ROLE OF CULTIVATION SYSTEMS IN ENVIRONMENTAL POLLUTION BY CO_2 EMISSION FROM THE SOIL

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SUMMARY

In the last decades the physical and biological status of the soils in Hungary significantly decreased. Contrary to the alternative soil tillage systems, higher mass of soil is moved in conventional tillage. The degree and intensity of CO_2-production of the soil is in close correlation to the structural status and organic matter content of the soil. The principle of alternative tillage systems is the moderated disturbance of the soil resulting in less disturbance of its bio-dynamics, hence higher organic content and better availability of nutrients can be expected. In a complex soil tillage experiment at Karcag in situ measurements have been carried out since 2002 in order to determine the CO_2-emission of the soil, while in a newly set experiment the effect of different residue managements are tested. Our results gained so far show that increased CO_2-emission from the soil can be expected after a sudden change from conventional to reduced tillage system.

INTRODUCTION

Our planet operates as a very complicated and complex system. On changeable CO_2 stock of atmosphere oceans reacts slowly because of their slow blending. In the last two hundred years CO_2 concentration of atmosphere has increased to 80 ppm, till in oceans it average has risen to 8 ppm (Siegenthaler és Sarmentio, 1993). Soil/Biosphere system is very sensitive on environmental conditions changing so its carbon-dioxide admission is not permanent process. While accumulated CO_2 by photosynthesis is close correlation with logarithm of CO_2 concentration of atmosphere, CO_2 emission from respiration has exponential relationship with temperature (Haszpra, 2002).

Soil is the main source and at the same time the potential sink of greenhouse gases (e.g. CO_2, CH_4). Greenhouse gases arise under soil surface and in deeper layers too. Rate and magnitude of gas production from these gas resources are not available, so measurements have to be taken to determine dynamics and effect of these processes.

20 per cent of rising greenhouse gas effect originated from agriculture on the whole it involves 50-75 % methane and 5% CO_2 by anthropogenic greenhouse gases. Forest exploitation, biomass incineration and land use changes influences further 14 % greenhouse gases (Gyuricza et al., 2002). Quadruple carbon stock of biomass from mainland stores the soil (Faragó és Kerényi, 2003). Carbon cycle between soil and atmosphere could be compensated $\pm$ 2-5 Gt C/year by natural fluctuation (Kindermann et al., 1996). Mainland atmosphere can completely compensate carbon fluctuation or it can duplicate the effect of anthropogenic emission in atmosphere which is at around 3.3 Gt C/year (Schiemel et al., 1995).

Soil as planting area serves not only economic purposes, but biodiversity preservation too (Várallyay és Láng, 2000). Sustainable development basis on renewable resources reasonable/rational use, as keeping quality and multifunction of soil which is one of most important challenge for environmental protection and agriculture by Hungary (Várallyay, 2000).

Water under soil surface contains carbon or CO_2 by adsorbed and absorbed forms. Direct or indirect intervention of soil partly conduce mobilisation of carbon stock. Frequent soil cultivation, plough, soil loosening rearrange natural process of the soil. During cultivation one of essential effect is soil airing, which promotes CO_2 mobilization from soil. Optimal case soil cubic content consist of one fourth piece air, one fourth piece water, 45 per cent mineral soil, 5% organic soil. Air which is between different sizes of pore content contains 6 per cent CO_2 (in air: 0.0037 v %). Soil aeration effects greenhouse gas emission (CO_2, CH_4, N_2O) and because of its CO_2 concentration changing it generates higher O_2 concentration so oxidative processes become dominant. This induces detoxification of deeper layer but it induces higher O_2 concentration too so carbon is mobilized. Soil cultivation methods induces disturbances of the soil and changes biodynamic of the soil. However its effect on plant production is contradiction. Tillage reduces organic carbon content of the soil and in the same time increases its CO_2 emission. Cumulative carbon-dioxide concentration become limitation content in the soil because it blocks water, potassium, nitrogen, phosphorus, calcium, magnesium uptake of plants.

Environmental damage factors like soil density, soil powdery, soil crusting, soil impoverishment, high carbon-dioxide emission due to conventional tillage. In spite of these damages only a few agronomic advantage contribute to this cultivation system (Birkás, 2002). Aspect of soil protection is very important to change conventional tillage – basis on twill – to reduced tillage that suitable climate and soil conditions (Nyiri, 1997).

Before every agricultural cultivation intervention knowledge of cultivated area is very important because global problems are solved by understanding local ones (Tamás, 2001).

Reduced tillage is one of the bases of conservation agriculture. Applying alternative soil cultivation methods based on reduced disturbance of the soil more favourable conditions can be created in order to increase the organic matter content of the soil and the availability of the nutrients for the crops. It uses minimal chemicals. However conventional tillage uses a lot of chemicals, and it causes soil impoverishment, soil pollution and other environmental damages like decreasing biodiversity, low energy consumption, and further more contributes global warming (Kertész, 2004). In addition CO_2 emission on arable land highly increases because of regular soil rotation by plough (Reicosky, 1998; Percze, 2002).

Agrotechnical methods indirectly increase CO_2 emission of the soil. Indirect processes like soil degradation (deflation, erosion), land drainage are resources of carbon mobilisation (Gyulai, 2006). Alternative tillage systems advantages are better energy consumption, low mechanical inputs thus dwindle CO and CO_2 emission. Due to SO_2 emission decreases and moderates atmospheric acidity as well. In addition biodiversity grows, soil structure, soil porosity, adsorption capacity are gravelled and appropriate water management. Soil density rarely occurs because of lower mechanical inputs. Soil surface is covered by plant residues so erosion is avoid and organic matters are kept into the soil. Organic matters have significant affect on soil structure, buffer capacity, water retention ability, biological activity and nutrient equilibrium (Holland, 2004). According to carbon content of the soil decrease to 2%, erosion could start (Evans, 1996). Organic content of the soil rapidly fall off by conventional tillage. Estimate of Kinsella (1995) most of agricultural soil lose 50 % of organic matters.

MATERIAL AND METHODS

In the Department for Soil Utilisation and Rural Development of Karcag Research Institute of the University of Debrecen, Centre for Agricultural Sciences and Engineering in close co-operation with the Department of Water- and Environmental Management broad examination of new soil tillage methods was started in 1997 based on the research achievements gained in the past decades. In 2007 a reduced cultivation system and a conventional tillage system were used in that expermet (H-1) of 15 ha divided into two plots (*Figure 1.*). Previously rape occupied the plots. In the case of conventional tillage all the crop residues were baled and removed from the subplot. In the reduced tillage system crop residue covered the soil surface. Correlation was measured between CO_2 emission of the soil in different cultivation systems. The aim of this experiment is to get information about CO_2 cycle at variant soil, cultivation and climate conditions in cropland. In order to determine the effects of the different soil tillage operations as the elements of the prospective reduced tillage systems, we designed and set a new, hopefully long-term, experiment in 2007.

Figure 1.:**Plot H-1**

The experiment was set on two plots. Plot I-2 (*Figure 2.*) of 9.4 ha is divided into four sub-plots according to the treatments. In this experiment tillage systems of direct seeding and reduced tillage based on mulching were compared to the conventional cultivation system based on ploughing. The soil type of the investigated plot is meadow chernozem solonetzic in the deeper layers, a soil type that is characteristic for the Trans-Tisza Region of Hungary.

Figure 2.: **Plot I-2**

Previously winter barley occupied the plot, after harvesting it, the soil tillage operations were carried out as the treatments of the experiment. In the case of conventional tillage all the crop residues were baled and removed from the subplot, then millet was sown conventionally. In the reduced tillage treatments direct seeding was used but three different methods were applied regarding the fate of the crop residues: all residues remained (mulch), remaining mulch and application of a mulch tiller and pure direct seeding with no mulching.

One fraction of the experiment is to investigate the CO_2-emission from the soil and the soil state determined by the tillage operations, hence by measuring the CO_2-emission the effect of various tillage operations as the elements of different soil cultivation systems on the microbiological activity of the soil can be judged.

In order to quantify this, in situ CO_2-emission of the soil was measured by means of an ANAGAS 98 infrared gas analyser. For the spatial delimitation of the measuring area the original cylinders (Zsembeli et al., 2005) were substituted with a newly developed frame+bowl set (*Figure 3.*). Six sets were constructed, hence we could measure in two different points at the same time. There are several methods and tools for the delimitation of the measuring area. In Hungary Tóth and Koós (2006) also developed their own technique, that also accommodate to the requirements of the measuring environment.

After measures we collected data into database by Microsoft Office Excel. So the measured ppm concentration degrees were calculated into CO_2-emission which unit is $g*m^{-2}*h^{-1}$.

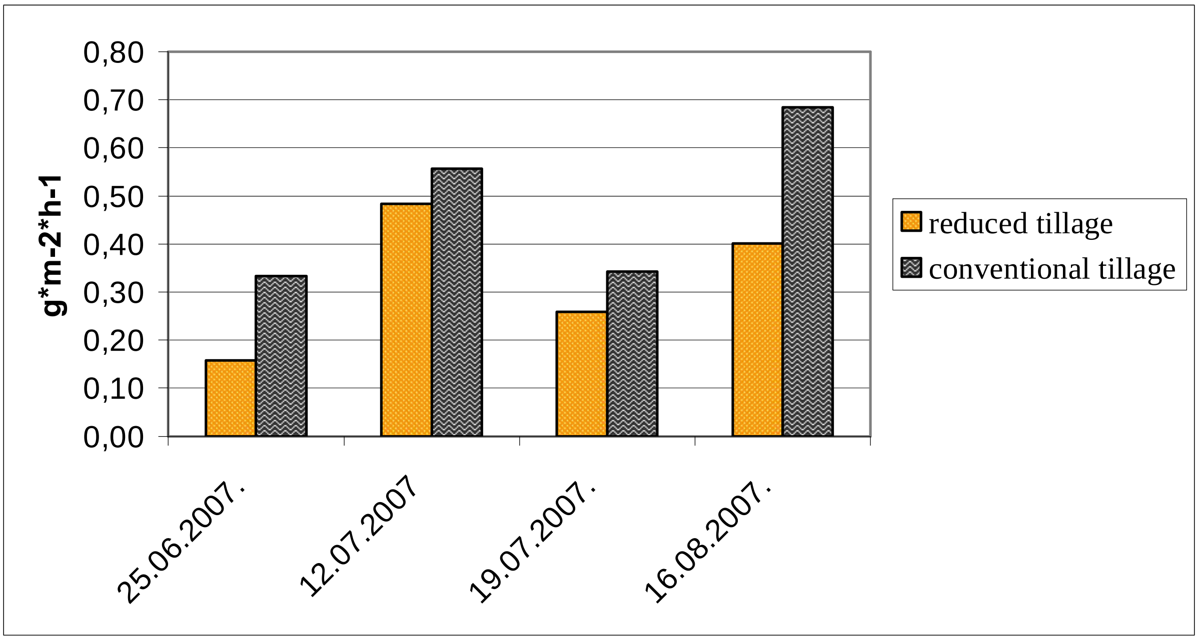
Figure 3.: **The infrared analyser and frame+bowl set**

At the same time soil moisture is measured by TTN-M (40 cm depth), soil thermal (5 cm and 10 depths) and air thermal is measured by digital thermometer. These data are required to discover the relationship between CO_2 emission of the soil, soil and air thermal and soil moisture.

RESULTS AND DISCUSSION

The highest carbon-dioxide emission degrees were calculated in conventional tillage plots instead of plots of alternative tillage systems. In line with higher air thermal, CO_2 emission of the soil was growing too. In addition cultivation differences were shown as well. The data of four measurement dates are indicated, these four measurements were carried out between the middle of June and middle of July, a one-month-long period directly following the sowing of millet. Our goal involved the determination of the differences due to the treatments as well as the duration of their effect. As the microbiological activity of the soil, hence its CO_2-emission are in strong correlation to the moisture content of the soil, we took the amount of precipitation fallen in the investigated period into consideration. In June, before the start of the measurements, 12.8 mm of rainfall was detected, between the first and the second measurements 18.9 mm, while 9.5 mm and 33 mm between the second and the third and between the last two ones respectively. These amounts, which are considered high in the summer period, ensured the relatively high values of CO_2-emission along the investigated period.

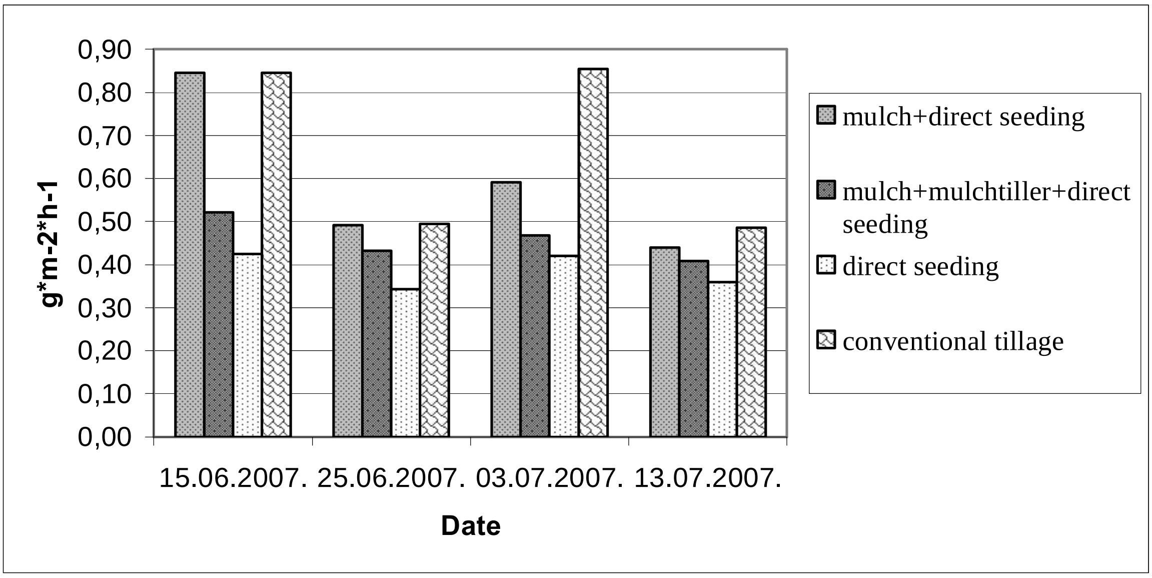
Figure 4.: **CO_2 emission on plot H-1**



In earlier set on long term cultivation experiment (H-1) higher CO_2 emissions were calculated than it used to (*Figure 4.*). Reasons of this strange result are investigated. There wasn't remarkable difference between the crop yields in variant cultivating plots but in ploughed plot were bigger root weigh and deeper root development. The case of conventional tillage all the crop residues were baled and removed from the subplot so it could be influential factor.

Our data, gained in other experiments previously, showed that in dry periods the CO_2-emission increasing effect of different soil cultivation operations lasts 6-10 days only. This duration is in correspondence with the literature data (Franzlubberz et al., 2000; Fieber and Schiemel, 2003). Nevertheless *Figure 5.* shows no significant decrease in the absolute values, but the differences originating from the soil tillage treatments were remaining during the investigated period. In accordance with the literature, all the tillage operations induced increased CO_2-emission. The highest values were detected in the case of the conventionally cultivated, in other words ploughed plot, and this highest value was characteristic all along the investigated period. This was an unexpected result as reduced tillage is considered to be resulted in higher emission. Of course the shortness of the investigated period and the high amount of precipitation can not let us to conclude general conclusions, but there is no doubt that we gained remarkable results about the correlation between the soil status and the CO_2-emission from the soil. These results motivate us to continue our investigations.

Figure 5.: **CO_2 emission on plot I-2**



After changing cultivation system – from conventional cultivation system to alternative tillage – CO_2 emission of the soil maybe increases for a temporary period (few years). These promising measurements are being continued at different weather and hydrologic conditions and soil surfaces.

The degree and intensity of CO_2 emission of the soil is strong correlation with soil structure and its organic matters. Our results generated from the CO_2 emission measurements can contribute to the reveal of environmental pollution of CO_2 emission of the soil, hence agriculture could be developed pursuing an environmental friendly way in the future by the use of alternative tillage systems.

REFERENCES

Birkás M. (2002): Környezetkímélő és energiatakarékos talajművelés, Szent István Egyetem, Gödöllő.

Evans R. (1996): Soil Erosion and its Impacts in England and Wales. Friends of the Earth. London.

Faragó T.-Kerényi A. (2003): Nemzetközi Együttműködés az éghajlatváltozás veszélyének, az üvegházhatású gázok kibocsátásának csökkentésére. Környezetvédelmi és Vízügyi Minisztérium és Debreceni Egyetem. 7-10.p.

Fierer N.-Schimel, J. (2003): A proposed mechanism for the pulse in carbon dioxide production commonly observed following the rapid rewetting of a dry soil. Soil Sci. Soc. Am. J. 67:798-805.

Franzluebbers, A.-Haney, R.-Honeycutt, C.-Schomberg, H.-Hons, F. (2000): Flush of carbon dioxide following rewetting of dried soil relates to active organic pools. Soil Sci. Soc. Am. J. 64:613-623.

Gyuricza Cs.,-Birkás M.-Jóri J. I. (2002): Művelési rendszerek hatása a talaj CO_2 kibocsátására (*Tillage-induced CO_2 emission from soil*). Innováció, a tudomány és a gyakorlat egysége az ezredforduló agráriumában. SZIE–DE ATC, Debrecen, 2002 április 11-12. Kiadvány (szerk. Jávor A., Pepó P.), 57-62.p.

Gyulai I. (2006): A biomassza dilemma. Magyar Természetvédők Szövetsége 40-46.p.

Haszpra L. (2002): A légköri szén-dioxid-koncentráció méréseinek újabb eredményei. Kutatás és környezet.

Holland J. M. (2004): The environmental consequences of adopting conservation tillage in Europe: reviewing the evidence. Agriculture, Ecosystems and Environment 103. 1-25.p.

Kindermann J., Würth G., Kohlmaier G. H. and Badeck F. W. (1996): Interannual variation of carbon exchange fluxes in terrestrial ecosystems. Glob. Biogeochem, Cycles, 10, 737-755.p.

Kertész Á. (2004): A környezetkímélő mezőgazdálkodás hatása a tájra, MTA Földrajztudományi Kutató Intézet, 783-792.p.

Kinsella J. (1995): The effects of various tillage systems on soil compaction. Farming For a Better Environment: A White Paper. Soil and Water Conservation Society, Ankeny, IA. 15-17.p.

NyiriI L. (1997): Az aszálykárok mérséklése, Mezőgazda Kiadó, Budapest.

Percze A. (2002): Az őszi búza gyomviszonyainak vizsgálata talajművelési tartamkísérletben gödöllői barna erdőtalajon, Növénytermelés (megjelenés alatt).

Reicosky D. C. (1998): Tillage and short-term CO_2 emissions from soils in the laboratory, Kézirat.

Schiemel D.-Alves D.-Enting I.-Heimann M.-Joos F.-Raynaud D.-Wigley T.-Prather M.-Derwent R.-Eehhalt D.-Fraser P.-Sanhueza E. Zhou X.-Jonas, P., Charlson R.-Rodhe, H.-Sadasivan, S., Shine, K.P., Fouquart, Y.-Ramaswamy V.-Solomon S.-Srinivasan J.-Albiritton D.-Isaksen I.-Lal M.-Wuebbles D. (1996): Radiative forcing of climate change, In: Climate change 1995 (eds.: Houghton J. T., Meira Filho L. G., Callander B. A., HarrisA., Kattenberg A. and Maskell K.), 65-132.p.

Siegenthaler U.-Sarmentio-Jéki L. (1993): Atmospheric carbon dioxide and the ocean. Nature, 365, 119-125.p.

Tamás J. (2001): Precíziós Mezőgazdaság, Mezőgazdasági Szaktudás Kiadó, Budapest. 56.p.

Tóth E. – Koós S. (2006): Carbon dioxide emission measurements in a tillage experiment on chernozem soil. Cereal Research Communications. Vol. 34. No. 1. 331-334.

Várallyay GY. (2000): Talajfolyamatok szabályozásának tudományos megalapozása. In: „Székfoglalók", Magyar Tudományos Akadémia. Budapest, 1-32.p.

Várallyay GY.-Láng I. (2000): A talaj kettős funkciója: természeti erőforrás és termőhely, A Debreceni Egyetem „Honoris Causa" cím átadása alkalmából (Debrecen, 2000. május 2.) megtartott előadás.

Zsembeli J.-Tuba G.-Juhász Cs -Nagy I.(2005): CO_2-measurements in a soil tillage experiment. Cereal Research Communications. Vol. 33. No. 1. 137-140.