The role of conservation agriculture in landscape protection

Ádám Kertész[1]–Balázs Madarász[1]–Béla Csepinszky[1] and Szabolcs Benke[1]

Abstract

Because of population growth the global demand for food is rapidly increasing. As a consequence of this agriculture is expanding and becoming more intensive. Agricultural land use has the highest share among land use categories in the world therefore it is very important that farming activities are sustainable for the landscape and environment friendly. The aim of this paper is to present the positive role of conservation agriculture in landscape protection on the example of the results of the SOWAP (Soil and Surface Water Protection) project, supported by EU LIFE and Syngenta. Within the framework of the project tillage plots were established at two locations in Hungary, near Lake Balaton on Luvisol and Cambisol soils. The experimental program included soil erosion, biodiversity, soil microbiology measurements and agronomic traits. Runoff from the conservation tillage treatments was reduced by 66.8%, soil loss by 98.3%, TOC loss by 94.1%, nitrogen loss by 86.8%, phosphorus loss by 95.6% and potassium loss by 78.8% relative to values measured on the conventional plots. Soil moisture conditions have improved in the upper 20 cm under conservation tillage. Rainfall simulation experiments indicate the protection of plant residues resulting in the reduced number and volume of rills under conservation tillage. Yields of winter wheat, winter oilseed rape, sugar beet and maize were similar from plowed fields and conservation-tilled fields. There was a considerable improvement of biodiversity conditions on the conservation plots. The results of the SOWAP project give a reliable evidence that conservation agriculture is sustainable and it is an adequate tool for landscape protection.

Keywords: landscape protection, conservation agriculture, soil erosion, biodiversity

Introduction

World population is growing very rapidly. According to the United States Census Bureau the population of the world is 6.8 billion as of today and by 2020 it will reach 8 billion (UN 1996). It is well known that the rate of population growth is much higher in the third world. By 2020 84% of the estimated population will live in the third world. Demand for food will rise with popu-

[1] Geographical Research Institute, Hungarian Academy of Sciences. H-1112 Budapest, Budaörsi út 45. E-mail: kertesza@helka.iif.hu, madaraszb@mtafki.hu, h5535cse@helka.iif.hu, benkesz7@freemail.hu

lation increase and food supply will be extremely important. From the aspect of geography the key question is where this huge amount of food will be produced. The answer is very simple: the food will come from the agricultural areas. The possible impact of intensified and expanded agricultural activity on the soils and landscapes has to be addressed properly. At least the present quality of soils should be preserved and the landscapes be protected.

The relationship between population growth and food supply has been recognized long ago. The theories of Malthus and Ricardo are notorious (Held, R.B. and Clawson, M. 1965). These concepts overemphasize the role of population increase and take no notice of technological development. If technological changes are considered part of a state of the art, complex and dynamic socio-economic environment the danger and risk related to food supply can be minimized. The development of landscape and environmental protection is also part of continuous technological change. Conservation agriculture is one of the most up-to-date methods of sustainability.

The solicitude about food supply and soil degradation can be supported by the striking fact, that altogether 22% of the Earth surface is cultivatable (Wicherek, S. 1999), however, only half of it is cultivated today. Reserves of cultivatable land diminish very quickly.

The objective of this paper is to present the positive role of conservation agriculture in landscape protection not only generally but also on the example of the results of the SOWAP project (see below), concerning soil erosion, runoff, soil moisture and those of the ecological studies.

Landscape protection is understood here in a very broad sense, but concentrating only on those aspects which are included in the SOWAP project to be able to show exact measurement data supporting the positive role of conservation agriculture in landscape conservation.

Landscapes and agriculture

In the developed countries of the world natural landscapes have been transformed by human activity and today human society is the main landscape forming agent. The public opinion about the impact of the society upon landscapes is that the landscape forming activities are associated with urbanization, industrial plants and facilities and transport lines. The reason for this is obvious: the above activities cause dramatic and sometimes irreversible changes in the landscape. A natural, or semi-natural landscape is going to be transformed to a man-made, artificial environment, the “green” will turn into “grey”. We are inclined to forget that replacing natural vegetation by agricultural fields and forests means also a change of natural conditions, it is also a landscape transformation, in spite of the fact that “green” remains “green”.

The influence of agriculture on the landscape and landscape functions is as important as that of other anthropogenic activities. Another significant aspect is that the percentage of agricultural areas among land use categories is the highest in the world hence the effect has extended over a very large territory (see *Table 1*). The table presents interesting data about the development of agriculture. It is surprising that while the percentage of agricultural land in Europe and in Hungary is decreasing, it is increasing in the world.

Table 1. Agriculture in Hungary, in Europe and in the World (The World Bank 2007)

Territory	Agricultural land (% of land area)		Land under cereals (thousand hectares)		Fertilizer consumption (100 g/ha of arable land)		Agricultural employment (% of total employment)	
	1992	2005	1992	2005	1992	2005	1992	2005
Hungary	70.7	65.4	2,803	2,940	796	993	11.3	6.0
Europe (EMU*)	49.7	47.5	32,976	31,419	2,332	2,059	7.3	4.9
World	37.7	38.3	704,675	677,585	925	1,020	41.8	–

*EMU – European Monetary Union

The areas used for agriculture today had been covered by some kind of natural vegetation before and this vegetation cover was removed, extirpated. The situation is even more alarming if the area was deforested. Landscape change begins with preparing the soil for agricultural production by various cultivation treatments.

In order to carry out a successful plant production the landscape will undergo several interventions over the year, especially in the vegetation period by various cultivation and plant protection procedures. The character of the interventions is critical for the future of the landscape (Tóth, A. and Szalai, Z. 2007).

As already mentioned global increase of agricultural area is needed to ensure growing food supply. Those areas which can be used for agriculture in the future are in the tropics. Areas with better conditions are already in use so that agriculture can expand only to land with unfavourable conditions, i.e. to slopes with shallow soils. Transforming them into agricultural areas will immediately lead to severe land and soil degradation problems (Jakab, G. and Szalai, Z. 2005).

Soil degradation has not been considered to be a major problem in many European countries until recently. In Europe, according to Oldeman, L.R. *et al.* (1991), water erosion endangers 12% of the total land area and wind erosion 4%, and an additional 16% of the cultivated land is prone to different kinds of soil degradation.

Conventional and conservation agriculture

Two thirds of the area of Hungary is used for agriculture (see *Table 1*) and roughly half of the country is arable land. These arable fields are important habitats of numerous plant and animal species. The intensive agricultural activity on hilly areas may lead to severe soil erosion and biodiversity loss. Conservation agriculture is a sustainable way of farming playing an important role in soil and biodiversity conservation.

Conservation agriculture is the new discovery of "old fashioned" agriculture (i.e. of the agriculture practised before the discovery and application of high-tech machinery in agriculture). Even before the usage of modern soil cultivation machines, inverting the soil was performed by using a plow or similar tools. Conventional agriculture is based on tillage and it is highly mechanised. Conventional agriculture causes severe land degradation problems including soil erosion, pollution, loss of biodiversity and wildlife, low energy efficiency and a contribution to global warming (Boatman, N. *et al.* 1999).

The SOWAP project (Soil and Surface Water Protection Using Conservation Tillage in Northern and Central Europe, 2003–2006, EU LIFE Project, ID. Number: LIFE03 ENV/UK/000617) defined *Conservation Tillage* as tillage practices specifically intended to reduce soil disturbance during seedbed preparation. The objective is to improve soil structure and stability. Conservation tillage encompasses a range of tillage practices up to and including "Zero (No) Tillage".

Conservation Agriculture (CA) is a holistic approach to crop production, which encompasses Conservation Tillage and also seeks to preserve biodiversity in terms of both flora and fauna. Activities such as integrated crop, weed, and pest management form part of Conservation Agriculture. The concept of "as little as possible, as much as is needed" will be the guiding principle when it comes to chemical usage for SOWAP crop production.

Generally it can be said that CA is an important tool in those regions of the world where soil erosion is a major problem and where the retention of soil moisture is an important goal. Keeping water in the soil is equally important if floods and droughts are to be avoided.

Conservation agriculture is beneficial for the landscape. The positive effects apply to the landscape as a whole and to the landscape forming factors. It is very difficult to characterize the effects on the totality of the landscape in an exact form. The present paper presents the influences on several landscape forming factors.

Conservation agriculture is beneficial for the soil. The main benefit of conservation agriculture is that the soil will be preserved more or less in semi-natural conditions as soil disturbance by cultivation is minimized and physical and chemical depletions are reduced. Soil structure remains very good with enhanced drainage, porosity, adsorption capacity and structural stability (Lavier, B. *et al.* 1997). Compaction and loss of soil structure can be reduced or stopped by applying CA since there is less traffic on the field and crop residues are not buried in the soil. It is good for soil organic matter, too.

As it is well known, organic matter influences soil structure, soil stability, buffering capacity, water retention, biological activity and nutrient balance, all of which also affect erosion risk (Holland, J.M. 2004). Erosion losses can lead to catastrophic diminishment of organic matter (Szűcs, P. *et al.* 2006). The organic matter content of the soil decreases under conventional cultivation rather quickly. Kinsella, J. (1995) estimated that most agricultural soils loose 50% of initial soil C. When conservation agriculture is applied crop residues remain on the soil surface offering very good protection against erosion.

The environmental benefits of conservation agriculture include on-site and off-site effects, the latter having local, regional or global importance. From global aspects, carbon dioxide and other greenhouse gases have to be mentioned first. Conservation agriculture means the reduction of energy consumption and mechanical work, reducing the emissions of CO_2 and CO gases. CA promotes carbon sequestration in soils. Reduced mechanical activity means less SO_2 emissions from motors mitigating acidification of the atmosphere. As a consequence of conservation agriculture, air pollution is also reduced.

Concerning global biodiversity, conservation agriculture offers better nesting sites and better food supplies (Belmonte, J. 1993). Conservation agriculture fields host higher bird, small mammal and game populations (Guedez, P-Y. 2001). The benefits for soil biodiversity are self-evident. Excellent food and habitat are provided for micro-organisms, earthworms and insects, promoting bioactivity and biodiversity of the soil.

As mentioned above, soil moisture conditions are much better, than under conventional agriculture. An improvement of water management of the soil is manifested in reduced runoff by 15–89% (Holland, J.M. 2004).

In addition to the positive influence of conservation agriculture on infiltration, runoff and leaching, conservation agriculture helps to reduce the risk of pollutants to reach surface and groundwater. There is an indirect positive affect on aquatic ecosystems, too.

The SOWAP project

Recognizing the benefits of conservation agriculture, a demonstration project (SOWAP, Soil and Surface Water Protection Using Conservation Tillage in Northern and Central Europe, 2003–2006, EU LIFE Project, ID. Number: LIFE03

ENV/UK/000617) was launched in 2003 supported by the EU LIFE Programme, involving several organizations[2]. This three-year, 4 million EUR project is co-funded (50:50) by EU LIFE and Syngenta. The project ended in 2006 but the measurements in Hungary are ongoing, financed by Syngenta.

The objective of the SOWAP project is to assess the viability of a more "conservation-oriented" agriculture, where fewer tillage practices replace different ways of cultivation carried out under more "conventional" arable farming systems.

The main study topics of the project include soil erosion, aquatic ecology, biodiversity, soil microbiology, agronomy and economics.

In Hungary two sites were selected near Lake Balaton *(Figure 1)*. The first site, Szentgyörgyvár is for soil erosion studies. Four large plots (120 m^2 each) were established on a slope with 10% gradient. The parent material of the soil is sandy loess, the soil type is Luvisol. Mean annual precipitation is 700 mm. An automatic weather station is installed, too.

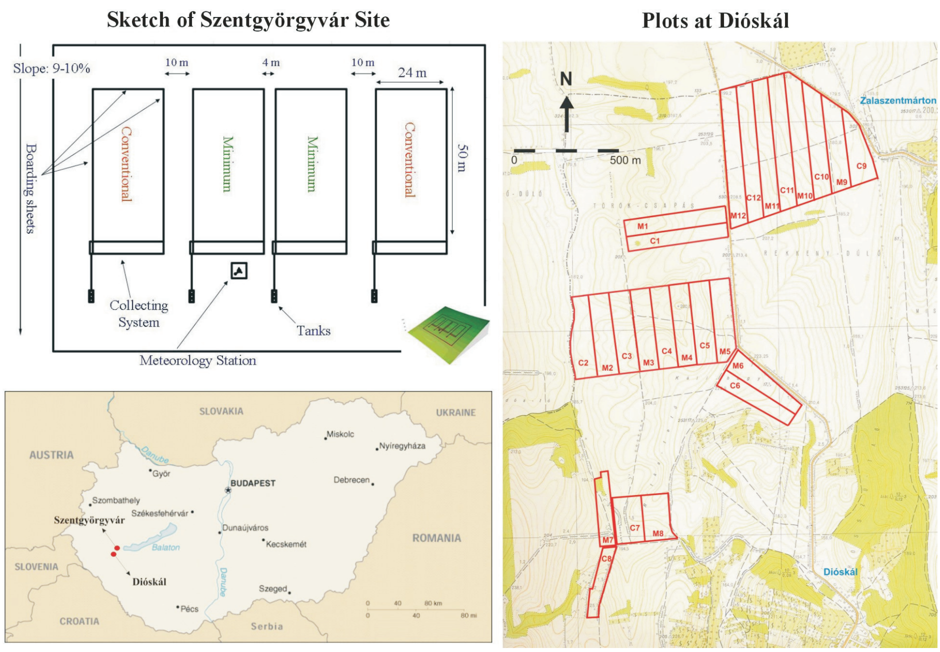

Fig. 1. Location of study sites

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[2] Agronomica, U.K.; Cwi Technical Ltd, U.K.; FWAG, U.K.; Harper Adams University College, U.K.; Geographical Research Institute of Hungarian Academy of Sciences, HU; National Trust, U.K.; Cranfield University – NSRI, U.K.; RSPB, U.K.; Syngenta, U.K./HU; The Allerton Trust, U.K.; The Ponds Conservation Trust, U.K.; University of Leuven, Belgium; Vaderstad, U.K./HU; WOCAT, The Netherlands; Yara (UK) Ltd, U.K.

The second site, Dióskál (*Figure 1)* is for farm scale demonstration and for ecological studies. It is a farm of 107 ha situated on a gently sloping, hilly area with similar environmental conditions as the first site.

Methods

a) Erosion plots. Runoff amount is determined after each event. Runoff and soil loss are measured after each tank emptying, followed by sampling. The samples will undergo the following analyses. Runoff: pH, soluted N, P, K, total suspended sediment, TOC, total salt content, herbicide content; eroded soil: dry mass, particle size distribution, N, P, K and organic matter content. Crop quality, quantity and biomass are also investigated. Economic viability of the practices employed (e.g. production costs) will be calculated whenever applicable.

b) Ecological plots. For the terrestrial ecology survey 24 plots were identified at *Dióskál* (12 conventionally tilled and 12 minimum tilled). The ecology experiment includes the survey of weeds, soil micro-organisms, birds and earthworms-insects-seeds as important food sources for birds. Conservation tillage was direct drilling and, if soil conditions were not appropriate, direct drilling was preceded by a shallow discing.

Results

Runoff, soil loss and soil moisture

The main results concerning runoff and soil loss are presented in *Figure 2*. The results show that there was a remarkable difference between the two tillage types. Runoff and soil loss on the conservation plots were always less than on the conventional plots.

Average runoff on conservation plots was only 33.2% of that on conventional plots and the percentage of soil loss was only 1.7% *(Figure 2).* These results support the positive environmental effect of conservation tillage, especially with regard to soil loss.

The average soil loss per year was 2.44 t ha^{-1} versus 0.08 t ha^{-1} *(Figure 3),* and the average runoff volume per year was 453.8 m^3 ha^{-1} versus 172.6 m^3 ha^{-1} *(Figure 4).*

The difference between the two treatments is less in case of runoff. This can be explained by the characteristics of surface cover and soil structure under the two treatments. If a high intensity rainfall hits the soil surface the minimum tilled soil may not offer the best structure for infiltration.

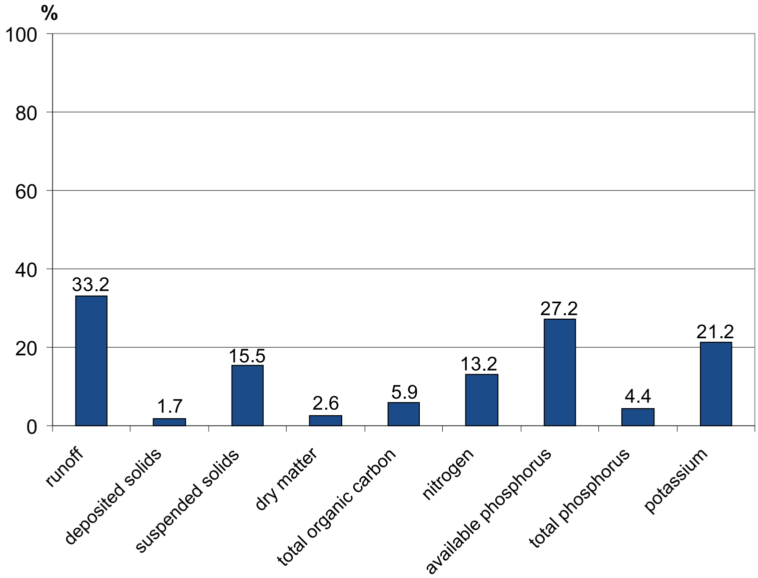


Fig. 2. Average runoff, soil loss, TOC and nutrient loss on conservation plots as a percentage of that on conventional plots (2004–2006)

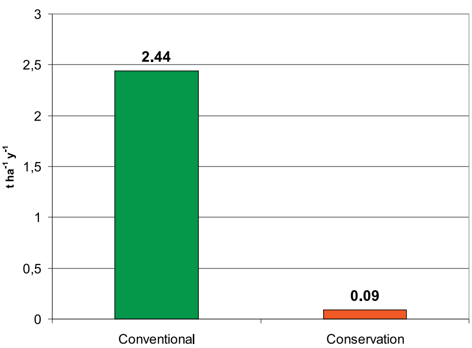


Fig. 3. Soil loss on conventional and conservation plots

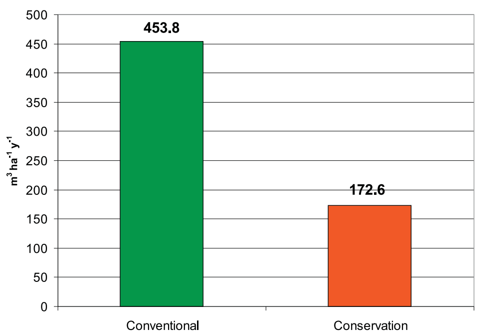
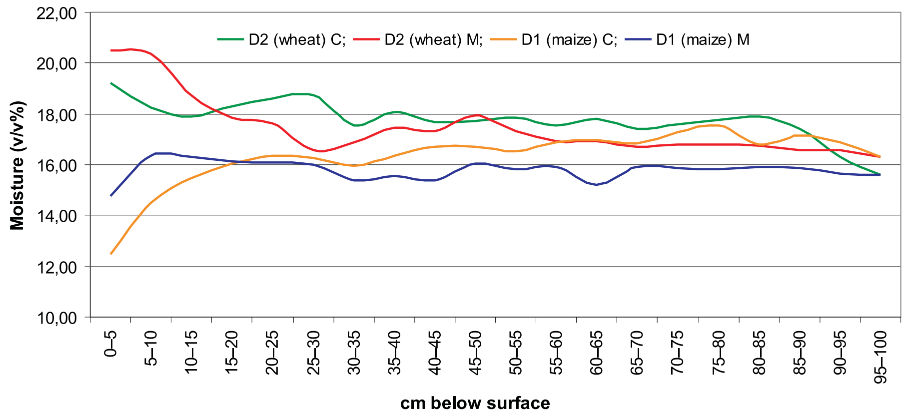


Fig. 4. Runoff on conventional and conservation plots

Gravimetric soil moisture measurements were carried out at Dióskál *(Figure 5)*. The upper 20 cm of the conservation plots had higher soil moisture content values (8.8% on the average). Below 20 cm the difference between conservation and conventional plots diminishes and conventional plots have slightly better conditions (on the average 1.77% higher moisture content). As soil moisture in the upper 20 cm is more important for plants and the difference below this level is negligible, conservation tillage appears to provide better soil moisture conditions.

a) Spring 2005



b) Autumn 2005

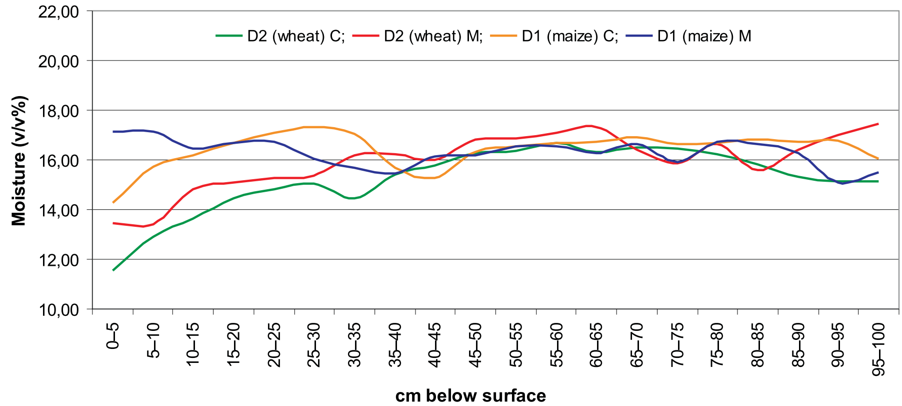


Fig. 5. Soil moisture content curves representing conventional (C) and conservation (M) fields at Dióskál 1 (D1) and Dióskál 2 (D2). Samples were taken at 3 points along the slope profiles and the data shown are mean values of these for each curve

Organic matter and nutrient contents of runoff

Figure 2 shows that not only soil loss and runoff values are lower on the conservation plots but nutrient loss is much less, too.

TOC, nitrogen, phosphorus and potassium concentrations of sediments were affected by tillage remarkably. In the case of conservation tillage these values are higher than with conventional tillage, which shows the better nutrient status and higher TOC content of the topsoil. Presumably the difference in the nutrient concentrations of the sediment from the two plot types is also due to the higher humus and nutrient content on the conservation plots.

Rill erosion

A rill erosion survey was performed on the Dióskál 1 experimental field (plots C4 and M3, see Figure 1) in early June 2005 and. Rill widths and depths were measured on 120 m long and 10 m wide plots. In 2005 the plots were covered with maize sown in early May. The amount of precipitation during the preceding two months was 105.2 mm. There was a striking difference between conventional and conservation tillage fields. On the conventionally tilled fields, rills occurred almost in every row while there were hardly any rills on the conservation plot.

The total volume of rills on conventional tillage was 13 m^3, versus 0.5 m^3 on conservation till. Soil loss due to rill erosion was 141.7 t ha^{-1} on conventional plot, versus 5.4 t ha^{-1} on conservation plot. There is a slight difference in bulk density values (1.3 g cm^{-3} versus 1.36 g cm^{-3}). The soil of the conventional plot was less compacted because of the effect of plowing.

The explanation of much better conditions on the conservation plot is due to the protection of plant residues from the previous year and the remnants of the winter cover crop (rasp) which was disced into the soil after the harvest. After plowing, the soil surface of the conventional plot was bare, without any protection against erosion.

Ecological survey

Conservation agriculture offers better conditions for the activity of earthworms. The number of earthworms on the conservation plots was significantly higher than on the traditional plots. This was the case during the whole monitoring period of two years under two different crop rotations *(Figure 6).*

Altogether 37 bird species were registered during two winter seasons including 28 protected species (76% of total). One third of these species are significant from European perspective indicating that agricultural areas are also important from the aspect of nature conservation.

Seeds play a key role in the nutrition of 22 species (60%) and, as a consequence of this, an important function of agricultural fields is to provide food during the critical winter period *(Figure 7).*

Conservation agriculture plots proved to be more favourable for birds, first of all for small warblers like skylark (*Alauda arvensis*), goldfinch (*Carduelis carduelis*), yellowhammer (*Emberiza citrinella*), greenfinch (*Carduelis chloris*) and tree sparrow (*Passer montanus*), than traditional plots did in both of the winter seasons investigated. Conservation agriculture provides a better food supply and improves winter survival reducing the negative effect of agriculture on bird fauna.

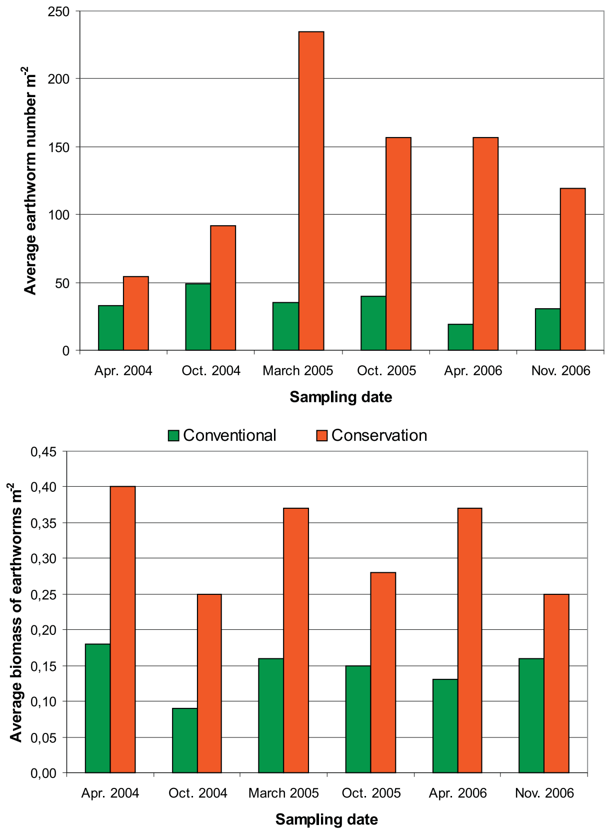


Fig. 6. Average earthworm number and average biomass per square meter at Dióskál

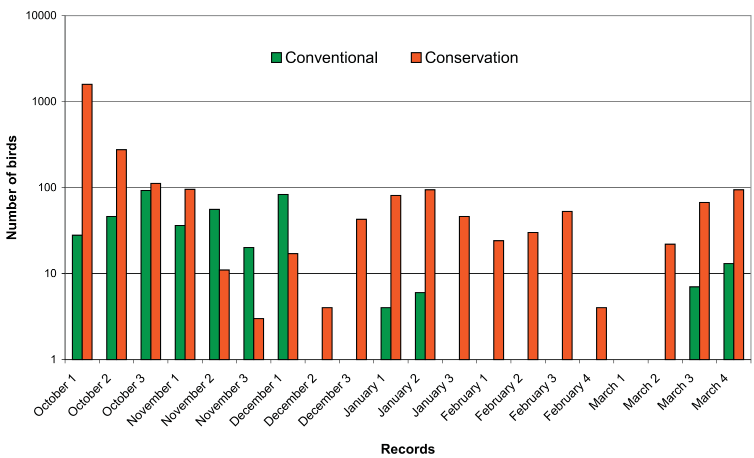


Fig. 7. Total number of birds recorded at Dióskál between October 2004 and March 2005

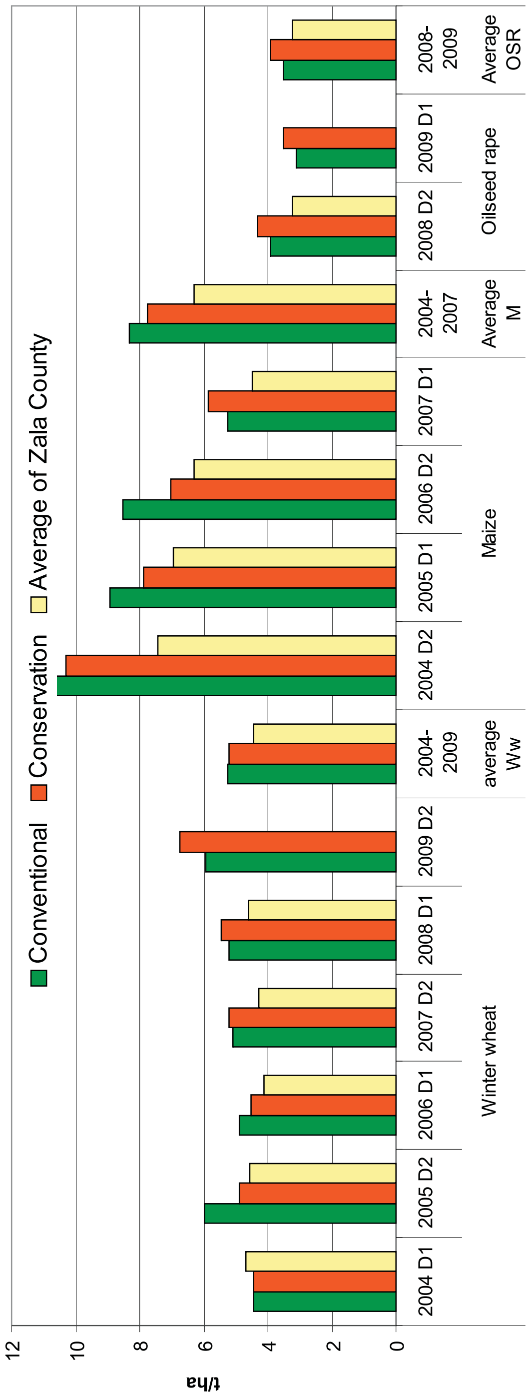


Fig. 8. Crop yields at Dióskál (2004–2009) and the average values for Zala county

Crop yield and production costs

Crop yield on the Dióskál plots was practically the same under the different tillage systems *(Figure 8).* The same is valid for the production costs *(Figure 9).*

Conclusions

Agricultural activities have an important impact on the landscape. Conservation agriculture is a sustainable way of farming with favourable effects on the landscape. The results of the SOWAP project support this statement. Conservation tillage techniques have reduced soil loss and water runoff from fields compared to conventional plowing. According to the statistical analysis under conservation tillage runoff was reduced by 66.8%, soil loss by 98.3%, TOC loss by 94.1%, nitrogen loss by 86.8%, phosphorus loss by 95.6% and potassium loss by 78.8% relative to quantities measured on the conventional plots. Soil moisture conditions were better in the upper 20 cm under conservation tillage. Rainfall simulation experiments indicated the protection of plant residues under conservation tillage. The number and volume of rills diminished un-

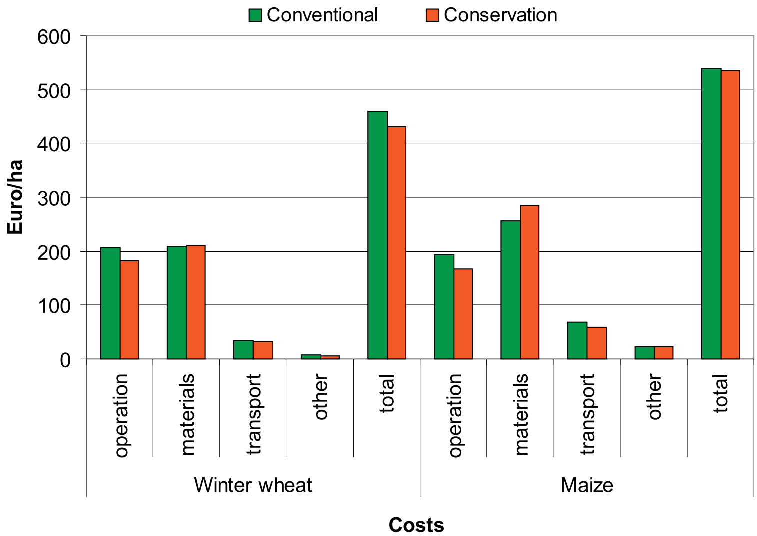


Fig. 9. Average values of production costs at Dióskál (2004–2006)

der conservation tillage. Yields of winter wheat, winter oilseed rape, sugar beet and maize were similar from both plowed and conservation-tilled fields. Biodiversity conditions were also much more adequate on the conservation plots. Conservation tillage has significant advantages for the soil itself and the environment alike.

Acknowledgement: The SOWAP project was funded by the EU LIFE programme and by Syngenta Ltd. This support is gratefully acknowledged.

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