ENVIRONMENTALLY-SOUND ADAPTABLE TILLAGE – SOLUTIONS FROM HUNGARY

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Abstract
In the last centuries, the need for tillage was to provide suitable soil conditions for plant growth (crop-focusing tillage). During the last decades, traditional goals of soil tillage have really been improved considering environmental consequences (environment-focusing tillage). In the next decade a new task is stressed, that is mitigating the climate induced losses (climate-focusing tillage). New challenges for the future are prevention of tillage-induced soil quality deterioration, and to reduce climate induced damages by the use of environmentally-sound adaptable tillage. In the adaptable tillage program ten important steps are suggested, namely: (1) Risk assessment in the fields. (2) Prevention of tillage induced defects affecting climate stresses. (3) Maintaining an optimal soil physical and biological state and fertility. (4) Use soil structure conservation methods in any seasons. (5) Mulch the surface at least in summer. (6) Improve soil loading capacity connected with carbon conservation. (7) Utilize stubble residues rationally. (8) Maintain an optimal water management in soils by the soil state improving. (9) Create small water-loss surface at tillage operations. (10) Improve a harmony between soil disturbance and environmental requirements.

Key words: environment, tillage, adaptability, soil quality, climate mitigation

Introduction
Throughout the last 100 years, the tillage philosophy in Hungary can be characterized as a fight against extreme climatic and economic situations (Birkás et al., 2004, 2007). In the past, the need for tillage was to provide suitable soil conditions for plant growth (namely crop-focusing tillage). During the last decades, traditional goals of soil tillage have really been improved considering deterioration of soil quality and (Dexter, 2004, Várallyay, 2007) the environmental consequences (namely environment-focusing tillage). In the next decade a new important task is stressed, that is mitigating the climate induced losses (namely climate-focusing tillage). In the next decade three important tasks are stressed, that is prevention of tillage-induced soil quality deterioration, and to decrease climate induced damages by the use of environmentally-sound adaptable tillage.

Material and methods

This paper based on soil condition monitoring and measuring that started 32 years ago in Hungary by Department of Soil Management at Szent István University Gödöllő (Birkás et al., 2004). Field trials have also been running in frame of long term project at different experimental sites in which soil condition aspects of variants of tillage systems are studied. Conventional (P), soil condition improving (L, C), shallow (D), and direct drilling (DD) tillage variants are included in each of the sites. The trials involved the production of crops such as winter wheat, maize and soil state improving crops (phacelia, mustard). The trials were set, the tillage versions were arranged and the measurement of the soil condition parameters at each of the sites in accordance with the relevant standards and regulations (Tóth et al., 2005; Jug et al, 2007, Birkás, 2008). The amount of evaporated water during the period (E) was measured in accordance with the formula worked out by Szász and Tőkei (1997): $E = W_0 - W + P$; where W = the soil moisture content at the end of the period concerned; W_0 = the soil moisture content at the beginning of the period concerned and; P = precipitation during the period. The importance of the environmentally-sound adaptable tillage is discussed below.

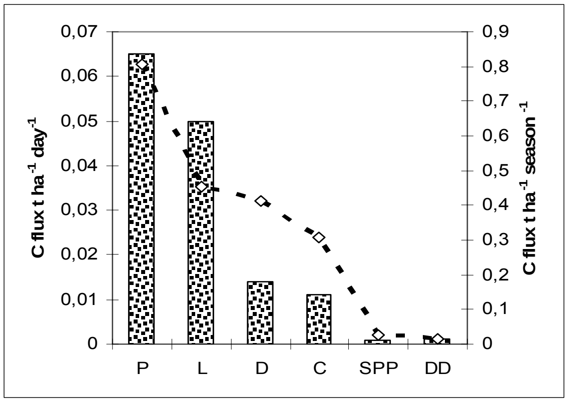
Results and discussion

Role of soil quality
According to authors, quality of a soil is characterised by the relationship between its physical state, biological condition and fertility (e.g. Dexter, 2004; Karlen, 2004). Any material change in any of these will affect the others and this may result in upsetting the ‘harmony’ among these elements. If the soil is too compact not only will its biological state decline but its water transport characteristics, the process of decomposition making nutrients available, as well as the availability of nutrients will also be restricted and finally even its very suitability for crop production will be undermined. Extreme physical and biochemical soil conditions qualify as environmental damage deteriorating the quality of life through reducing the standards of production as well.

Carbon-dioxide emission
In view of the given processes of climate change C-flux is considered to be a new soil condition and tillage quality factor. Soil disturbed to greater depths releases more carbon. In our case the C loss of soil equals some 50-60 kg ha^{-1} (P, L) measured over a period of three days (Figure 1), lower than data in the literature (e.g. Koós et al., 2005, Tóth and Koós, 2006), since in our experiments primary tillage was always followed by surface preparation. We found low rates of carbon loss after mulch tillage (11-14 kg ha^{-1} at D, C), and the lowest (1.1) at DD. Similar differences are found in seasonal C flux. In the case of primary tillage the soil carbon-dioxide flux is affected by: (1) soil disturbance (depth, mode), (2) surface cover, (3) soil moisture, (4) the temperature on

the top and in the soil, (5) crop residues mixed into the soil, and (6) wind.

Figure 1 C flux at different tillage variants (Hatvan, 2002-2007)

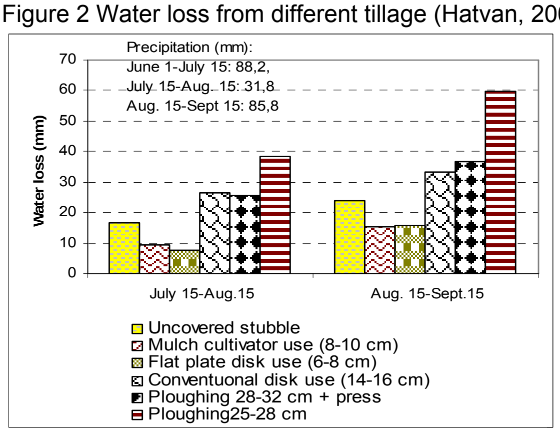


Legend: P: Ploughing + preparation, L. Loosening + preparation, D: Disking + preparation, C: Cultivator use, SPP: Seedbed preparation and plant, DD: Direct drilling

Role of soil water conservation

The importance of reducing water loss is underpinned by the necessity of creating favourable biological soil conditions (mellowing; encouraging the decomposition of crop residues) at the beginning of the growing season as well as by the need to improve workability, whereby mechanical damage and the energy intensity of tillage can be reduced. Summer tillage operations can be assigned to groups in relation to land surface incline and surface cover, on the basis of moisture loss (Figure 2). We found that quick alternation of wet and dry periods and higher precipitation rates do not reduce the importance of soil water conservation. More emphasis should be laid on leaving mulch cover on the fields after harvest and on covering the surface even after sowing. In the system of producing a given crop efforts aiming to mitigate climate damage should be started by stubble treatment practices, since this is the period during which the soil can rest and recover.

Figure 2 Water loss from different tillage (Hatvan, 2007)



Environmentally-sound adaptable tillage

Soil protection comprises preventing soil damage and improving as well as preserving the soil physical and biological condition to keep up the quality of the environment and to maintain the standards of farming. The state of soil resulting from tillage and farming in general over a shorter or a longer period of time must not be harmful to the environment.

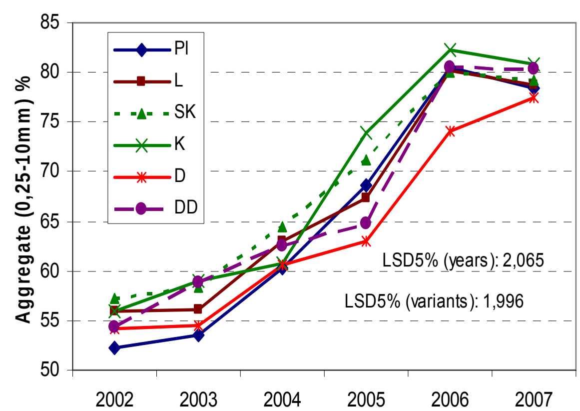
Environmental factors related to tillage are:

- soil looseness,
- soil aggregation,
- water conservation,
- soil surface conservation,
- carbon-dioxide flux,
- OM and carbon (C) conservation,
- conserving earthworms habitat.

Soil looseness. Factors improving soil looseness (state free from compaction) in the trials were as follows: (1) depth of tillage from 0 to 45 cm; (2) use of a soil structure conservation method (Fig.?); (3) mulch on the surface out of the growing season; (4) reduce soil load; and (5) use crops with different rooting depth.

Agronomical structure. At the beginning of the trial average ratio of the clod:aggregate:dust were 35:55:11 %, which is considered to be medium (optimal aggregate rate >70%). The aggregate ratio has steadily increased over the years, with a 13:79:8 % ratio in the sixth season. On average, the tendency of the aggregate % is optimal however differences occur between tillage methods (Figure 3).

Figure 3 Trend of soil aggregation at different tillage methods and under different plants (Hatvan, 2002-2007)



Legend: Pl: ploughing, L: loosening, SK: shallow cultivatoring, K: cultivatoring, D: disking, DD: direct drilling. Crop sequence: 2002: mustard, 2002/2003: w. wheat, 2003/2004: rye, 2004: pea, 2004/2005: w. heat, 2005: mustard, 2005/2006: w. wheat, 2006: phacelia, 2007: maize

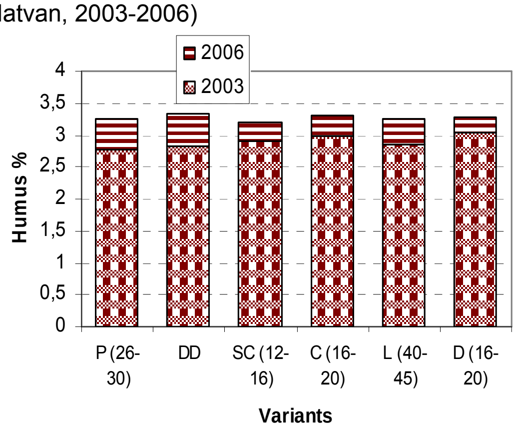
Factors improving aggregation were: (1) structure-conserving tillage with less clod and dust formation. (2) prevention of compaction. (3) decrease of water loss by surface mulching. (4) traffic minimization and correct-timing of soil disturbance. (5) cash and catch crop growing, their residues being used for mulching and recycling. (6) prevention of both soil drying and water-logging. As we stated, wide row cropping may limit or hinder the aggregation of soil.

Water conservation. As Macák (2001) noted, the moisture balance (rate of the use and the loss or rate of the intake and the loss) is influenced by soil condition. In our experiments factors improving water management are: (1) loosen soil layer at least to 20 cm and surface cover of 30 % at least, moderate surface roughness to prevent soil slumping, and at least a moderate plant biomass or yield. (2) deeper loosened soil layer and a smooth, non-compacted surface to be suitable both for water infiltration and conservation. (3) minimized soil disturbance and surface cover of 50 % at least. The soil moisture loss was decreased significantly by the use of mulch tillage combined with soil loosening.

Soil organic material. The balance of humus ratio in soil has important role both in water conservation and climate damage mitigation. In the trial all tillage variants are adaptable to OM conservation (Figure 4). In this fact both stubble residues recycling, reduced soil disturbance and surface cover had important role. Progress in soil humus content was remarkable, that is (in average of tillage variants): 1983 (2.73%), 2003 (2.79%) 2006 (3.27%).

Earthworms. Number and activity of earthworms can be used to quantify soil condition. In our trials, factors that promoted earthworm activity are: (1) soil loosening with less disturbance; (2) maintaining a humid, non-dried conditions during summer; (3) surface mulching after harvest; (4) stubble residue recycling; (5) biological loosening (mustard, phaelia); and (6) less chemicals (used integrated farming).

Figure 4 Soil conservation impacts on humus content (Hatvan, 2003-2006)



Legend: P: ploughing, DD: direct drilling, SC: shallow cultivatoring, C: cultivatoring, L: loosening, D: disking, (26-30): depth of tillage; $p = < 0.05$

The concept – environmental impact or environment capability or environmentally-sound – was created in putting together the new guidelines for tillage. A tillage process qualifies as being *environmentally-sound* if it does not cause damage (e.g. compaction, re-compaction, heavy clodding, pulverising, loss of OM and water) and if its final output (e.g. depth, loosening, improving/protecting effects, long lasting effects, leaving mulch cover etc.) is highly likely to meet soil and environment protection regulations in addition to lying the groundwork for cropping (Birkás, 2008).

Adaptation in tillage means adjustment to environmental and economic conditions. Introducing adaptable tillage foresight or recognition of facts is more favourable and more encouraging than actions taken under the pressure of losses already suffered. For this reason environmentally-sound adaptable tillage is based on applying economical and conserving techniques in producing crops best suited to the given site and conditions as well as circumstances of farming in general, that do not lead to increased risks of production even over a longer run.

In Hungary, the adaptable tillage program points ten important steps in the near future, namely: (1) Risk assessment and risk knowledge in the arable fields. (2) Prevention of tillage induced defects affecting climate stresses (compaction, soil pulverisation). (3) Maintaining an optimal soil physical and biological condition and fertility. (4) Use soil structure conservation methods in any seasons. (5) Mulch the surface at least in summer. (6) Improve soil loading capacity connected with organic material and carbon conservation. (7) Utilize stubble residues rationally (for surface mulching and then recycling. (8) Maintain an optimal water management in soils by the soil state improving tillage. (9) Create small water-loss surface at tillage operations (this fact will be critical not only during summer, but during winter as well). (10) Improve and maintain a harmony between soil disturbance (as crop production requirement) and environmental requirements.

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