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Soil conservations tillage methods

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Summary

There are several arable sites in Hungary where the soil structure is degraded and damaged by erosion; therefore, successful farming cannot be achieved. Inspired by this fact, reduction and prevention of these harmful processes are essential. The tillage methods directly modify the structure of soil and the process of water and wind erosion. The soil conservation land use within agronomical protection provides facilities to prevent and to reduce harmful soil degradation and erosion. Hereby, the safety of agricultural activity and crop production in sloping area can be increased.

According to the researches, one of the main reason of global warming is that green house gases – especially carbon dioxide – get into the atmosphere and their concentration increases. Agricultural activities contribute to the increase of atmospherical quantity of greenhouse gases. The international commitments encourage for reducing the emission of carbon dioxide. Concerning crop production, the solution could be the application of conservation and sustainable land use.

The aims of the research were as follows:

1. Comparison of conventional and ridge tillage based on the amount of runoff soil, the eroded humus and the runoff water and on the effect on soil structure in sloping area.
2. Evaluation of different soil tillage treatments' effect on carbon dioxide emission from the soil, in connection with the changing of the humus content of soil.

It is proved that the application of the soil conservation and sustainable tillage methods are highly recommended. The soil structure and the humus content can be protected and the emission of carbon dioxide – emitted from agriculture – can be reduced with the application of conservation tillage. Preservation of the soil surface is highly recommended especially in sloping production site.

Keywords: tillage systems, CO_2 emission, climate change, erosion, agronomical texture of soil.

Introduction and review of litarature

In our days one of the most important topics is rational utilization, protection, conservation and function's maintenance of our soil resources, which is a fundamental element of sustainable development. Unfortunately this rightful expectation is not fulfilled or just occasionally realized. Soil degradation has speeded up because of human activity to such an extent that soil forming processes are no longer able to compensate the damages caused by the erosion.

The physical condition can be directly modified by tillage. Extreme clodding can occur by using inappropriate tools for tillage in dry and severe compacted soil. Natural and human induced degradation processes and long lasting mechanical stresses can produce the dust formation of the soil. In a conventional tillage system both cold and dust formation are typical and go through annual cycles as a consequence of using equipments unsuitable for soil condition. These two soil agronomical texture degradations are the most typical problems in Hungary (*Beke et al.* 2005). These problems can be solved through conserving and soil protecting land use (including reduced, improving or maintaining tillage, using mulch and catch crop).

The physical and biological condition of the soil can be degraded in consequence of inadequate land use and tillage, usually apart from soil type. The soil condition can be quantified by its environmental impacts and suitability to crop production. Soil through the favourable physical and biological features, can be simultaneously the main factor for the cultural environment and crop production (*Birkás* 2001).

Soil erosion by water is a major worldwide problem with both on-site effects for agriculture and off-site effects regarding sedimentation problems (*Schwertmann et al.* 1987). Surface runoff influences soil erosion and the amount of nutrients and pesticides lost from agricultural fields to surface waters (*Ulen* 1997). This runoff of nutrients can reduce the yields of crops and to lower the productivity of soil.

Water and wind erosion occurred mainly on arable slope sites and light, sandy soils. Nowadays as a result of traditional multitraffic tillage and intensive management erosion spreads to heavier plain soils too. Where soil conservation is difficult and expensive the solution for prevention can be the change of land use (*Birkás et al.* 2006).

Our Earth's climate is changing continuously and human activity has a role in this changing. The effect of human activities (industry, traffic, agriculture) exercises a demonstrable influence not only on the micro- and macro-, but also on the global climate. Agricultural production has a great effect on atmosphere quantity of the greenhouse gases. Soil is one of the main source and at the same time the potential sink of greenhouse gases (e.g. CO_2, CH_4). It is widely known that the mean annual temperature has been increasing (in Europe the temperature is 0.3–0.6 °C higher than ten years ago) and the main cause of this trend is that the CO_2 concentration of the atmosphere has been rising too (EEA 1998). The rising CO_2 concentration has an influence on plants. The intensity of photosynthesis is depending on the CO_2 concentration of atmosphere too. If the soil moisture and nutrient content is appropriate the higher carbon dioxide concentration can be advantageous for growth of

plants (this is the so-called carbon dioxide manuring). But, if other environment factor is changing (for example moisture content of soil) this positive effect can decrease or not happened (*Veisz et al.* 1996, *Anda* és *Lőke* 2006). The prognosis for Hungary connection with the global climate change is that the climate will be warmer and arid (*Várallyay* 2006).
Five percent of annual CO_2 emission originates from soil tillage (*Cole* 1996). It is a well-known fact that the conventional land use, including tillage, may influence even in climatic changes (*Gyuricza* 2004). The soil inversion by ploughing regularly induces a great carbon dioxide emission from the croplands. There is scientific evidence that intensive soil tillage has been a significant component of the increase in atmospheric CO_2, which has occurred in the last decades. Intensive tillage results in the reduction of carbon resources by 30–50 %, mainly due to the breaking of the soil (*Birkás et al.* 2006). The carbon dioxide evolving during the increased mineralization of the organic matter can vanish into the atmosphere. In opposition to this the conservation tillage technologies (inversion free technologies, no-tillage etc.) can increase the humus content of the soil by 1 ton per year *(Gyuricza* 2004). The humus content of the soil has an effect on the plants. If the soil humus and nutrient content is appropriate the yield of agricultural crops is higher (*Blazenka et al.* 2007).

Material and methods

We participated in a research program of the Department of Soil Management (Szent István University) to examine different tillage systems. One of the adjectives of this program was to study the interaction between tillage systems and CO_2 emission from soil.
The other main objectives of this program are to compare ridge tillage and conventional tillage based on the amount of runoff soil, the eroded humus and the runoff water and on the effect on soil structure in sloping area.
The agronomical texture of soil and the damages of water erosion were examined in a long-term experiment. The investigations were carried out on the experimental field, which was set up in 2003 in Józsefmajor, in the region of Hatvan, Northern-Hungary, which represents two different tillage treatments, which are the followings:

1. Conventional (ploughing 22–25 cm), surface and seed-bed preparation, sowing
2. Ridge tillage – ploughing, preparation of ridges, sowing into median plane of ridge (2004) and forming of ridges after sowing (2005)

The ridge tillage experiment is situated on a sloping field, exposed to soil erosion. Plot-area is adjusted to the character of terrain and width of tillage/sowing implements. The plot area in 2004 was 75 m^2 (10 m x 7,5 m), and total area 600 m^2, in 2005 plot area was 160 m^2 (20 m x 8 m), and total area 1280 m^2. Plots have been formed at right angles to slope. Number of replications: 4, split-plot design (2004), strip-design (2005). NPK mineral fertilizer was used, according to the nutrient content of soil. Since April 2003 to November 2005 maize was grown in the field.
The amount of runoff soil and water was measured on 1 m^2 surface in examined plots. The agronomical texture was defined by dry screening (*Várallyay* 1993). The agronomical

texture was classified by the size of aggregates, which were measured and divided into three fractions (> 10 mm clod; 10–0.25 crumb; < 0.25 dust) (*Stefanovits* 1992.). The physical condition of soil is better, if the rate of crumb fraction is higher (*Tóth* 2001).

The CO_2 emission from soil and the humus content were examined in an other long-term experiment. The experiment was set up in 2002 in Hatvan region (Józsefmajor) in Hungary. The experimental site is loam soil, the type is Calcic Chernozem. The size of the experimental site is 312 x 50 m= 4,68 ha, with 4 replications in split-plot design. The experiment represents six different tillage treatments, which are the followings: a1: ploughing (26–30 cm); a2: direct drilling; a3: French cultivation (8–10 cm); a4: cultivation (16–20 cm); a5: disking (16–20 cm); a6: loosening (35–40 cm) and disking (16–20 cm). The crop sequence is as follows: 2002: white mustard (*Sinapis alba* L.), 2002/2003: winter wheat (*Triticum aestium* L.), 2003/2004: rye (*Secale cereale* L.) (catch crop and forage), 2004: pea (*Pisum sativum* L.) (forage), 2004/2005: winter wheat (*Triticum aestium* L.), 2005: white mustard (*Sinapis alba* L.), 2005/2006: winter wheat (*Triticum aestium* L.).

The CO_2 emission of soil was measured in situ, by means of an INNOVA 1312 (Multi-gas monitor), after cultivation and after sowing, in case of five different tillage treatments (a1, a2, a4, a5, a6). We covered the soil surface with a plastic chamber, and we measured the changing of the CO_2 concentration after determined time. The INNOVA 1312 multi-gas monitor measure the CO_2 emission in mg/kg. To calculate maximum CO_2 emissions from soil in flux the following formula was used *(Zsembeli at al.* 2006):

$$F = d * V/A * (c_2–c_1)/t * 273/(273 + T)$$

$F = CO_2$-flux (kg m^{-2} h^{-1})
d = 1,96 kg m^{-3} (density of CO_2)
V = volume of head space of chamber (m^3) /= 0,00366 m^3/
A = area of chamber (m^2) /= 0,0314 m^2/
$c_1 = CO_2$ concentration at time of start (m^3 m^{-3})
$c_2 = CO_2$ concentration at time o fend (m^3 m^{-3})
t = duration of measurement (h)
T = air temperature (°C)

Results and discussion

Soil erosion is one form of soil degradation. Rain and wind induced soil degradation is a natural process, which can be accelerated because of the human intervention. In general, geological erosion removes soil at roughly the same rate as soil is formed. But 'accelerated' soil erosion – loss of soil at a much faster rate than it is formed – is a far more recent problem. It is always a result of mankind's unwise actions, such as overgrazing or unsuitable cultivation practices. These leave the land unprotected and vulnerable. Then, during times of erosive rainfall or windstorms, soil may be detached, transported, and (possibly travelling a long distance) deposited.

Accelerated soil erosion by water or wind may affect both agricultural areas and the natural environment, and is one of the most widespread of today's environmental problems. It has impacts which are both on-site (at the place where the soil is detached) and off-site (wherever the eroded soil ends up).
Table 1. shows the amount of runoff soil, humus content and the amount of runoff water in case of ridge tillage and conventional tillage in 24. August 2005. Before sampling 191 mm rain was measured (during period of 8. July 2005–24. August 2005).
It can be concluded that ridge tillage gave better results in the three examined factors than conventional tillage method. The amount of runoff soil and eroded humus content was significant lesser in case of protection tillage. At top of the slope 9.6 kg more, at the bottom of the slope 3 kg more humus content stayed in cropland thanks to the protection effect of ridge, which is a big amount if we consider that the humus content need long time (years, decades) to arise.

Table 1. The amount of runoff soil, humus content and the amount of runoff water (Józsefmajor, 24. 08. 2005.)

	Ridge tillage		**Conventional tillage**		$SZD_5\%$
	Top of the slope	**Bottom of the slope**	**Top of the slope**	**Bottom of the slope**	
Runoff soil (g/m^2)	***52,70***	*46,30*	***67,30***	*57,90*	9,110
Runoff humus (g/m^2)	***1,16***	*1,29*	***2,12***	*1,59*	0,437
Runoff humus (kg/ha)	***11,60***	*12,90*	***21,20***	*15,90*	4,370
Runoff water (l)	***8,75***	*7,20*	***9,82***	*8,10*	nsz

* non significant

Next sampling was 8. November 2005, before harvesting when 73 mm precipitation was measured (during period of 8 November 2005–24 August 2005). *Figure 1–3.* show similar tendencies as the date of August. The amount of runoff soil was higher in the summer, because the wetter was rainier and thunderstorms were more often. Runoff volume and intensity depend on the interaction between rainfall amount, intensity and seasonal distribution. The amount of runoff soil, humus content and water was statistically proved lesser in case of ridge tillage compared to conventional tillage.
According to our experiences the ridge tillage supports the soil protection as the conservation method could be the solution for the prevention of the erosion. It has a big importance, because soil and wind erosion endanger more than 43% of the land in Hungary.
The agronomical structure of soil has an effect on erosion. Well structured soil can resist the hitting effect of rain. Aggregates, which have bigger size (crumb) can be hardly removed by water than dust fraction. The agronomical structure is closely related to tillage methods. *Figure 4.* shows the changes of agronomical texture during 3 year (between 2002 and 2005) in different tillage treatments. It can be concluded that ridge tillage has a favourable effect on soil structure, the rate of dust fraction decreased and the rate of crumb fraction increased during the examination time. In case of application of conventional tillage system

the soil structure declined, namely the rate of crumb fraction reduced and compared to the characteristic agronomical texture of soil. The rate of clod fraction increased in case of both tillage treatments using. This unfavourable results can be the consequence of the lack of crop rotation (in the experimental site maize was applied from April 2003 to November 2005). The ridge tillage treatment gave statistically proved better results than conventional tillage concerning clod and dust fraction of soil.

Figure 1. The amount of runoff soil at ridge and conventional tillage methods (Józsefmajor, 08. 11. 2005.)

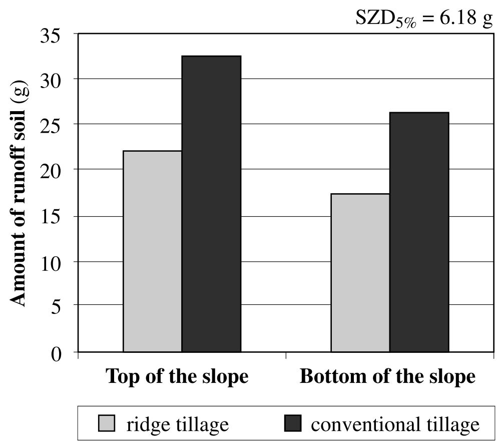


Figure 2. The amount of runoff water at ridge and conventional tillage methods (Józsefmajor, 08. 11. 2005.)

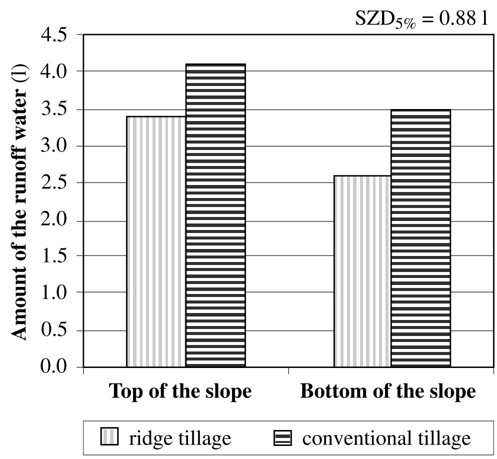


Figure 3. The amount of runoff humus content at ridge and conventional tillage methods (Józsefmajor, 08. 11. 2005.)

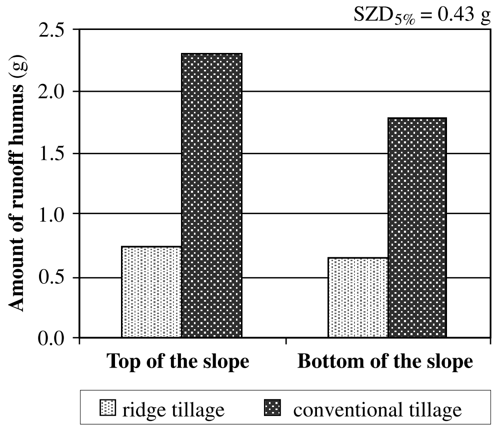
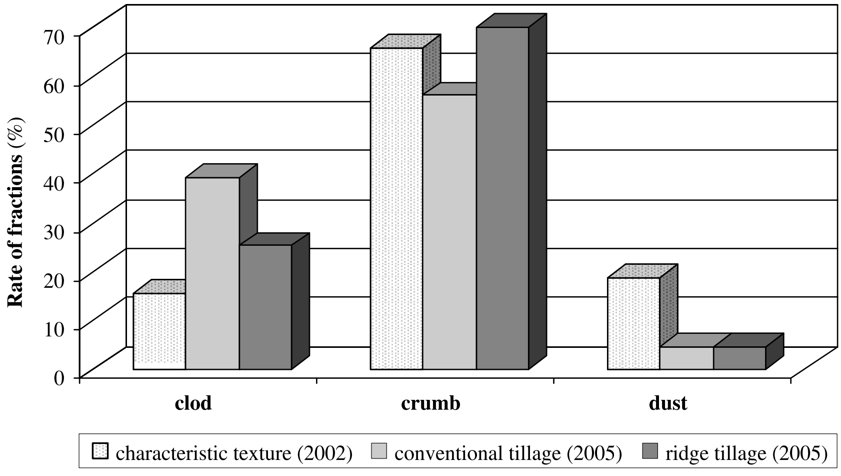


Figure 4. Trends in agronomical texture at conventional and ridge tillage methods between 2002 and 2005 (Józsefmajor)



Finally it can be concluded that soil conservation and protection tillage have prosperous effect on the agronomical texture and the physical condition of the soil. And it can be stated that ridge tillage can reduce the amount of runoff soil, humus content and water in a sloping area. This tillage can provide the crop production under unfavourable field condition in sloping area.

Figure 5. shows the CO_2 emission at different tillage methods after cultivation in mg/kg.

Figure 5. CO_2 emission at different soil tillage practices after cultivation (Józsefmajor, 13. 09. 2004)

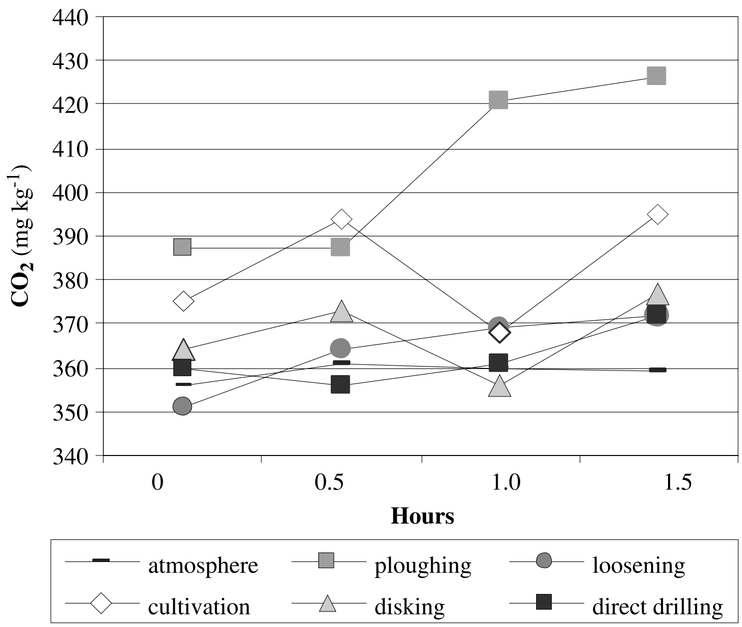


Figure 6. presents the maximum CO_2 flux using different tillage treatments, in kg m^{-2} h^{-1}. The most CO_2 emission from soil was measured in a ploughing plot both during the experiment time and in case of maximum emission too. The range of treatments based on maximum carbon dioxide emission (kg m^{-2} h^{-1}): ploughing (5.63); loosening and disking (3.03); cultivation (2.89); disking (1.88); direct drilling (1.73). The range of treatments is different a little bit if we consider the complete measure time, loosening combined disking plot has less CO_2 emission than using cultivation and same as in case of disking treatment. It can be concluded that the conventional and intensive tillage treatments cause more carbon dioxide loss than the soil conservation tillage technologies.

Figure 7. shows the change of CO_2 emission from soil at five different tillage methods after sowing. Immediately after sowing the most carbon dioxide emission from soil was measured in direct drilled plot, but during the period of examination it have not increased significantly. If we consider *Figure 8.*, it can be concluded that the maximum CO_2 flux was the least in case of direct drilling. The most carbon dioxide emission was measured in case of using ploughing. But this results is more better compared with another ploughing plots' emission (in Hungary), thanks to the suitability of tools and the quality of the soil surface drilling. Loosening combined disking and disking plots gave similar results, which were followed by cultivation tillage treatment.

Figure 6. Maximum CO_2 flux at different tillage methods after cultivation (Józsefmajor, 13. 09. 2004.)

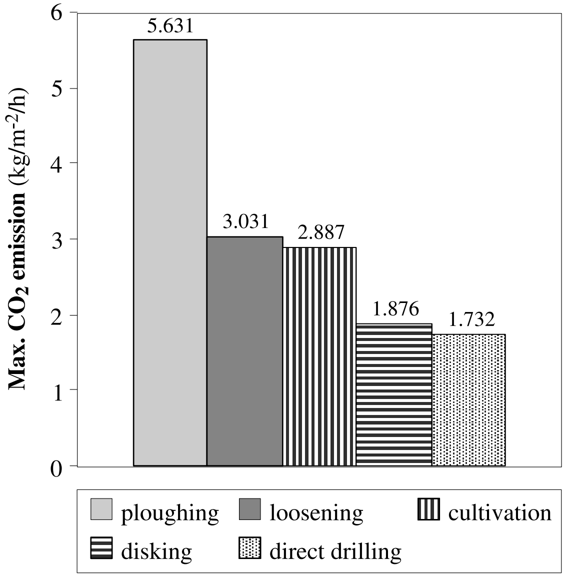


Figure 7. CO_2 emission at different soil tillage practices after sowing (Józsefmajor, 04. 10. 2004.)

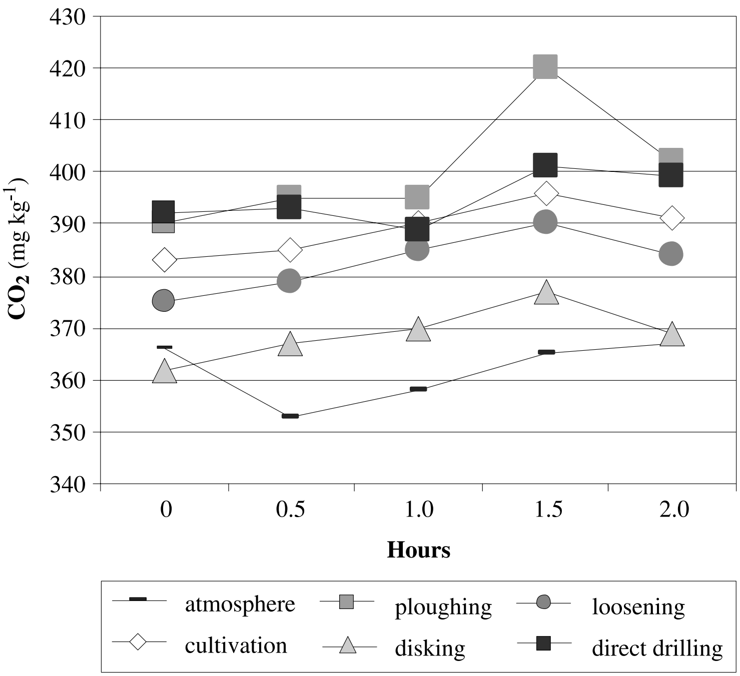
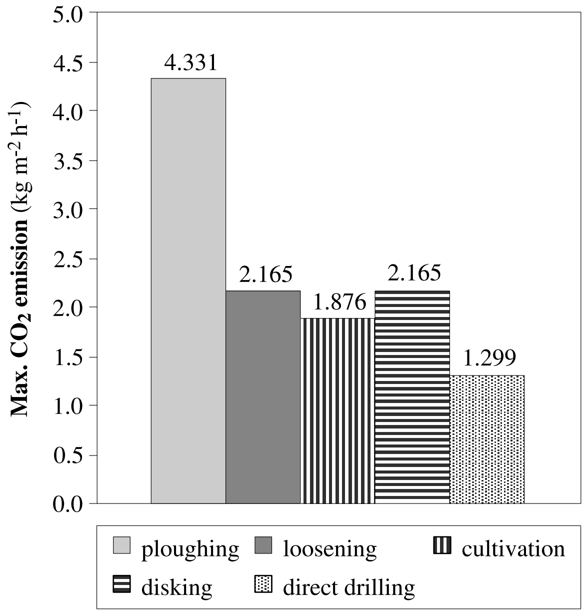


Figure 8. Maximum CO2 flux at different tillage methods after sowing (Józsefmajor, 04. 10. 2004.)



The humus content and the intensity of tillage methods closly related to each other, because the airing of soil provide facilities for the increased aerobmicrobiological activity, which go hand in hand with consumption of humus content.

Figure 9. The organic matter content in case of different tillage methods in the year of 2003 and 2006

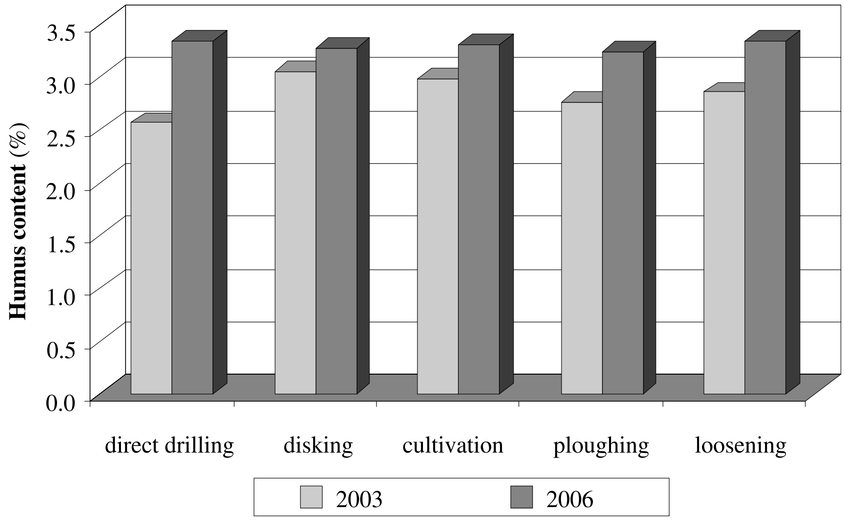


Figure 9. shows the changing of organic matter content in case of different tillage methods during the examination's period. In our experiment the humus content increased in each plots, and the rise was significant in case of application of direct drilling compared to other treatments.
According to our experiment, which examines the carbon dioxide emission from soil at different land use, it can be concluded that the conservation tillage gave the best results compared with the conventional tillage treatments. The carbon dioxide emission is in connection with humus content, it decreases the carbon resources of soil and this is unfavourable for plants and crop production too.

Conclusions

We have proved that in sloping area the protection of soil surface has a favourable effect not only on the soil structure but on the reduction of erosion damages as well. According to the results obtained in case of ridge tillage, it can be concluded that rainwater holding in croplands has an important role just as the prevention of soil, water and humus runoff.
The results of the examination confirmed, that there is a strong relationship between soil tillage methods and soil agronomical texture. It can be concluded, that clodding and dusting can be positively modified by conservation tillage.
The results of soil carbon dioxide emission examinations showed that the lowest emission level was measured in case of conservation tillage. With the reduction of the excessive soil disturbance (intensive soil tillage) the airing of the soil can be decreased, which has favourable effect on humus content.
The results of the examinations confirmed that we have to consider (in case of proper land use) not only the tillage methods' effect on soil but also the suitability of tools and the quality of the soil surface drilling.

Talajkímélő művelési módok

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Magyarország több termőhelyén fordulnak elő olyan degradált szerkezetű, erózió által károsodott talajok, amelyeken eredményes gazdálkodás nem folytatható. Ez arra ösztönöz, hogy e káros folyamatokat mérsékeljük, illetve megakadályozzuk. A talajhasználati módok közvetlenül befolyásolják a talaj szerkezetét és az eróziós és deflációs folyamatokat. Az agronómiai védelem, ezen belül is a talajkímélő talajhasználat lehetőségeit kihasználva megelőzhető, illetve csökkenthető a talaj lepusztulása. Ezáltal a veszélyeztetett, lejtős területeken növelni lehetne a gazdálkodás, benne a növénytermesztés biztonságát.

A globális felmelegedés egyik fő oka – a kutatások szerint – az üvegházhatást okozó gázok, különösen a szén-dioxid légkörbe jutása, koncentrációjának növekedése. Az üvegházgázok légköri koncentrációjának emelkedéséhez a mezőgazdaság is hozzájárul. A nemzetközi állásfoglalások a szén-dioxid kibocsátás csökkentését sürgetik. A megoldást – a szántóföldi növénytermesztésre vonatkoztatva – a környezetkímélő és fenntartható talajhasználat alkalmazása kínálja.
Az kutatás célkitűzései a következők:

1. Lejtős területen a hagyományos és a bakhátas termesztési mód összehasonlítása a csapadék által lehordott talaj, a lemosott humusz és az elfolyó víz mennyiségének alapján és a talaj agronómiai szerkezetére gyakorolt hatásuk alapján.
2. Eltérő talajművelési eljárások hatásának értékelése a talaj szén-dioxid kibocsátására, valamint ezzel összefüggésben a talaj humusztartalmának változására.

Az eredmények a talaj- és környezetkímélő művelési mód alkalmazásának szükségszerűségét igazolják. A kímélő talajhasználat segítségével a talaj szerkezete és humusztartalma megóvható, a légkör mezőgazdaságból származó szén-dioxid terhelése csökkenthető. Fontos szempont lehet lejtős termőhelyen a talajtakaró megőrzése, legalábbis a termesztésre, gazdálkodásra alkalmas szinten.

Kulcsszavak: talajművelés, szén-dioxid kibocsátás, klímaváltozás, erózió, a talaj agronómiai szerkezete.

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