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Conservation tillage for rational water management and soil conservation

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Abstract

Flooding and waterlogging events showed a frequency rising sharply during the last decades so their prevention has become a very actual task. Prevention should start where surface runoff is generated, i.e. over the areas used for agriculture and forestry of hilly and mountainous watersheds. Conservation agriculture is a very successful method for keeping rainwater in the soil and for decreasing the sediment and nutrient load of surface waters. The increased amount of soil moisture is favorable both for the plants and for soil fauna. The mitigation of runoff, soil and nutrient loss is due to the organic matter which remains in the topsoil as it is not disturbed and moved downwards in the soil by ploughing as well as to the activities of soil edaphon. By applying non-inversion, shallow tillage runoff can be reduced to a mere one third and soil loss to the thirtieth-fortieth of the values measured under conventional tillage, depending on weather conditions of the given year. Experiments show that conservation agriculture provides for profitable production and at the same time it is beneficial for the environment.

Keywords*:* conservation agriculture, soil erosion, water management, flood

Introduction

As it is well known the occurrence of extreme rainfall events is related to climate change. Global warming is detectable also at regional scales. Warming trends in seasonal average values and mainly drying tendencies in seasonal precipitation have already been established in country-wide observations in Hungary (Szalai, S. *et al.* 2005; Bihari, Z. *et al.* 2007). According to these analyses the warming trend is the strongest in winter and summer, whereas the drying trend is valid in all seasons but in summer. Both the overall warm-

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ing and the overwhelmingly drying tendencies lead to deteriorating water balance and to an increasing water deficit. Besides these tendencies of seasonal averages, the daily precipitation data show a paradoxical behaviour. Parallel to drying in the long run, the number of rainy days with an ample amount of precipitation increases, leading to more frequent peak values that sometimes even result in flash floods (Gyuró, Gy. *et al.* 2007). Both the long-term, regional climate tendencies and the occurrence of dry and wet extremities due to global warming make the soil surface more vulnerable; that is why proper and sustainable land use will be extremely important. Modelling studies support the above statements. The frequency of frost days, expected to decrease with large-scale warming does not support the anticipated negative tendency (Mika, J. and Lakatos, M. 2010)

In the spring and summer of 2010 intensive rainfall events occurred throughout the country. Soil erosion and runoff from the slopes of the hills and mountains, floods and inundations on valley bottoms and in the plains have caused extensive damage and misery to those directly affected and also did harm to the national economy.

The question is whether all have been done to mitigate the damage. Looking at the events of 2010 it is obvious that no adequate precaution measures were undertaken. During the last few decades there were no financial sources available for water management and regulation in agricultural areas. The prevention should start at the places where runoff is generated, i.e. in the hilly countries and mountains used for agriculture or sylviculture.

Regarding flood prevention the floodplain is generally referred to (e.g. technical problems, such as construction on floodplains, lack of maintenance and water management investments etc.), but as a rule nothing is said about how to increase the water holding capacity of the catchment areas. Cattle and pig stocks of Hungary have gradually decreased below 40% of the stock 30 years before (Horn, P. 1997). Monocultural crop production alternating with oil crops is quite typical today. Besides their great stem volume maize and sunflower growing is unfavorable from the aspect of soil conservation. Ploughing depth doubled between 1965 and 1985 in order to increase crop capacity. The related tillage technology and the application of a huge amount of fertilizers resulted in a spectacular increase of plant volume and grain crop (Kádár, I. 1997). In line with the achieved results cultivation costs increased as well, while soil edaphon was damaged, humus content decreased, soil structure deteriorated, ground and surface waters were polluted to a harmful degree (Szabó, L. 1996; Várallyay, Gy. 2004). The change of the water management system leads to extremities even within one season. After ploughing favourable infiltration conditions of the rainwater can be expected in autumn and winter, however, in spring soil aggregates tend to fall apart and they may be washed off. Even a rainfall event of low intensity may cause runoff and soil loss (Birkás, M. 2002).

Soil erosion research based on measurements and observations started in the last century (Ádám, L. 1967; Ádám, L. 1975; Erődi, B. *et al.* 1965; Pinczés, Z. 1968). Results of this research were not adopted in the practice, i.e. prevention measures were not performed. During the socialist era quite a few soil conservation projects (e.g. contour tillage, shrub belts) were elaborated and successfully implemented at various locations. After the change of regime in 1989 most of these schemes created in the framework of the previous soil conservation projects became abandoned. The objective of the present paper is to show the benefits of conservation tillage for the environment under the conditions of climate change with a special emphasis on water management.

Soil, water and nature conservation from the aspect of agricultural production

It is well known that improper tillage destroys soil structure and soil aggregates and thus it may lead to colmatation. With topsoil inversion the majority of the living edaphons get from an optimal to a less favourable soil layer, in terms of temperature, oxygen, water and/or nutrient supply. Possibly mechanical tillage does not pose a threat for the quickly reproducing microflora and microfauna (up to 200 micron), if the soil aggregates are not damaged. Contrary to microflora and microfauna, macro and megafauna (2–20 mm) can get injured or even perish due to the mechanical disturbance of plough (inversion). If they get to an unfavourable place, they need considerable time to get back to the original layer and build out their routes. Only then they are capable to perform their tasks in maintaining biocoenoses. According to soil biologists the total weight of all living organisms in the upper 15 cm of the soil is 25 tons per hectare. Microflora (bacteria, fungi, algae) adds up to ca 20 tons, soil fauna accounts for ca 5 tons (Fehér, D. *et al.* 1954). This quantity has an important effect on agricultural production. Soil conservation is also concerned about living organisms in the soil, not only about the physical state of the soil.

Tillage is a mechanical operation which destroys soil structure and along with rainfall intensity it is the main influencing factor of soil erosion in hilly regions (Bádonyi, K. 2006a). The farmer is not always the owner of the cultivated land, rather its user, and in his decisions he prefers the more „economic" interventions at the moment to the long term effects. Such an example is when the autumn deep ploughing in hillslope direction carried out on wet soil, results in micro relief driving down the precipitation during the season from autumn to early spring. Soils cultivated this way dry out quickly and in a cloddy way in spring, after disking the clods become dusty and are looking forward to be drilled with decimated soil fauna. Their surface is silting up and crusting after the first heavy rainfall event. Its consequence during production is water, soil, nutrient and herbicide lost. All of them load surface waters.

Conservation tillage

In the middle of the last century prominent Hungarian experts (Manninger, Fehér, Frank, Kreybig, Szabados, Várallyay; Fehér, D. *et al.* 1954) underlined the favourable effect of non inversion tillage under dry conditions. The technical development of machinery and the availability of more effective herbicides provide a good basis for the application of the method. Non inversion tillage (minimum tillage, no-tillage) was introduced, also for economic reasons first in the U.S. and later in Western Europe.

In the topsoil of chernozem in primeval state the proportion of water stable soil aggregates larger than 1 mm is 40%, which is one order of magnitude higher compared to cultivated arable soils (according to the experiments by Dvoracsek, in Kemenesy, E. 1961). Kemenesy had established that this primeval state could not be restored when annual crops were grown. The state of water soluble aggregates can be improved and non-inversion tillage technologies can offer the solution for this improvement.

Conservation tillage avoids inversion and uses shallow discs and subsoiler instead. An important component of the technology is the perfect chop and partial shallow incorporation and rolling of plant residues after harvest. Organic plant residues (mulch) left on soil surface have a fundamental role in the protection against soil erosion. Drilling is carried out with a shallow seedbed preparation and/or direct driller. Weeds are not treated as a hindering factor from every respect because the application of post-emergent herbicides they can play a positive role in the prevention from soil erosion. Conservation tillage aims at providing survival, reproduction and optimal life conditions for soil fauna inhabiting different soil layers (Bádonyi, K. *et al.* 2008a). The role of soil fauna and conscious use of its functions are essential in establishing the optimal (stable aggregated) structure of the soil. Non-inversion tillage does not damage these layer-specific organisms. Organic material will be transported to the appropriate layer and transformed to humus by the help of its symbiotes. A macropore system will be established, which is capable to absorb rainwater quickly and it plays an important role in the aeration of soil as well. Plant residues protect the soil surface, keep the macropores open and at the same time provide natural nutrition for macrofauna (*Photo 1)*.

What advantages can be expected from conservation tillage?

1. Better rainwater storage on the fields, which increases specific yield compared to the ploughed fields.

2. Less runoff and soil loss (better soil protection), more nutrients and herbicides remaining on the fields.

Photo 1. Macropores on the Conservation (a) and Conventional (b) tilled plot

3. More habitable environment, less surface water and environmental pollution (surface water protection is expanded to the whole catchment area).

4. Maintenance of biological diversity (Field, R.H. *et al.* 2007).

5. Production of better quality food raw material.

6. Less CO_2-emission from the agricultural machines due to the reduced soil tillage.

7. Decreasing CO_2-emission from the soil due to shallow tillage, up to an order of magnitude, or even more in very hot and dry periods (Zsembeli, J. *et al.* 2006; Birkás M. *et al.* 2007), and to the reduced use of artificial fertilizers (ca. 25%: Koós, S. and Németh, T. 2007).

Methods

Plot studies

The main objective of the experiments carried out in the catchment of Zala river since 2003 (Bádonyi, K. *et al.* 2008a; Bádonyi, K. *et al.* 2008b; Kertész, Á. *et al.* 2010; Madarász, B. and Kertész, Á. 2010) is to compare the effects of conventional (inversion) tillage and conservation (non-inversion, shallow) tillage on two levels:

1. medium size (1200 m^2) plot experiments on soil loss, runoff and nutrients (two treatments, two replicas) at Szentgyörgyvár;

2. large plot experiments (18 plots, 4–5 ha each) on crop production at Dióskál.

The soil erosion measurement station was established in 2003 as an experimental site to attain the objectives outlined above. It is special in size (each plot is 50x24 m = 1200 m^2). This size allows cultivation carried out by the common farm machinery. Contour tillage was applied here to protect the soil on a gentle slope of 10–11%. Since October 2003 the two outer plots have been cultivated in a conventional way (inversive ploughing), while conservation tillage (non-inversion shallow disking) has been applied on the inner plots. The description of the experimental site is given in previous publications of Bádonyi, K. 2006b; Bádonyi, K. *et al.* 2008b and Kertész, Á. *et al.* 2010.

For plot bounding 3 mm thick iron sheets were used at a length of 496 m (!), which were removed before tillage and replaced afterwards. This provided more favourable conditions for measurements than the Wischmeier plots (Wischmeier, W.H. and Smith, D.D. 1978), first of all because the "damage" caused to the soil by removing and replacing the sheets is less by one order of magnitude *(Table 1).*

Table 1. Perimeter, area and fence length ratio of selected rainfall simulator plots and field erosion plots

Plot	Perimeter (m) (P)	Area (m^2) (A)	P/A (m/m^2) (R)
Kazó-type rainfall simulator[1]	1.8	0.3	7.09
Leuven-type rainfall simulator[2]	3.0	0.6	5.36
PANNON-R2 rainfall simulator[3]	16.0	12.0	1.33
Wischmeier plot[4]	48.3	44.3	1.09
Szentgyörgyvár experimental plot[5]	148.0	1200.0	0.12

[1] Kazó, B. 1966; [2] Poesen, J. *et al.* 1990, 1995; [3] Jakab, G. és Szalai, Z. 2005; [4] Wischmeier, W.H. és D.D. Smith 1978; [5] Bádonyi K. *et al.* 2008b.

Surface runoff is captured by a collecting system (Bádonyi, K. *et al.* 2008b; Kertész, Á. *et al.* 2010). With this solution we could measure a 95–97 mm runoff of a ca. 100 mm rainfall event. The amount of runoff water and that of the eroded soil were determined. Organic carbon and nutrient contents were identified during 2004–2006.

Climate change studies: characterization of year-types

Effects of conservation tillage on runoff and soil loss depend on weather conditions of the given year. This aspect can be investigated in the following way.

a) The two years of wheat production (2004 and 2007) were pre-selected and retained for comparison. The four years of maize production (2006, 2008, 2009, and 2010) are treated separately, together with the single year of sunflower production (2005). This addition is explained by the fact that sunflower exhibits similar features to those of maize with respect to water and soil conservation.

b) Summer half-year temperature and precipitation averages are calculated for each year, including the De Martonne aridity index (Dunkel, Z. 2009). This index combines precipitation (mm) and temperature (°C) by the equation: DM (P, T) = P/(T+10).

c) This index divides the seven years into three groups effectively as presented in *Figure 1*. The two years with the highest index values for WET years (2005, 2010), covered by maize, are separated from the three DRY low-index (2006, 2008 and 2009), maize-covered years by the two INTERMEDIATE, wheat-covered years (2004, 2007). *Table 2* indicates average climate characteristics of these groups, starting from the temperature and precipitation to the De Martonne index. This subdivision of the seven years of investigation is later compared to expected climate scenarios to interpret the observed differences in terms of climate change.

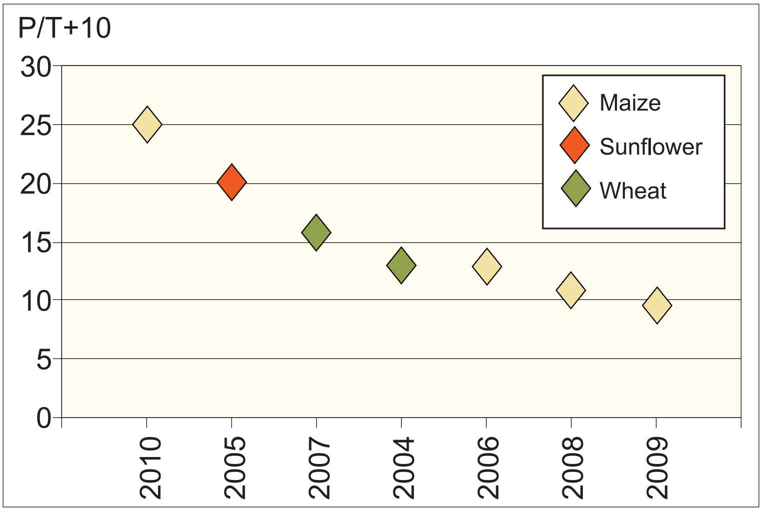

Fig 1. De Martonne aridity index of the summer half-year with different plant cultures at Szentgyörgyvár. The years from left to right: maize (orange mark) – 2010; sunflower (red) – 2005; winter wheat (green) – 2007, 2004; maize (orange, again) 2006, 2008, 2009

Table 2. The three year-types selected from the seven years (2004-2010) at Szentgyörgyvár

Year-types (summer half-year)	Temperature	Precipitation	De Martonne index
WET and COOL with maize (2010, 2005*)	16.2	585	22.3
DRY with maize (2006, 2008, 2009)	17.4	305	11.1
INTERMEDIATE with wheat (2004, 2007)	18.3	414	14.6

*sunflower in 2005, which is similar to maize from erosion and runoff point of view. (See the text for explanation.)

Table 3. Total amount of runoff and eroded soil at the experimental site of Szentgyörgyvár

Years	Rainfall (mm)				Runoff (mm)		Runoff rate	
	Total(A)	Leading to runoff (B)	B/A	No. of rainfall events with erosion	Conv.	Cons.	Conv.	Cons.
2004–2006	1859.6	625.4	0.336	27	130.5	45.6	0.209	0.073
2007–2009	1805.4	653.7	0.362	31	26.2	9.4	0.040	0.014
2004–2009	3665.0	1279.1	0.349	58	156.7	55.0	0.122	0.043
Average/year	611	213		10	26.1	9.2		
Years	Soil loss (t/ha)			Infiltrated water (mm)			Infiltration rate	
	Conv.	Cons.	Cons/Conv	Conv.	Cons.	Cons/Conv	Conv.	Cons.
2004–2006	10.95	0.35	0.032	494.9	579.8	1.172	0.791	0.927
2007–2009	1.54	0.58	0.379	627.5	644.3	1.027	0.960	0.986
2004–2009	12.49	0.93	0.074	1122.4	1224.1	1.091	0.878	0.957
Average/year	2.08	0.15		187	204			

Results

During the six years of measurement (2004–2009) annual mean precipitation amounted to 611 mm. 35% of it caused nearly tenfold measurable runoff on the plots *(Table 3).* Total rainfall amount was roughly the same during years 1–3 (2004–2006) and 3–6 (2007–2009). There was no significant difference between rainfall amounts causing runoff. However, there were significant differences between treatments concerning runoff and soil loss.

During the six years of the experiment on the conventional plots 157 mm, on the conservation plots 55 mm runoff was recorded, i.e. runoff was 2.85 times higher on the conventional plots than on the conservation plots. Rainfall events had roughly the same erosive effect throughout the whole measurement period. Concerning runoff there is a remarkable difference between the first and second halves of the observation period. In the first three years (2004–2006) runoff volume was five times more than in the second period (2007–2009). Rainfall events of higher intensity during the first period were responsible for this.

The average soil loss was 12.5 t/ha from conventional plots and only 0.93 t/ha from the conservation plots (7.4%). Four heavy rainfall events of the first period were responsible for 90%

of soil loss on conventional and 66% of that on conservation plots. In the second period rainfall intensities rarely exceeded the water holding capacity of the soil. It is not by chance that 88% of the total eroded soil was recorded during the first period, when 27 rainfall events occurred, from the conventional plots runoff was 130.5 mm, from the conservation plots only 45.6 mm. In the first period the soil of the conservation plots was able to receive an average of 28.3 mm more rainwater annually. A greater proportion of runoff water was available for the crops, while soil and nutrient loss were reduced *(Table 4).* The amount of the eroded soil on conservation plots was one thirtieth of that on the conventional plots. This value only increased by runoff moving on the soggy soil surface caused by still and sustained rainfall events, but even so it remained under one tenth.

Looking at the mean values of the six years runoff amount (9–16 mm/year) and soil loss (0.15–2 t/ha/year) could be assessed as remarkable on the conservation plots, and good on the conventional ones. Cultivation of the plots was carried out along the contour lines on all plots. The most important result is that with consistent conservation tillage practice runoff was reduced to one third and soil erosion dropped to one thirtieth-fortieth. Concerning the macro elements 15.5 kg/ha fertilizer (NPK) active substance was washed off annually from the conventional plots and only 4.3 kg/ha from the conservation plots. The latter held back 80% nitrogen, 88.5% of phosphorus and 63.5% of potassium *(Table 4).* The only way to reduce nutrient loss is to decrease runoff and to increase infiltration. This can be achieved in practice by protecting soil fauna, so that it maintains and continuously develops adequate soil physical and water management conditions *(Figure 2).*

Table 5 shows that in the WET and COOL years runoff was higher by roughly 3.5 times than in the DRY years. Conservation tillage was slightly more effective in WET and COOL years as well (30% vs. 33%). As expected, winter wheat retains much more moisture than maize due to its almost full year coverage (2.6 mm compared to 71.1 mm for the WET years, and 20.7 mm for the DRY ones). In case of winter wheat conservation tillage was even more effective, allowing just 5% of the runoff observed in case of conventional tillage.

Table 4. Nutrient loss (kg/ha/year, 2004–2006)

	N	P_2O_5	K_2O	NPK
Conventional	6.597	0.887	8.073	15.556
Conservation	1.306	0.102	2.938	4.346
Cons./Conv.	0.198	0.115	0.364	0.279
%	19.8	11.5	36.4	27.90
Conv. nutrient structure (%)	42.4	5.7	51.9	100
Cons. nutrient structure (%)	30.0	2.3	67.6	100

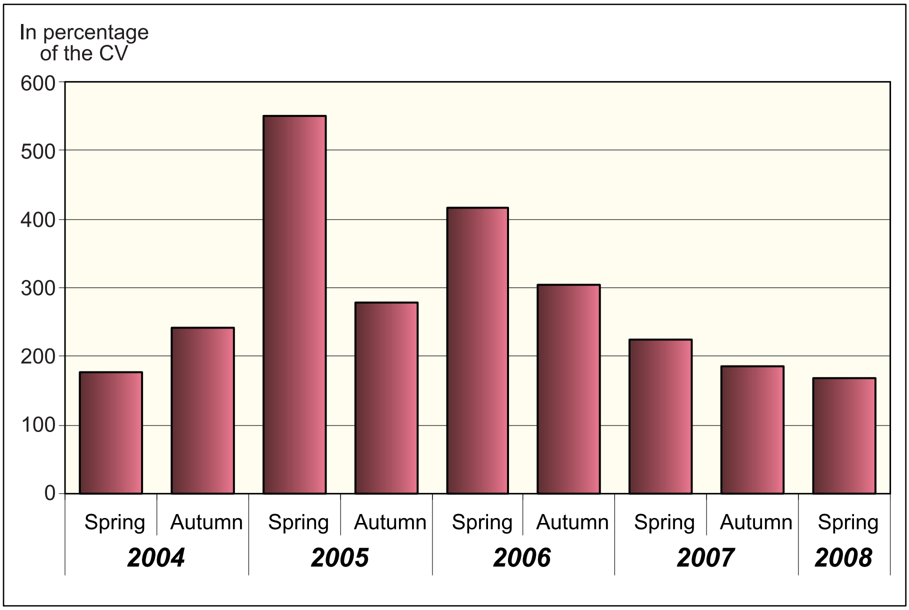

Fig. 2. Average number of earthworms on the conservation plots at Dióskál in percentage of the conventional plots

Table 5. Total amount of runoff and eroded soil at the experimental site of Szentgyörgyvár. (CV – conventional tillage; CS – conservation tillage)

Year-types	Runoff (mm)			Soil loss (t/ha)		
	CV	CS	CS/CV (%)	CV	CS	CS/CV (%)
WET and COOL with maize (2010, 2005*)	71.1	21.3	30	6.84	0.10	1
DRY with maize (2006, 2008, 2009)	20.7	6.8	33	2.51	0.21	8
INTERMEDIATE with wheat (2004, 2007)	2.6	0.1	5	0.07	0.00*	3
AVERAGE IN 7 YEARS (2004–2010)	30.0	9.0	30	3.05	0.12	4

*0.002

Soil loss was also much heavier in the WET year but there was a striking difference in efficiency of conservation tillage allowing just 1% of the loss at conventional tillage. The same value was 8% in the DRY years. In this respect the wheat coverage resulted in much less soil loss than maize, with an effect of the conservation tillage representing an approximate average of the WET and DRY years, i.e. 3% compared to 1% and 8% of soil loss in case of conventional tillage.

The two maize-covered, i.e. WET and DRY groups of years differed substantially in their average precipitation from each other than it would have been suggested by any reasonable climate scenario, based either on global climate model simulations, regional modelling or empirical analogy (Mika, J. 2009).

Hence, a rough approximation has to be implied presuming proportionality between the De Martonne differences and the effects on runoff and soil loss, i.e.

$$\Delta Y = \Delta Y_{obs}*\Delta DM_{sc}/\Delta DM_{obs} \quad (1)$$

where ΔY is the estimated effect of climate change in runoff or soil loss between the groups,

ΔY_{obs} is the observed difference between the two groups,

ΔDM_{sc} is the climate scenario expressed in De Martonne index,

ΔDM_{obs} is the difference in De Martonne index between the two groups.

For example, taking the PRUDENCE Project projections into consideration, based on 50 km grid-point distance regional models, one may expect 25 mm decrease in precipitation and 1,5°C increase in temperature. These figures are obtained by using the PRUDENCE seasonal changes of precipitation expressed in per cent of the reference period (Christensen, J.H. 2005). These changes are multiplied by the reference precipitation, using the weights 2, 3 and 1, according to the number of months in the summer half-year from the given seasons. Considering also that the summer half-year mean temperature at Keszthely (near Szentgyörgyvár) is 18°C and the mean precipitation is ca 400 mm, one may get the following De Martonne indices: Reference: 14.29, year 2030; scenario with 1°C global warming 12.71. The difference between the two values is $\Delta DM_{sc} = 1.58$, which is just one seventh part of the $\Delta DM_{obs} = -11.2$ (see the WET vs DRY difference in the last column of *Table 2*) in eq. (1). Following the substitution of the terms into eq. (1), the corresponding values of ΔY_{obs} obtained are -50.4 mm and -14.5 mm of runoff with conventional and conservation tillage, respectively. For soil loss the similar numbers are $\Delta Y_{obs} = - 4.33$ t/ha and +0.11 t/ha. One must remark, however, that this increase of soil loss despite the warming of the year is just a consequence of small samples, exactly by extreme precipitations in spring 2009. Finally, putting the above $DM_{sc} = -1,58$ mm/°C change in the De Martonne index, one may get the following rough estimates for the effects of 1°C global warming at Szentgyörgyvár: change in runoff with conventional tillage: -7.1 mm/yr; the same with conservative tillage: -2.0 mm/yr. The soil loss is -0.6 t/ha in the first case with (probably false, due to a small-sample error attributable to the irregular spring in 2009) 0.02 t/ha in the second case.

One must consider, however, that both the short period of survey, the uneven distribution of heavy rain within the year and also the order of magnitude difference between the analogous years and the scenarios make the above estimations just first approaches likely outlining the magnitudes of the effect of climate change. Moreover, since the efficiency of conservation tillage is nearly the same in the WET and DRY groups of years for runoff, the climate change may not indicate big difference in this efficiency, either. For the soil loss, on the other hand, the difference between the WET and DRY groups of years was of unexpected sign in case of the conservation tillage. Hence, it is difficult to estimate the impact of climate change upon the efficiency of conservation tillage on this phenomenon.

Reducing production risk

As stated above at the experimental site of Szentgyörgyvár the soil received more rainwater under conservation tillage. If the site is deemed to be representative for similar areas in the region of Transdanubia more moisture can be provided for crops between half of "one irrigation norm" (28 mm in the first study period) and one tenth of that (5 mm in the second period). This is a remarkable amount during the periods of drought. Thus the yield loss due to irreversible damages can be mitigated and production risk is lower. Runoff, soil and nutrient loss are also reduced due to the protecting effect of the mulch on the soil surface not ploughed in and to the insistent activity of soil edaphon.

Yield variations

To establish and use a new technology on a farm may be risky. It is expensive and more complicated compared to conventional methods. For the introduction of a new technology preparation and some routine are needed. The critical question is weather it is worth to change.

The experiment started in autumn 2003 with 9 plot pairs, winter wheat, maize and later oil seed rape were applied. After the initial 3 years a yield decline was established, but during the last 4 years the yields measured on the conservation plots exceeded those on the conventional plots *(Figure 3)*. It seems that on the basis of the rather short 7 years period the trend of initial decline reversed (probably due to the technological switch). This coincides with the results published in the literature (Nicolas, D. 2007). The average variation of crop yields (conservation in percentage of conventional) is as follows: +0.4% (winter wheat), -5.2% (maize) and +12.0% (oil seed rape) *(Figure 4)*. The initial

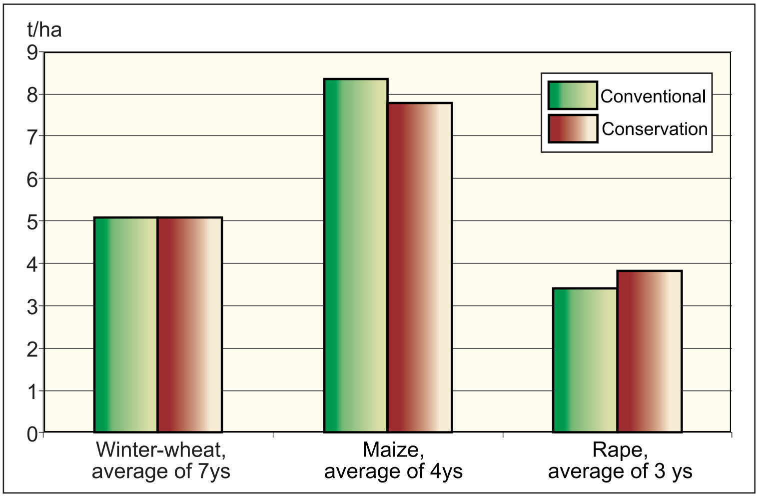

Fig. 3. Yield by treatment at Dióskál (2003–2010)

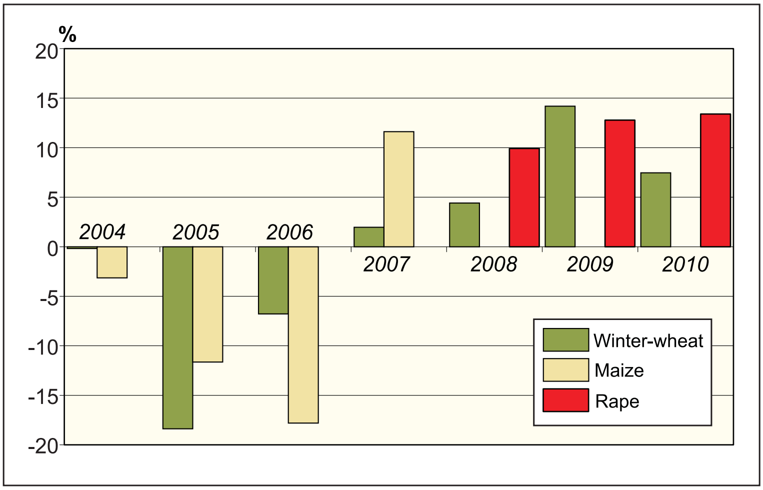

Fig. 4. Annual yield on conservation plots compared with conventional plots. (The percentage values indicate the surplus/deficit on the conservation plots)

yield decline of maize (above 10%) can be explained by the lack of appropriate machinery or by that of experience.

The first year was not favourable for wheat, but it proved to be good for maize, indicated by the 4.5 t/ha and the 10.2 t/ha yields, respectively. Weather conditions affected the experimental site in the same way however, the conservation plots showed a more favourable variation trend. This can be explained by the fact that conservation tillage gradually modifies the water and nutrient management of the soil. This change is beneficial for the farmer as well.

These facts focus the attention on the importance of the close and attentive observation of the crop and its environmental conditions when conservation tillage is applied and more professional knowledge on agronomy and technology is necessary.

Cultivation costs

Conservation tillage is manifested in the reduced number of passes using combinators and direct drilling. As a consequence cultivation costs were decreased by 12–13%. Material costs of conservation tillage were slightly higher, but even taking this into account it was still possible to save 2–6% of the costs *(Table 6).*

However, one should keep in mind that at the beginning conservation tillage needs considerable investments, which obviously return in the long run. In other words proper machinery is essential for conservation tillage, moreover, sufficient knowledge and proper attitude are also important, since only in their possession one is able to harmonize the aspects of agricultural production with soil and nature conservation.

Conclusions

Lately Hungary has been experiencing frequent floods and waterlogging, so it would be very useful, if rainwater could be kept on site. Conservation tillage proved to be a good tool for this. With its application the soil can retain more rainwater, thus increasing soil moisture content and at the same time decreasing surface water pollution. Investigations have shown that soils and the environment could be protected even under the conditions of intense agricultural production. With conservation tillage both soil erosion and nutrient loss can be reduced considerably. The extent of soil erosion can be kept under the value of tolerable soil loss, thus the productivity can be maintained and a long term sustainable production can be

Table 6. Average cultivation costs at Dióskál (2004–2006, in Euro, 1€=275Ft)

	Winter wheat					Maize				
In Euro	Cultivation	Materials	Transport	Other	Total	Cultivation	Materials	Transport	Other	Total
Conventional	207	209	35	7	459	193	257	68	23	540
Conservation	182	211	33	6	431	167	285	60	23	535

secured. The farmers would profit, nature and water protection benefit from the conscious and consistent application of a soil conservation technology. It can be recommended that non-inversion tillage be promoted by means of the agricultural policy of Hungary and of the EU, at least on the level of research, development and consultancy.

Certainly there is a need for further development of the appropriate agrotechnology concerning nutrient supply, and effective physical, chemical and biological weed control techniques.

On the basis of the results of the investigations it would be important that agricultural practice should support and the society appreciate the application of conservation agriculture technology.

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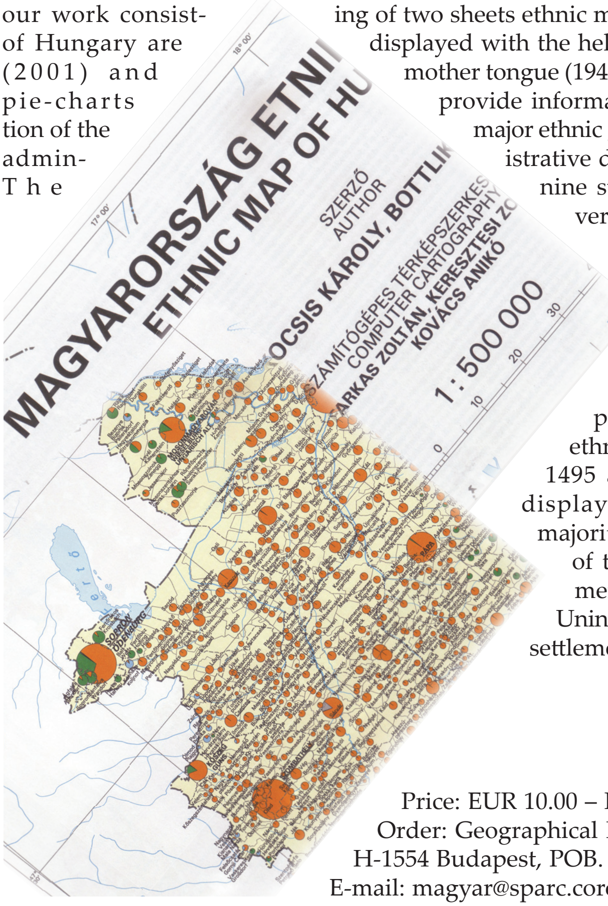
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