – PLe-gln-w* soil under the Lithuanian climatic conditions retains the main physico-mechanical properties of the soil and ensures good maize yields as in applying the conventional tillage technology of deep ploughing.
2. The sustainable soil tillage technologies in cultivating maize in *Endohypogleyic-Eutric Planosols – PLe-gln-w* soil under the Lithuanian climatic conditions allow decreasing CO_2 emissions from the soil after autumn and spring soil tillage as well as during vegetation compared with the conventional tillage technology.
3. The application of sustainable soil tillage technologies for maize cultivation allows the reduction of fuel costs, labour time costs, costs for mechanized operations and CO_2 emissions into the envirionment from agricultural machinery compared with the conventional soil tillage.
4. The application of no-tillage and shallow ploughing (12–15 cm) technologies in maize cultivation in *Endohypogleyic-Eutric Planosols – PLe-gln-w* soil under the Lithuanian climatic conditions allow achieving higher energy efficiency compared with the conventional soil tillage.

Originality of research work. It was the first time that the soil tillage technologies of different intensity were investigated in a complex way in terms of environmental, energy and economical aspects; the impact of autumn and spring tillage on the main physico-

mechanical properties of *Endohypogleyic-Eutric Planosols – PLe-gln-w* soil and CO_2 emissions from the soil into the environment was established under the Lithuanian climatic conditions. The energy efficiency of various tillage technologies while cultivating maize was assessed.

Significance of Work. The sustainable soil tillage technologies, which do not include deep ploughing, allow the reduction of labour time and fuel costs and the decrease of agricultural production costs while retaining the main physico-mechanical properties of soil and good yield of maize. At the same time the sustainable soil tillage technologies reduce a negative impact on soil while reducing the emissions of CO_2 gas that cause the greenhouse effect both from soil and from agricultural machinery.

Approval of Dissertation Work. The topic of the dissertation has been announced in 10 publications of which in 2 journals refereed in *"ISI Web of Science"* data base of the Institute of Scientific Information with citation indexing, 2 publications announced in other journals refereed in *"ISI Web of Science"* data base of the Institute of Scientific Information, 2 – in reviewed scientific journals refereed in other international databases, 2 – in other reviewed scientific journals and 2 – in the journals not attributed to scientific edition groups. 2 verbal presentations on the dissertation topic were delivered at the international scientific conferences abroad: Engineering for Rural Development (Latvia, Jelgava, 2011 and 2012), and at the international scientific conferences in Lithuania: Agricultural and Environment – 2011, and Youth Seeks Progress – 2009.

Structure of Work. The dissertation work is written in the Lithuanian language. The work consists of: introduction, litereture review, research methods, research results and their analysis, conclusions and the list of 248 literature sources cited. The main material is arranged in 112 pages including 7 tables and 86 figures.

RESEARCH METHODS

Place and Time of Experimental Research. The experimental research took place in 2009–2012 at the Experimental Station of ASU in *Endohypogleyic-Eutric Planosols – PLe-gln-w* soil under the meteorological conditions of Middle Lithuania (Buivydaitė et al., 2001). The Experimental Station is located on the left bank of the Nemunas in Ringaudai Eldership, Kaunas District, to the south-western part of Kaunas City. The facilities of long-term experimental research (Manager, V. Bogužas) based at the Experimental Station were chosen for the research of the impact of soil tillage on the properties of soil and environment; the facilities had been used for different tillage research activities in accordance with a uniform and well-established system for more than 20 years.

Tilage variants and technological scheme. The research was carried out with four repetitions using five different tillage technologies:

- Deep ploughing at 23–25 cm depth (control) (abbreviation DP);
- Shallow ploughing at 12–15 cm depth (SP);
- Deep cultivation by cultivator at 25–27 cm depth (DC);

- Shallow cultivation by disc harrow at 12–15 cm depth (SC);
- No-tillage, i.e. direct sowing (NT).

The control, often called regular or conventional tillage technology, was selected to compare the influence of other 4 sustainable tillage technologies on the physico-mechanical properties of soil and CO_2 emissions into the environment. The experimental plots were arranged in the randomized order. The initial plot area was 126 m^2 (14×9 m), the record plot area – 84 m^2 (12×7 m). For the purpose of the experimental research maize with winter wheat as a preceding crop was chosen due to its good nutritive properties and an increasing need for bioenergy production. After the harvesting of winter wheat in all options except the NT one stubble cutting was performed by *Väderstad Carrier 300* stubble cultivator. The NT option was sprayed with herbicide *Roundup* 4 l ha^{-1}. Depending on the meteorological conditions autumn tillage operations were carried out according to the above described technologies at the end of September or in October. In spring before maize sowing shallow (6–8 cm) surface tillage was performed by the cultivator equipped with passive working parts in all technologies (DP, SP, DC, SC) except NT. Maize *Pioneer P8000(x027)* was sown at the beginning of May. The seed rate was 100 thou. u. ha^{-1} of fertile seeds. The row spacing was 45 cm. At sowing all maize plots were fertilized with NPK 16:16:16 fertilizer, rate 250 kg ha^{-1}. After the sowing herbicides *Maister* 150 g ha^{-1} and *Actirob* 2 l ha^{-1} were applied. At the end of June the maize was fertilized with ammonium nitrate (NH_4NO_3), rate 180 kg ha^{-1}. The maize biomass yield was harvested at the end of September or at the beginning of October (depending on meteorological conditions).

Ways and instruments to establish the main physico-mechanical properties of soil and CO_2 gas emissions. Soil hardness was measured by the electronic hardness meter by Eijkelkamp (PENETROLOGGER) down to the depth of 34 cm. The soil hardness was established before spring and autumn tillage and after it as well as every 15 days during the vegetation period of maize. The density and moisture of the soil were established by the method of weighing taking samples with Nekrasov drill from two soil layers: 0–10 cm and 10–20 cm. The density and moisture were also measured once a month during maize vegetation. To establish soil porousness samples were taken from each of the investigated technologies before autumn tillage and after it. The soil porousness was established by a vacuum air pycnometer. The soil structure and the resistance of its particles to water were established by using N. Savinov method in two layers of soil: 0–15 cm and 15–25 cm. The soil structure was established by the dry sieve method and the particle resistance to water – by the wet sieve method. The soil temperature and CO_2 gas emissions from the soil to the environment were measured by *PasPort* analyzer. The measurements were taken right after the autumn and spring soil tillage and during the vegetation of maize. CO_2 concentration in the soil was measured by *Honold G200–X* gas measurement device.

Assessment of soil tillage technologies in terms of energy, environment and economy. Energy and economy indicators were calculated according to the recommendations prepared by the Lithuanian Institute of Agrarian Economics for agricultural companies, farmers, enterprises and other organizations rendering services to

farmers and performing agricultural operations. The energy efficiency ratio *EE* for all maize cultivation technologies was calculated using the following formula:

$$EE = \frac{E_P Y}{E_T}, \quad (1)$$

where E_P – maize energy value, MJ kg^{-1};

Y – maize yield, kg ha^{-1};

E_T – all technology energy costs, MJ ha^{-1}.

All technology energy costs E_T are calculated using such formula :

$$E_T = E_F + E_{SFP} + \frac{E_H + E_{AM}}{FC}, \quad (2)$$

where E_F – fuel energy costs, MJ ha^{-1};

E_{SFP} – energy costs for seeds, fertilizer and pesticides, MJ ha^{-1};

E_H – labour energy costs, MJ h^{-1};

E_{AM} – agricultural machinery energy costs, MJ h^{-1};

FC – efficiency of agricultural machinery, ha h^{-1}.

The energy values of agricultural machinery, fuel, fertilizer, pesticide and other costs in MJ are chosen pursuant to the research works by other researchers.

The economic evaluation of maize cultivation technologies was carried out only for mechanized technological operations assessing the price of the used agricultural machinery and fuel, salaries for the employees and other costs related with mechanized operations.

While assessing different maize cultivation technologies in terms of environmental protection it was established how much fuel is required to perform individual mechanized operations and how much fuel is consumed to perform the entire technology. On the basis of the research resuls by other researchers, that consuming of 100 litres of diesel fuel causes the emissions of around 376 kg of CO_2 into the environment, all the analysed maize cultivation technologies were assessed.

Statistical data processing. To evaluate the reliability of the achieved results the research data was assessed by the dispersion analysis method, using Excel spreadsheet. Arithmetic means, their standard deviations and confidence intervals with probability 0,95. Substantive differences between the data of investigated options were established by calculating substantive difference margin $R_{0,05}$.

RESULTS

Soil hardness. The experimental research established that the autumn tillage in the upper soil layer (0–9 cm deep) significantly reduced soil hardness in DP, SP and DC technologies (Fig. 1). The influence of tillage on soil hardness in SC and NT technologies was smaller. The least soil hardness was recorded at the depth of 5–9 cm in DP soil – about 0.69 MPa after autumn tillage. The lowest influence of tillage on soil hardness was observed in SC technology.

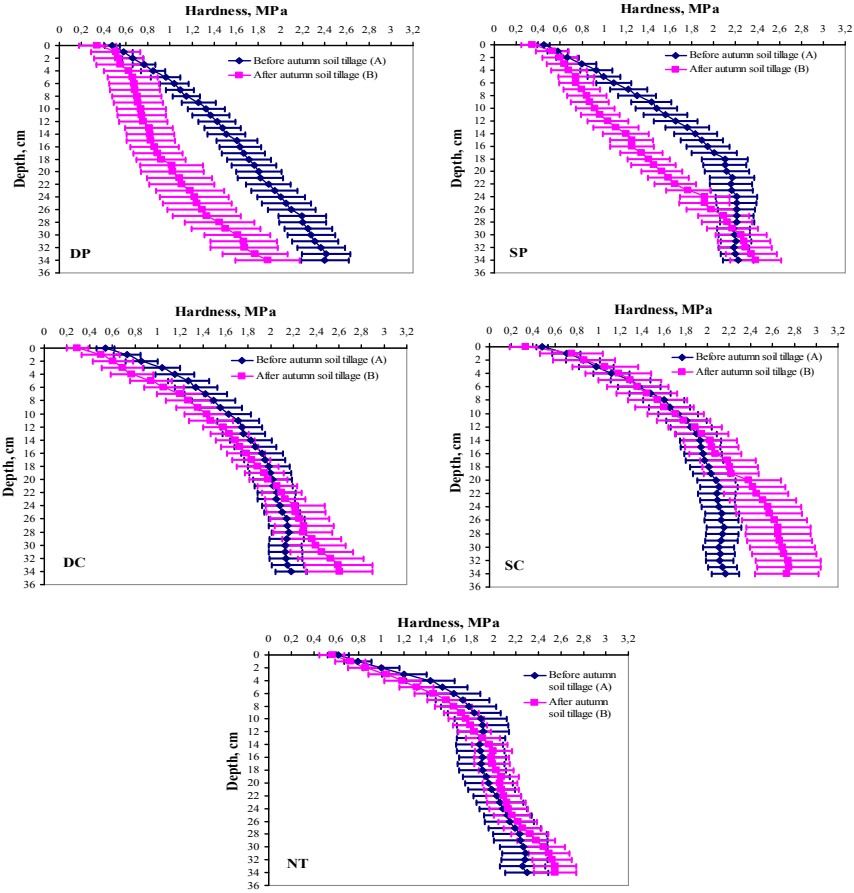


Fig. 1. Soil hardness before and after autumn soil tillage (2009–2011)

The autumn tillage significantly reduced soil hardness in the upper layer in DP and SP technologies which include intensive soil turning technological processes. The influence of the sustainable tillage technologies (DC, SC and NT) on the soil hardness in autumn was much lower compared with DP and SP. The spring tillage reduced soil hardness only in the upper layer of soil and deeper layers were even more compacted due to the physico-mechanical processes taking place in soil, namely, the weight of tillage machinery, vibration and other side factors were transferred. It was established that during the vegetation period soil hardness depends a lot on the environmental conditions. At high temperatures and low amount of precipitation soil becomes dry and very hard.

Soil density. The experimental research of three years established that the autumn tillage reduced the soil density in the upper layer (0–10 cm) in all three technologies (Fig. 2). After the autumn tillage the highest (1.48 g cm^{-3}) soil densinty was recorded in NT. The reduction of soil density in all other tillage technologies was significant. Both the conventional tillage technology and the sustainable ones (SP, DC and SC) reduced soil density due to the impact of the working parts of the tillage machinery on the soil. The sustainable tillage technologies (SP, DC and SC) reduced the soil density to the value favourable to plants (1.39 g cm^{-3}).

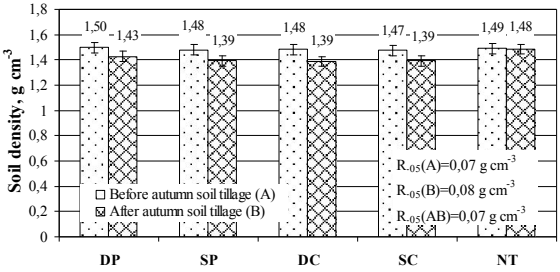


Fig. 2. Soil density before and after autumn tillage in upper 0–10 cm layer of soil (2010–2012)

Autumn tillage reduced the soil density in a deeper layer (10–20 cm) in all tillage technologies except SC (Fig. 3). Significant differences after autumn tillage were established in DP and SP technologies, which included intensive turning of the soil by ploughing. The assessment of the soil density after tillage in individual technologies gave no significant differences. In NT option the same tendencies remained in the deeper layer as in the upper one.

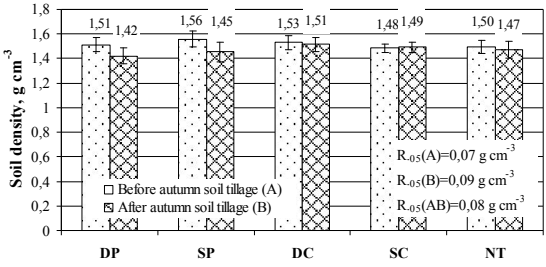


Fig. 3. Soil density before and after autumn tillage in 10–20 cm layer (2010–2012)

The research of soil density variation dynamics during the maize vegetation period established that due to meteorological conditions and the natural processes present in soil the soil density in July has a tendency to decrease and later, after more abundant precipitation, it increases again at the end of summer.

Soil moisture has the greatest influence in spring as it is required for the maize seeds to germinate and develop. After spring tillage soil moisture decreased in all technologies and ranged from 18.8 to 22.7 % (Fig. 4.). Significant differences were established between the non-ploughing tillage technologies (DC, SC and NT) and the technologies (DP and SP), which used a plough. The comparision of the soil moisture content before and after spring tillage showed that the soil moisture decreased significantly in DP and SP technologies. The research results demonstrate that it is possible to reduce the soil moisture in spring much faster in the soils intensely ploughed in autumn compared with other soil tillage technologies. This property is much preferred, when it is required to dry soil as fast as possible in wet spring and start maize sowing. However, being aware of the fact that in Lithuania and the whole region small amounts of precipitation fall in spring and sometimes the seeds are short of soil moisture to germinate, the upper soil layer drying is not required. The purpose of spring soil tillage is both to prepare the seedbed well and to retain soil moisture as high as possible. After spring tillage the upper soil layer in DP and SP technologies retains lower soil moisture compared with the sustainable soil tillage technologies.

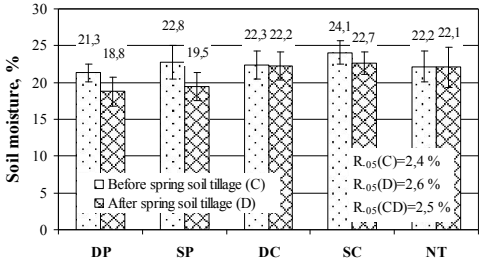


Fig. 4. Soil moisture before and after spring soil tillage in 0–10 cm layer (2010–2012)

The results of the soil moisture experimental research indicate that the sustainable soil tillage and NT technologies allow absorbing and retaining higher amounts of water in the upper soil layer during the vegetation period compared with the DP technology. Autumn soil tillage which is mainly performed when the weather becomes colder has no substantial influence on the soil moisture content neither in the upper nor the deeper soil layer.

Soil temperature. Spring tillage has the opposite influence on autumn tillage. If autumn soil tillage reduces the soil temperature, spring tillage increases it. The analysis of the experimental research results of 2012 testified that the soil temperature before spring tillage was rather high and ranged from 15.86 ºC to 16.36 ºC (Fig. 5) compared with other years. There were no significant differences between the tillage technologies. The high soil temperature before tillage was determined by high air temperature at the end of April. After spring tillage the soil temperature increased significantly in all technologies except NT. More air gaps appear in the soil disturbed by tillage machinery and the ambient temperature penetrates into the soil faster.

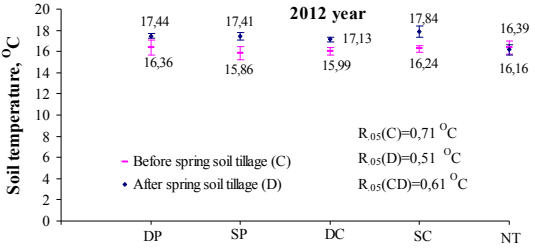


Fig. 5. Soil temperature before and after spring tillage in 2012

The highest influence on the soil temperature is made by the ambient air temperature. Soil tillage only activates the process of warming or cooling. The soil turned, mixed, loosened or disturbed in other ways by tillage machinery cools down faster in autumn and warms up faster in spring. During vegetation the soil tillage technologies had no significant influence on the soil temperature.

Soil structure resistance. Before autumn tillage the highest average resistance of soil structural particles to water in the upper soil layer was observed in DC technology (Fig. 6 a). There were no significant differences between the technologies. The autumn tillage and environmental factors increased the resistance of soil structural particles in all technologies. The most resistant soil structure in 0–15 cm layer was established in NT technology. The significant differences were achieved between NT and SP, NT and DP, and NT and DC technologies.

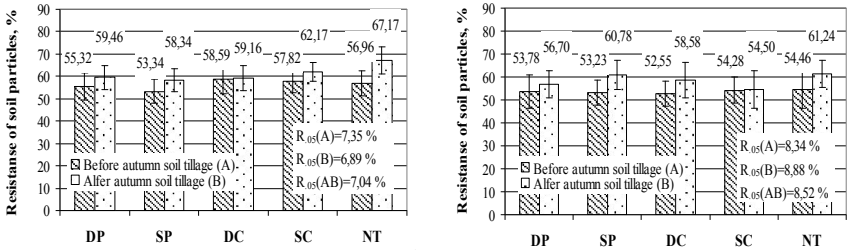


Fig. 6. Resistance of soil particles to water before and after autumn tillage (2010–2012): a – 0–15 cm layer; b – 15–25 cm layer.

Autumn tillate in a deeper (15–25 cm) soil layer maintains the same tendencies of the soil structure particle resistance to water as in the upper layer. The highest soil structure resistance both before autumn tillage and after it was established in NT technology (Fig. 6 b). None of the tillage technologies was characterized by a significant increase or decrease of soil structure resistance.

The average resistance of soil structural particles to water before spring tillage in the 0–15 cm layer varied from 60.4 to 71.82 % (Fig. 7 a). The highest resistance of the soil

structure in the upper layer (0–15 cm layer) was achieved in NT technology. The most resistant soil structure after spring tillage was established in NT technology (74.01 %); significant differences were established between SP and NT technologies. The comparison of the soil structure resistance to water before and after spring tillage indicated significant differences in DP and SP options.

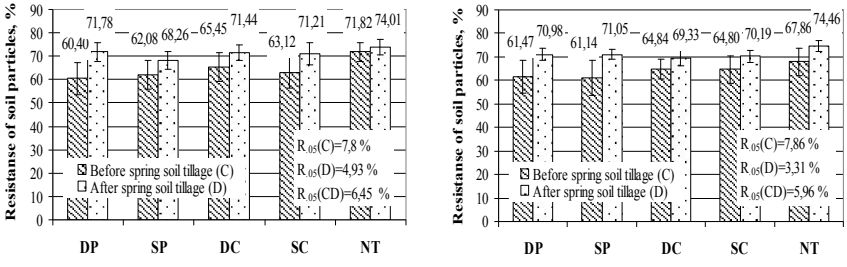


Fig. 7. Resistance of soil particles to water before and after spring tillage (2010–2012): a – 0–15 cm layer; b – 15–25 cm layer.

Before spring tillage the highest resistance of soil structural particles to water in the 15–25 cm soil layer was observed in NT technology (67.86 %) (Fig. 7 b). However, there were no significant differences between all options. After spring tillage the soil structure resistance to water increased in all technologies; significant differences were established between NT and and all remaining soil tillage technologies. The comparison of data before and after spring tillage established the significant differences of soil structure resistance in DP, SP and NT technologies.

CO_2 gas emissions from soil. The research of the impact of soil tillage technologies on the environment carried out in the autumn of 2009 established that the highest CO_2 gas emissions into the environment were achieved in DP technology both before autumn tillage and after it (Fig. 8).

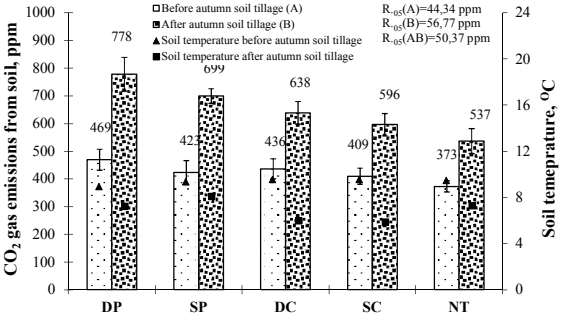


Fig. 8. CO_2 gas emission from soil and soil temperature before and after autumn tillage in 2009

In the sustainable soil tillage technologies the impact of SP, DC, SC ir NT on CO_2 gas emissions from soil was less compared to DP. The lowest CO_2 emissions before tillage were established in NT technology (373 ppm). Whereas there were no significant differences between the different sustainable soil tillage technologies, the significant difference was established between DP and NT, DP and SC, and between DP and SP. The analogous tendency remained after autumn tillage as well. The lower intensity of soil tillage resulted in lower CO_2 emissions from the soil.

While analysing the influence of autumn soil tillage on CO_2 gas emissions into the environment it was established that they increased significantly in all tillage technologies. Having performed the temperature measurements of the upper soil layer at the same time higher influence of it on CO_2 gas emissions was not observed due to minor temperature fluctuations.

The year of 2010 was exceptional in terms of CO_2 emissions from soil (Fig. 9) as due to cool weather the soil temperature after autumn tillage decreased by about 6 ºC compared with the soil temperature before autumn tillage. It can be stated that due to this reason the autumn soil tillage had no big influence on CO_2 emissions from soil. After tillage somewhat higher CO_2 emissions (around 3.7 %) were recorded in SP technology compared to other technologies. Comparing of CO_2 emissions from soil before autumn tillage and after it no significant differences in any technology were recorded.

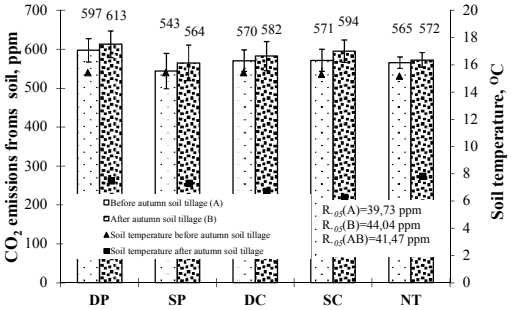


Fig. 9. CO_2 gas emissions from soil and soil temperature before and after autumn tillage in 2010

The experimental research results of 2011 both in terms of CO_2 emissions from soil and soil temperature were very similar to those of 2009 (Fig. 10). Before autumn soil tillage the highest CO_2 emissions from soil were identified in DP technology – 433 ppm, and the lowest (350 ppm) – in TS. The soil temperature before autumn tillage varied from 9.13 ºC to 9.70 ºC and after autumn tillage it decreased by 2–3 ºC. In autumn the decreasing weather temperature had its effect on the soil as well. After the autumn tillage it was established that CO_2 increased in all technologies. The more intensely the soil was tilled, the higher CO_2 emissions were achieved. There was no significant difference only between DC and SC technologies.

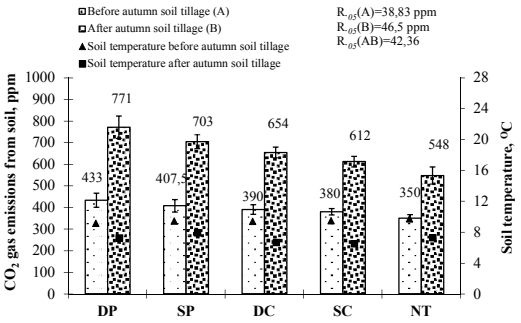


Fig.10. CO_2 gas emissions from soil and soil temperature before and after autumn tillage in 2011

The comparison of CO_2 gas emissions into the environment before autumn tillage (A) and after it (B) yielded a significant difference in all soil tillage technologies.

Having carried out the analogous investigations before spring soil tillage it was established that the lowest CO_2 gas emissions (854 ppm) from soil were achieved in NT technology and the highest emissions (1055 ppm) were achieved in SP (Fig. 11). After spring tillage CO_2 gas emissions increased and that increase was significant in all soil tillage technologies. The highest CO_2 gas emissions from soil were recorded in DP technology. The CO_2 gas emissions from the sustainable soil tillage technologies were lower after spring tillage.

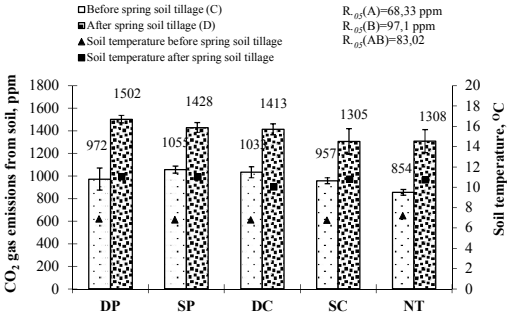


Fig.11. CO_2 gas emissions from soil and soil temperature before and after spring tillage in 2010

Strong relationship between CO_2 gas emissions and autumn tillage was observed. The more intensely the soil is tilled in autumn, the higher CO_2 emissions from soil are achieved after spring tillage. The soil temperature after tillage was similarly increased in all soil tillage technologies; therefore, there was no major influence of it on CO_2 gas emissions. Higher soil temperature stimulates the activities of soil microorganisms, processes of

organic matter degradation and intensifies the breathing of plant roots. The same CO_2 gas emission tendencies were observed during other research years as well.

Energy assessment. Having calculated the energy costs per technology investigated it was established that the costs for different technologies ranged from 16.1 to 18.1 GJ ha^{-1} (Table 1).

Table 1. Energy costs of maize cultivation using different technologies

Technological Costs	Units	Soil Tillage Technologies				
		DP	SP	DC	SC	NT
Labour	MJ ha^{-1}	9.54	8.66	7.31	7.17	3.23
Diesel fuel	MJ ha^{-1}	2662.70	2274.62	2318.18	2116.22	1123.85
Agricultural machinery (including self-propelled)	MJ ha^{-1}	1739.56	1578.82	1332.36	1307.35	589.38
Maize seeds	MJ ha^{-1}	459.00				
Herbicides	MJ ha^{-1}	634.25				1814.25
Nitrogen fertilizer	MJ ha^{-1}	10532.00				
Phosphorus fertilizer	MJ ha^{-1}	1316.14				
Potassium fertilizer	MJ ha^{-1}	774.69				
Total:	MJ ha^{-1}	18127.9	17578.2	17373.9	17146.8	16153.5

The major part of all energy costs in all maize cultivation technologies accounts for fertilizer and diesel fuel. In the conventional DP technology fertilizer made around 70 % and fuel – around 15 % of the costs; in NT technology – 78 % and 7 % respectively.

The calculations of energy efficiency ratio demonstrate the relationship between the energy amount obtained by assessing the maize yield cultivated using different tillage technologies in terms of energy indicators and the energy costs achieved by evaluating the use of agricultural machinery, diesel fuel, seeds, fertilizers, herbicides and other materials in terms of energy indicators. The best energy efficiency ratio (14.0) was achieved applying NT technology and a slightly lower ratio (13.4) was achieved applying shallow ploughing. The energy efficiency ratio in the conventional maize cultivation technology of deep ploughing was 12.4 (Table 2).

Table 2. Energy efficiency ratio of maize cultivation applying different soil tillage technologies

Soil Tillage Technologies	Energy Efficiency Ratio			
	2010	2011	2012	2010–2012 average
DP	6.9	17.3	13.0	12.4
SP	7.0	18.3	15.1	13.4
DC	5.4	19.7	8.9	11.3
SC	6.9	19.3	9.8	12.0
NT	10.4	18.6	13.0	14.0

Having made energy assessment it was observed that these results of the energy assessment duly represent the results announced in other authors' research works.

It was established by energy assessment calculations that the conventional soil tillage of deep ploughing is an expensive and inefficient technological process requiring a lot of labour time and fuel costs. The application of reduced tillage technologies such as shallow ploughing, deep cultivation, tillage by disc implements or no-tillage results in better economic and energy indicators compared with the conventional soil tillage. The economic analysis showed that the costs of all reduced tillage technologies for mechanized technological operations were from 3.5 (SP) to 40 % (NT) lower compared with the conventional soil tillage. The assessment of the maize yield indicated that in many cases in the conventional soil tillage technology it is similar or marginally higher compared with other reduced tillage technologies. Having carried out the experimental research it was established that the highest average yield of maize grain and biomass dry matter of three years was achieved both in the conventional DP (15.25 Mg ha^{-1}) and NT (15.39 Mg ha^{-1}) technologies.

Having calculated the costs of different technologies for labour time and fuel it was established that the application of the reduced tillage methods can reduce fuel costs from 12 (SP) to 58 % (NT) (Fig. 12 a), labour time from 8.4 % (SP) to nearly 3 times (NT) compared with the conventional DP technology.

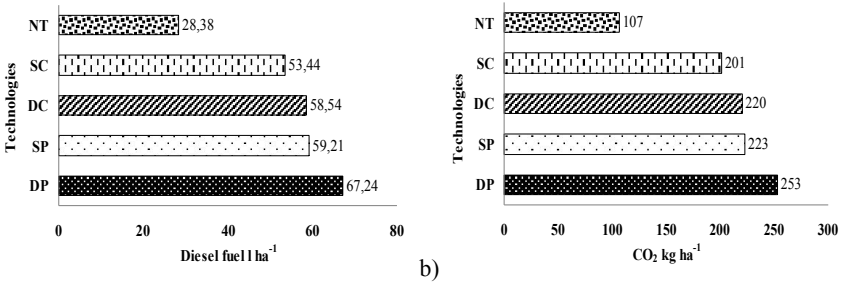


Fig. 12. a) – diesel fuel; b) – CO_2 gas emissions into environment from agricultural machinery units of different soil tillage technologies applied for maize cultivation

The reduction of diesel fuel use in agriculture is positive in terms of the environmental protection as the reduction of green-house effect causing CO_2 gas emissions reduces the environmental pollution. In the conventional maize cultivation technology agricultural machinery consumes fuel and emits around 253 kg ha^{-1} of CO_2 gas (Fig. 12 b). The application of reduced tillage SP, DC and SC technologies decreases CO_2 gas emissions from 12 to 22 %. The most environmentally friendly is NT technology resulting in CO_2 gas emissions of around 107 kg ha^{-1}.

CONCLUSIONS

1. The application of sustainable (shallow ploughing, deep and shallow cultivation and no-tillage) technologies allows maintaining the main physico-mechanical properties of soil and good yield of maize:

- After the autumn tillage the soil surface (0–9 cm) hardness did not exceed 1.8 MPa. The autumn silage tillage reduced the hardness of the soil upper layer significantly in deep ploughing (37 %), shallow ploughing (34 %) and deep cultivation (33 %) technologies. In deeper soil layers (5–28 cm) the significant decrease of soil hardness was achieved only in deep (27–45 %) and shallow ploughing (7–37 %) technologies. The spring ploughing reduced soil hardness from 7 to 14 % in the upper 0–4 cm soil layer in all technologies.
- The sustainable soil tillage technologies (shallow ploughing, deep and shallow cultivation) provided the soil hardness of the upper soil layer (0–10 cm) within the recommended limits (1.2–1.4 g cm^{-3}) after the autumn tillage. The autumn tillage significantly reduced the soil hardness (4.67–6.09 %) in all tillage technologies except the no-tillage technology.
- Autumn tillage has no significant influence on the soil moisture both in the upper (0–10 cm) and deeper (10–20 cm) soil layers. The spring soil tillage reduced the soil moisture significantly in the upper layer applying deep and shallow ploughing technologies – down to 18.8 and 19.5 %, respectively. More soil moisture (22.1–22.7 %) was preserved in deep cultivation, shallow cultivation and no-tillage technologies.
- The resistance of soil particles to water was higher than recommended (50 %) in all tillage technologies. The highest soil particle resistance to water was achieved in the upper and deeper soil layers when using no-tillage technology (74.01 % in 0–15 cm layer and 74.46 % in 15–25 cm layer). Other soil tillage technologies yielded the soil particle resistance to water which ranged from 68.26 % to 71.78 % in the upper soil layer after the spring tillage and from 58.34 % to 67.14 % after the autumn soil tillage.
- The highest average yield of maize grain and biomass dry matter was obtained in NT technology (15.39 Mg ha^{-1}). The deep ploughing technology gave 1 %, shallow ploughing and shallow cultivation – 8 % and deep cultivation – 12 % lower yields compared to the no-tillage technology.

2. All sustainable soil tillage technologies reduce CO_2 gas emissions from soil compared with the conventional deep ploughing technology. In the sustainable technologies CO_2 gas emissions from soil were lower compared to the deep ploughing tillage technology from 9.1 to 23.4 % after the autumn tillage, from 3.5 to 11.5 % after the spring tillage and from 6.1 to 16.1 % during the vegetation period.

3. In assessing the soil tillage technologies according to the costs incurred for mechanized technological operations it was established that the costs of the sustainable

tillage technologies were from 3.5 to 40 % lower compared with the deep ploughing technology.

4. Labour time and fuel cost calculations established that the application of the sustainable tillage technologies can reduce the fuel costs from 12 to 58 % and the costs of labour time – from 8.4 % to nearly 3 times compared with the deep ploughing technology.

5. In the conventional deep ploughing technology agricultural machinery units consume fuel and emit about 253 kg ha^{-1} of CO_2 gas into the environment. The application of the sustainable shallow ploughing, deep cultivation and shallow cultivation technologies reduces CO_2 gas emissions into the environment by 12 to 22 %. The lowest pollution is caused in the no-tillage technology as the CO_2 gas emissions into the environment are about 2.36 times lower compared with the deep ploughing technology.

6. Having assessed the energy consumption and the energy obained from the maize yield by the energy efficiency ratio calculations it was established that the best energy efficiency ratio (14.0) is achieved by applying the no-tillage technology and slightly lower ratio (13.4) is achieved by applying shallow ploughing. The energy efficiency ratio of the conventional deep ploughing technology is 12.4.

LIST OF PUBLICATIONS ON THE SUBJECT OF THE DISSERTATION

***Articles in journals indexed in ISI WOS List database*:**
Leidiniuose, referuojamuose Mokslinės informacijos instituto duomenų bazėje „ISI Web of Science“ ir turinčiuose citavimo indeksą.

1. **Buragienė, Sidona**; Šarauskis, Egidijus; Romaneckas, Kęstutis; Sakalauskas, Antanas; Užupis, Arnoldas; Katkevičius, Evaldas. Soil temperature and gas (CO_2 and O_2) emissions from soils under different tillage machinery systems // Journal of Food, Agriculture & Environment. Helsinki : WFL Publisher. ISSN 1459-0255. 2011, Vol. 9, No. 2, p. 480-485. [ISI Web of Science; CAB Abstracts]. [Citav. rod (F).: 0.517; bendr. cit. rod: 1.898]

2. Romaneckas, Kęstutis; Adamavičienė, Aida; Pilipavičius, Vytautas; Šarauskis, Egidijus; Avižienytė, Dovilė; **Buragienė, Sidona**. Interaction of maize and living mulch. Crop weediness and productivity // Žemdirbystė. Akademija, (Kėdainių r.). ISSN 1392-3196. T. 99, Nr. 1 (2012), p. 23-30. [ISI Web of Science; CAB Abstracts]. [Citav. rod (F).: 0.567; bendr. cit. rod: 1.481]

Publications referred in the Journals from Institute of Scientific Information (ISI) List

1. Šarauskis, Egidijus; **Buragienė, Sidona**; Romaneckas, Kęstutis; Sakalauskas, Antanas; Jasinskas, Algirdas; Vaiciukevičius, Edvardas; Karayel, Davut. Working time, fuel consumption and economic analysis of different tillage and sowing systems in Lithuania // Engineering for rural development: 11th international scientific conference: proceedings,

may 24-25, 2012. Jelgava, 2012. ISSN 1691-3043. vol. 11, p. 52-59. [ISI proceedings; CAB Abstracts].

2. Šarauskis, Egidijus; Romaneckas, Kęstutis; Vaiciukevičius, Edvardas; Jasinskas, Algirdas; Sakalauskas, Antanas; **Buragienė, Sidona**; Katkevičius, Evaldas; Karayel, Davut. Effect of environmentally friendly tillage machinery on soil properties // Engineering for rural development: 10th international scientific conference: proceedings, may 26-27, 2011. Jelgava, 2011. ISSN 1691-3043. vol. 10, p. 70-75. [ISI Proceedings; CAB Abstracts; AGRIS].

Publications referred in international databases from the list approved by Science Council of Lithuania

1. **Buragienė, Sidona**; Šarauskis, Egidijus; Romaneckas, Kęstutis; Adamavičienė, Aida; Avižienytė, Dovilė; Katkevičius, Evaldas. Skirtingų žemės dirbimo technologijų įtaka dirvožemio mechaninėms-fizikinėms savybėms // Žemės ūkio inžinerija. ISSN 1392-1134. Nr. 43(3) (2011), p. 24-42. [CAB Abstracts].

2. Šarauskis, Egidijus; Romaneckas, Kęstutis; **Buragienė, Sidona**. Impact of Conventional and Sustainable Soil Tillage and Sowing Technologies on Physical-Mechanical Soil Properties // Aplinkos tyrimai, inžinerija ir vadyba = Environmental research, engineering and management. Kaunas : Technologija. ISSN 1392-1649. 2009, Nr. 3(49), p. 36-43. [INSPEC; CAB Abstracts; EBSCO Publishing; VINITI].

Other reviewed scientific publications
(mokslo populiarinimo leidiniuose, nerecenzuojamų konferencijų medžiagoje ir kt.)

1. Užupis, Arnoldas; Nemčiauskas, Kęstutis.; Šarauskis, Egidijus; Katkevičius, Evaldas; **Buragienė, Sidona**. An Influence of Autumnal Soil Cultivation to $C0_2$ Gas Emission // Advanced Materials and Technologies and European Doctorate in Physics and Chemistry of Advanced Materials: 12-th Conference: Book of Abstracts of the Joint International Summer School-Conference: 27-31 August 2010, Palanga, Lithuania. Kaunas: Technologija, 2010. ISBN 1822-7759. p. 50.

2. Romaneckas, Kęstutis; Šarauskis, Egidijus; Pilipavičius, Vytautas; Butkevičienė, Lina Marija; Adamavičienė, Aida; **Buragienė, Sidona**; Milašaitė, I.; Vaicekauskas, M.; Avižienytė, Dovilė. Effect of primary soil tillage intensiv on maize (Zea Mays L.) crop // Šiuolaikinių žemdirbystės sistemų aktualijos: konferencija skirta profesoriaus Antano Stancevičiaus 90-osioms gimimo metinėms paminėti, Lietuvos žemės ūkio universitetas, 2010 m. kovo 25 d.: programa ir pranešimų santraukos. Akademija, 2010. ISBN 9789955896807. p. 61.

Straipsniai nepriskirti mokslo leidinių grupėms

(mokslo populiarinimo leidiniuose, nerecenzuojamų konferencijų medžiagoje ir kt.)

1. Pavalkytė, Laura; Šarauskis, Egidijus; **Buragienė, Sidona**. Tradicinių ir tausojančių žemės dirbimo mašinų poveikis dirvožemio fizikinėms-mechaninėms savybėms // Agroinžinerija ir energetika: LŽŪU Žemės ūkio inžinerijos fakulteto mokslo populiarinimo ir gamybos žurnalas. ISSN 1392-8244. 2011, Nr. 16, p. 116–121.
2. Baranauskaitė, Rima; **Buragienė, Sidona**; Adamavičienė, Aida. Žemės dirbimo ir sėjos mašinų poveikio dirvai tyrimai // Jaunimas siekia pažangos – 2009 / LŽŪU. ISSN 1822-2331. 2009, p. 186–190.

Short Profile

Sidona Buragienė was born in Kaunas on 16 June, 1977. In 1995 she finished Vyturio Secondary School in Kaunas. In 1996 she entered Kaunas Food Industry Technical School. In 1999 she entered the Lithuanian University of Agriculture and in 2003 obtained the Bachelor Degree in Engineering. During 2003–2005 at the same University she gained the Master Degree in Engineering. Since 2008 S. Buragienė is the doctoral student in the Faculty of Engineering of the Lithuanian University of Agriculture (now Aleksandras Stulginskis University).

Reziumė

Temos aktualumas. Žemės dirbimas yra vienas svarbiausių agrotechnologinių procesų, turinčių labai didelę įtaką kultūrinių augalų sėjai, sudygimui, augimui, derliui ir jo kokybei. Tuo pačiu žemės dirbimas yra ir vienas iš brangiausių ir energijai imliausių kultūrinių augalų auginimo agrotechnologinių procesų. Įprastinio žemės dirbimo technologijos, kuriose naudojamos verstuvinės ir intensyviai dirvą purenantys žemės dirbimo agregatai, greta teigiamo poveikio augalų sėklų guoliavietės paruošimui, yra pakankamai žalingos aplinkai, dirvai, jos savybėms, biologinei įvairovei, vandens telkinių taršai ir t.t. Įprastinio žemės dirbimo metu augalinės praėjusio derliaus liekanos yra įterpiamos į gilesnius dirvos sluoksnius ir dirvos paviršius lieka neuždengtas. Tokios dirvos yra žymiai jautresnės aplinkos veiksniams ir lengviau pažeidžiamos vėjo ir vandens erozijos. Kiekvienais metais, pasaulyje, dėl netinkamos žemės ūkio veiklos ir kintančių aplinkos sąlygų prarandama apie 6 mln. ha derlingų dirvos plotų. Kitas labai svarbus aspektas yra tas, kad žemės dirbimas gilaus arimo plūgais yra mažai našus, daug darbo laiko ir energijos sąnaudų reikalaujantis žemės dirbimas. Tuo pačiu daugkartinis didelės masės žemės ūkio agregatų važinėjimas po dirvą ne tik daro neigiamą įtaką jos savybėms, bet ir, sudeginant didelius kiekius dyzelinių degalų, stipriai teršia aplinką šiltnamio efektą sukeliančiomis dujomis. Todėl pastaruoju metu, siekiant mažinti žemės ūkio veiklos daroma neigiamą įtaką dirvos degradacijai, biologinei įvairovei, humuso nykimui, organinių ir cheminių maisto medžiagų išplovimui, natūralių biologinių dirvoje vykstančių procesų veiklai, pasaulyje vis plačiau taikomos aplinką ir energiją tausojančios žemės dirbimo technologijos. Pagrindiniai

tokių technologijų uždaviniai yra riboti intensyvų technologinį mechaninį, cheminį ir biologinį neigiamą poveikį dirvai, aplinkai ir augalams, mažinti invaziją į natūralius dirvoje vykstančius gamtos procesus, užtikrinti nuolatinį dirvos produktyvumo atsinaujinimą, tausoti biosferą ir išlaikyti ekonomiškai efektyvią bei konkurencingą žemės ūkio gamybą.

Nors, pasaulyje, kiekvienais metais vidutiniškai 4–5 mln. ha ir padidėja tausojančių dirvų plotai, tačiau tai toli gražu nėra paprastos ir lengvai įgyvendinamos žemės dirbimo technologijos. Įvairiose šalyse atliekami tausojančių žemės dirbimo technologijų tyrimai, rodo skirtingą technologijų įtaką įvairioms fizikinėms-mechaninėms dirvos savybėms bei CO_2 dujų emisijai iš dirvos į aplinką. Gaunami labai skirtingi ir prieštaringi mokslinių tyrimų rezultatai, pagal kuriuos, taikant tausojančias žemės dirbimo technologijas tikėtini mažesni kultūrinių augalų derliai ir mažesnis energetinis efektyvumas negu taikant įprastinio žemės dirbimo technologijas. Nepakankamai ištirti ir moksliniais tyrimais mažai pagrįsti žemės dirbimo technologijų įtakos skirtingų sudėčių dirvoms ir aplinkai klausimai neskatina Lietuvoje, o tuo pačiu ir visame Baltijos regione diegti naujas tausojančias žemės dirbimo technologijas.

Tyrimų hipotezė. Gilaus žemės dirbimo technologijos ariant plūgu pakeitimas seklaus arimo, gilaus ar seklaus purenimo arba tiesioginės sėjos technologijomis, leidžia sumažinti neigiamą poveikį aplinkai, sumažinti darbo ir energijos sąnaudas, išsaugant dirvos pagrindines fizikines-mechanines savybes, gerą kukurūzų derlių ir energetinį efektyvumą.

Tyrimų tikslas – ištirti skirtingo intensyvumo žemės dirbimo technologijų poveikį dirvos pagrindinėms fizikinėms-mechaninėms savybėms, CO_2 dujų emisijai iš dirvos į aplinką ir įvertinti technologijas kompleksiškai aplinkosauginiais, energetiniais ir ekonominiais aspektais.

Tyrimų uždaviniai. Tyrimų tikslui pasiekti numatyta:

1. Atlikti tausojančių žemės dirbimo technologijų poreikio analizę dirvosauginiais, aplinkosauginiais, energetiniais ir ekonominiais aspektais, išanalizuoti žemės dirbimo poveikį pagrindinėms fizikinėms-mechaninėms dirvos savybėms.
2. Ištirti gilaus ir seklaus arimo, gilaus ir seklaus purenimo bei tiesioginės sėjos įtaką dirvos kietumui, tankiui, drėgniui, temperatūrai, poringumui, struktūrai ir patvarumui vandenyje skirtinguose dirvos sluoksniuose.
3. Ištirti rudeninio ir pavasarinio žemės dirbimo įtaką CO_2 dujų emisijos kitimui iš dirvos. Nustatyti skirtingų žemės dirbimo technologijų įtaką CO_2 emisijai iš dirvos kukurūzų vegetacijos laikotarpiu.
4. Aplinkosauginiais, energetiniais ir ekonominiais aspektais įvertinti gilaus ir seklaus arimo, gilaus ir seklaus purenimo bei tiesioginės sėjos technologijas, nustatyti visų technologijų energetinį efektyvumą.

Ginamieji disertacijos teiginiai:

1. Tausojančių (seklaus arimo, gilaus ir seklaus purenimo bei tiesioginės sėjos) žemės dirbimo technologijų taikymas auginant kukurūzus giliau glėjiškame pasotintame palvažemyje (*Endohypogleyic-Eutric Planosols – PLe-gln-w*) Lietuvos meteorolo-

ginėmis klimato sąlygomis, išsaugo dirvos pagrindines fizikines-mechanines savybes, gerą kukurūzų derlių, kaip ir taikant įprastinę žemės dirbimo technologiją giliai ariant plūgu.

2. Tausojančios žemės dirbimo technologijos auginant kukurūzus giliau glėjiškame pasotintame palvažemyje Lietuvos meteorologinėmis klimato sąlygomis, leidžia sumažinti CO_2 dujų emisiją iš dirvos po rudeninio ir po pavasarinio žemės dirbimo, taip pat vegetacijos laikotarpiu, lyginant su įprastine žemės dirbimo technologija.
3. Taikant tausojančias žemės dirbimo technologijas kukurūzų auginimui, lyginant su įprastiniu žemės dirbimu, galima sumažinti degalų sąnaudas, darbo laiko sąnaudas, išlaidas mechanizuotiems darbams atlikti ir CO_2 dujų emisijas į aplinką iš žemės ūkio agregatų.
4. Tiesioginės sėjos ir seklaus arimo (12–15 cm) technologijų taikymas kukurūzų auginimui giliau glėjiškame pasotintame palvažemyje Lietuvos meteorologinėmis klimato sąlygomis leidžia pasiekti didesnį energetinį efektyvumą negu įprastinėje žemės dirbimo technologijoje.

Mokslinio darbo naujumas. Pirmą kartą kompleksiškai, aplinkosauginiais, energetiniais ir ekonominiais aspektais, ištirtos skirtingo žemės dirbimo intensyvumo technologijos, nustatytas rudeninio ir pavasarinio žemės dirbimo poveikis giliau glėjiško pasotinto palvažemio (*Endohypogleyic-Eutric Planosols – PLe-gln-w*) dirvos pagrindinėms fizikinėms-mechaninėms savybėms bei CO_2 dujų emisijoms į aplinką iš dirvos Lietuvos meteorologinėmis klimato sąlygomis. Įvertintas skirtingų žemės dirbimo technologijų energetinis efektyvumas auginant kukurūzus.

Darbo praktinė vertė. Tausojančios žemės dirbimo technologijos, kuriose neatliekamas gilus arimas plūgu, leidžia, išsaugant dirvos pagrindines fizikines- mechanines savybes ir gerą kukurūzų derlių, sumažinti darbo laiko ir degalų sąnaudas ir atpiginti žemės ūkio produkcijos gamybą. Tuo pačiu tausojančios žemės dirbimo technologijos mažina neigiamą poveikį aplinkai, mažindamos šiltnamio efektą sukeliančių CO_2 dujų emisijas į aplinką tiek iš dirvos, tiek ir iš žemės ūkio agregatų.

Išvados

1. Tausojančių (seklaus arimo, gilaus ir seklaus purenimo bei tiesioginės sėjos) žemės dirbimo technologijų taikymas auginant kukurūzus, leidžia išsaugoti pagrindines dirvos fizikines mechanines savybes ir gerą kukurūzų derlių:

- Po rudeninio žemės dirbimo visose technologijose dirvos paviršiaus (0–9 cm) kietumas neviršijo 1,8 MPa. Rudeninis žemės dirbimas dirvos viršutinio sluoksnio kietumą esminiai mažino gilaus arimo (37 %), seklaus arimo (34 %) ir gilaus purenimo (33 %) technologijose. Gilesniuose (5–28 cm) dirvos sluoksniuose po rudeninio žemės dirbimo esminis dirvos kietumo sumažėjimas buvo tik gilaus (27–45 %) ir seklaus arimo (7–37 %) technologijose. Pavasarinis žemės dirbimas visose technologijose dirvos kietumą viršutiniame 0–4 cm dirvos sluoksnyje mažino nuo 7 iki 14 %.

- Tausojančiose žemės dirbimo technologijose (seklaus arimo, gilaus ir seklaus purenimo) po rudeninio žemės dirbimo dirvos tankis viršutiniame dirvos sluoksnyje (0–10 cm) buvo rekomenduojamose ribose (1,2–1,4 g cm^{-3}). Rudeninis žemės dirbimas dirvos tankį esminiai mažino (4,67–6,09 %) visose žemės dirbimo technologijose, išskyrus tiesioginės sėjos technologiją.
- Rudeninis žemės dirbimas neturi esminės įtakos dirvos drėgniui nei viršutiniame (0–10 cm), nei gilesniame (10–20 cm) dirvos sluoksnyje. Pavasarinis žemės dirbimas, viršutiniame dirvos sluoksnyje, dirvos drėgnį esmingai mažino gilaus ir seklaus arimo technologijose, atitinkamai iki 18,8 ir 19,5 %. Gilaus purenimo, seklaus purenimo ir tiesioginės sėjos technologijose dirvos drėgmės buvo išsaugoma daugiau (22,1–22,7 %).
- Dirvos dalelių patvarumas nesuirti vandenyje visose žemės dirbimo technologijose buvo didesnis negu rekomenduojama (50 %). Didžiausias dirvos dalelių patvarumas nesuirti vandenyje viršutiniame ir gilesniame dirvos sluoksniuose buvo tiesioginės sėjos technologijoje (0–15 cm gylyje – 74,01 %, 15–25 cm – 74,46 %). Kitose žemės dirbimo technologijose viršutiniame dirvos sluoksnyje po pavasarinio žemės dirbimo dirvos dalelių patvarumas nesuirti vandenyje svyravo nuo 68,26 % iki 71,78 %, po rudeninio žemės dirbimo – nuo 58,34 % iki 67,14 %.
- Didžiausias vidutinis kukurūzų sausos masės grūdų ir biomasės derlius buvo tiesioginės sėjos (15,39 Mg ha^{-1}) technologijoje. Gilaus arimo technologijoje gautas 1 %, seklaus arimo ir seklaus purenimo – 8 %, o gilaus purenimo – 12 % mažesnis negu tiesioginės sėjos technologijoje.

2. Visos tausojančios žemės dirbimo technologijos CO_2 dujų emisiją iš dirvos mažina lyginant su įprastine gilaus arimo technologija. Tausojančiose technologijose po rudeninio žemės dirbimo CO_2 emisija iš dirvos buvo nuo 9,1 iki 23,4 %, po pavasarinio – nuo 3,5 iki 11,5 % ir vegetacijos laikotarpiu nuo 6,1 iki 16,1 % mažesnė lyginant su įprastine gilaus arimo žemės dirbimo technologija.

3. Vertinant žemės dirbimo technologijas pagal patiriamas išlaidas mechanizuotoms technologinėms operacijoms atlikti, nustatyta, kad tausojančio žemės dirbimo technologijų išlaidos yra nuo 3,5 iki 40 % mažesnės, lyginant su gilaus arimo technologija.

4. Darbo laiko ir degalų sąnaudų skaičiavimais, nustatyta, kad taikant tausojančias žemės dirbimo technologijas, degalų sąnaudas galima sumažinti nuo 12 iki 58 %, o darbo laiko – nuo 8,4 % iki beveik 3 kartų, lyginant su gilaus arimo technologija.

5. Įprastinėje gilaus arimo technologijoje žemės ūkio agregatai, degindami degalus, į aplinką išmeta vidutiniškai apie 253 kg ha^{-1} CO_2 dujų. Taikant tausojančias seklaus arimo, gilaus purenimo ir seklaus purenimo technologijas, CO_2 dujų į aplinką išmetama nuo 12 iki 22 % mažiau. Mažiausiai aplinka teršiama tiesioginės sėjos technologijoje, kurioje CO_2 dujų emisija į aplinką apie 2,36 karto mažesnė lyginant su gilaus arimo technologija.

6. Energetinio efektyvumo balanso skaičiavimais įvertinus energijos sąnaudas ir gaunamą energiją iš kukurūzų derliaus, nustatyta, kad geriausias energetinio efektyvumo koeficientas (14,0) pasiekiamas taikant tiesioginės sėjos technologiją, truputį mažesnis (13,4) – atliekant seklųjį arimą. Įprastinėje gilaus arimo technologijoje energijos efektyvumo koeficientas – 12,4.

Trumpos žinios apie disertantę

Sidona Buragienė gimė 1977 m. birželio 16 d. Kaune. 1995 m. baigė Kauno *Vyturio* vidurinę mokyklą. 1995 m. įstojo į Kauno aukštesnąją maisto pramonės mokyklą. 1999 m. įstojo į Lietuvos žemės ūkio universiteto Inžinerijos fakultetą. 2003 m. baigė studijas ir įgijo inžinerijos bakalauro kvalifikacinį laipsnį. 2003–2005 m. tęsė studijas tame pačiame universitete, įgijo inžinerijos mokslų magistro kvalifikacinį laipsnį. Nuo 2008 m. – Lietuvos žemės ūkio universiteto (2011 ASU) Žemės ūkio inžinerijos fakulteto žemės ūkio inžinerijos ir saugos instituto doktorantė.

Sidona Buragienė

SKIRTINGŲ ŽEMĖS DIRBIMO TECHNOLOGIJŲ POVEIKIS APLINKAI

Daktaro disertacijos santrauka

SL 399. 2013.11.12. Sp. 1,5. Tiražas 30. Užsakymo Nr. 51. Leido ir spausdino ASU Leidybos centras – 2013. Studentų g. 11, LT–53361 Akademija, Kauno r.