IMPACT OF DIFFERENT SOIL TILLAGE TECHNOLOGIES ON SOIL EROSION EFFECT MITIGATION*

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In 2004 a specialized experimental site (chernozem soil type, clay loam soil) was established in the locality Klapy, about 60 km NW from Prague, with three erosion-bounded plots; having a length of 75 m, 16 m width and about 10° slope. Runoff and soil losses were measured after erosion events. Three different tillage treatments were used: 1) conventional, 2) no tillage, and 3) minimum tillage. Maize for silage was grown in 2006. The results (assessment of measures, after the winter and vegetation erosion events), showed significant differences in both process and the consequences of water erosion of soils. The furrowed soil surface after ploughing and higher retention capacity of more-often loosened soil was more effective protected against water erosion from melting snow than the relatively flat, even if by crop residues that covered the surface of untilled or minimum tilled soils. Frozen-through untilled soil had decreased retention capacity. On the other hand, the no tillage system with mulch very effectively prevents water erosion during the vegetation period, and it can decrease soil losses very significantly.

erosion; conventional tillage; conservation tillage; runoff; soil losses

INTRODUCTION

The erosion of soils, exploited for agriculture, is a worldwide problem. As the consequence of this phenomenon, thousands of square kilometres of farmland are lost; equal to the erosion damage of about 24 billion tons of topsoil, on a worldwide basis. According to Australian literature sources, this amount of soil loss comports with the total topsoil loss from those areas where wheat is grown in Australia. The potential production from lost from this area represents 9 million tons per year. The data from expert reports shows that if soil losses are larger than 2 tons/ha/year, and the full-value compensation of this amount has lasted 50–100 years at many places around the world (H o l ý , 1994). For instance, in Great Britain, about 40% of the farmland have been devastated by water erosion. According to competent estimates, 3 million tons of soil, mostly quality topsoil, is being scoured into drainage systems and rivers every year. Water erosion has a similar unfavourable effect upon farmlands in other European countries, as well. In the Czech Republic, about 54% of arable land is endangered by water erosion (J a n e č e k et al., 2002). Many experts dealing with agriculture, especially with soil management, seek applicable answers to the question of how to decrease these losses, caused by water erosion. Moreover, they are aware that a universal answer does not exist, but rather, it is necessary to take into account the natural conditions of specific endangered localities.

However, there exist methods to reduce considerably these erosion effects. For water erosion, it is necessary to: decrease the incidence of kinetic energy of rain drops impinging on the soil surface, to increase water infiltration into the soil, to restrict the sediment function, and to ensure more harmless surface run-off diversions (H ů l a et al., 2003).

To achieve these objectives, anti-erosion measures are proposed. This is a list of organized, agronomical, and eventually construction arrangements which should be applied at plots, in compliance with concrete production-economic conditions, and in the interest of soil protection.

In the framework of agricultural measures, conservation tillage technologies of crop stand establishment are very important. Besides improvement of the economic parameters of crop production, water preservation in soil, soil structure enhancement, a favourable effect on soil fertility etc. (J a v ů r e k et al., 2006; T e b r ü g g e , D ü r i n g , 1999), conservation technologies have a significant impact on the decreased effect of erosion of soils (B a s i ć et al., 2004; S c h u l l e r et al., 2007; Z h a n g et al., 2007).

MATERIAL AND METHODS

With the aim to find the most available tillage method to mitigate the erosion effects on soil, especially decrease soil and nutrient losses, this field experiment was established at the Klapý site, about 60 km NW from Prague in 2004. This site is located in sugar beet production type

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Fig. 1. The collector is piped into the 3 tanks imbedded in sheet metal panelling pits separately for each variant

chernozem, clay-loam soil, at an altitude of 230 m above sea level. For this project, three erosion bounded plots having 75 m lengths and 16 m widths and about 10° slope were laid-out. The tillage treatments are used as follows: 1. conventional – plough (P) (i.e. mouldboard ploughing 0.2 m depth, usual seedbed preparation and sowing); 2. no tillage treatment (NT) (i.e. direct drilling into untilled soil; the soil surface is covered with chopped straw of fore crop); 3. minimum tillage (MT) (i.e. shallow disking and straw and post harvest residues incorporated into soil). No replication was set-up. All crop stands were established using the same sowing machine, precision drill machine Kinze 3600 with 12 two-disc drill coulters, to ensure comparable stand structures. Special catchment devices were installed for each of the erosion plots, in order to determine the amounts of runoff and soil sediments. Runoff water with soil particles collected along the bottom side of the plots is piped into the tanks (Fig. 1) imbedded in pits separately for each variant. All amounts of runoff water and soil sediments are measured from the whole area of each plot (0.12 ha). In 2005 sunflower (var. Alexandra), and in 2006 maize for silage were grown. Usual doses of nutrients for high growing intensity were used and standard herbicides were applied depending on the intensity of weed infestation at each site. In the both conservation variants glyphosate is used as need may be. Statistical evaluation of differences between individual treatments has not been done because it was not possible to do replications.

Water infiltration during winter erosion events was done according to coloured water infiltration method. The method of water infiltration coloured by blue food colouring agent and consequent image analysis of photograph pictures was used for water motion visualization and its quantification in the soil. On the soil surface was applied 0.3% water solution of the colouring agent "E 330 brilliant blue" in amount of 40 $dm^3.m^{-2}$ for individual variants. The infiltration time was 24 hours. Then followed uncovering of parts of soil profile (0.60 m width, 0.40 m deep) and their consequent photograph. The digital photograph pictures were processed by the program "BMPtool" where the pictures are transformed into two colours: blue (soil saturated with coloured water) and the red one. The assessment method is described in the work of A n k e n et al. (2004). The differences between blue colour concentrations in different layers of soil profile were described by statistical methods.

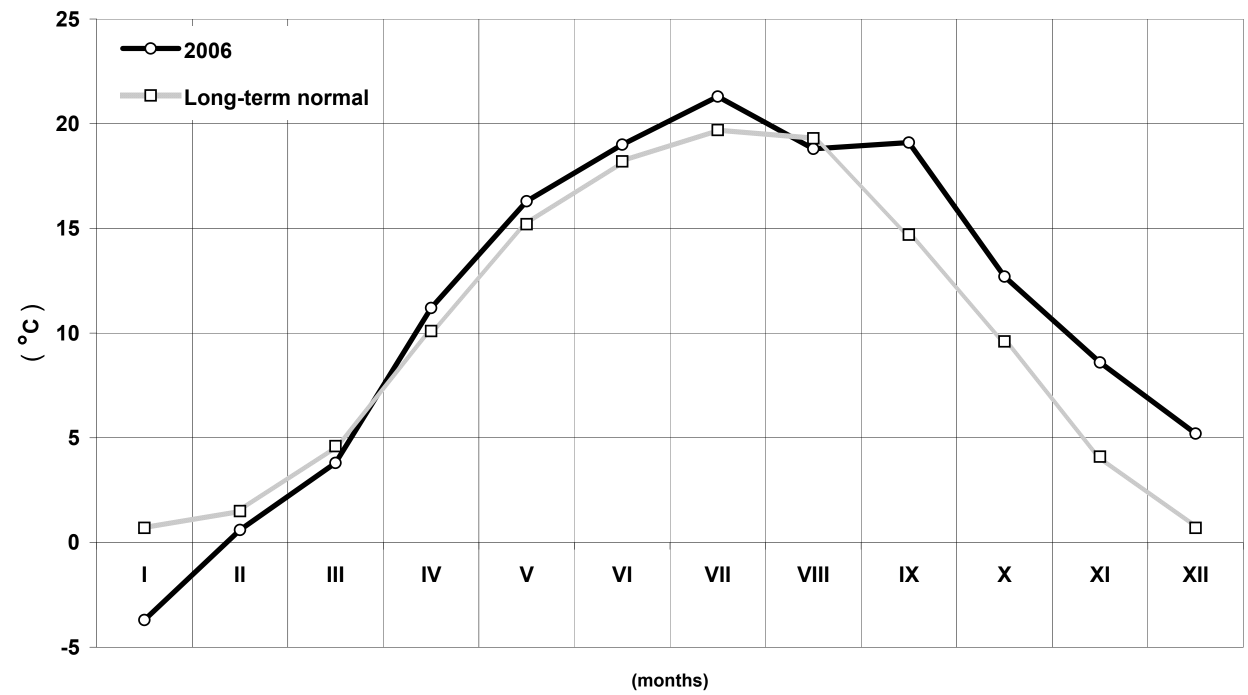

Fig. 2. Mean monthly air temperature at site Klapý

RESULTS AND DISCUSSION

The course of mean air temperature and sums of rainfall in the individual months of year 2006 in comparison to long-term normal are demonstrated in Fig. 2 and Fig. 3. The first erosion event with a measurable amount of runoff water was recorded in the middle of February 2006, which was followed by a further erosion event on March 10. Both of these events were initiated by a sudden warming after a previous frost with snow cover. Increases of daily temperature caused snow melting and infiltration reduced by frozen through topsoil started the erosion processes. The first erosion event was quantitatively larger than the second one because of a greater layer of snow.

The lowest runoff was found in P (100%), bigger in NT (138 %), and the biggest in the MT treatment (152%) – in both winter erosion events (Fig. 4). Statistically significant differences were not calculated because of no replications; however, differences of runoff between P and both conservation treatments seems to be significant. In the second erosion event (winter), the relationship among treatments was the same as in the first case (i.e. in P the lowest and in MT the biggest runoff was found, but differences were insignificant). These proportions correspond to soil losses, as well (Fig. 5). It is evident that in the second case, more soil particles were transported per unit of water; meaning that erosion was more intensive because of the defrosting of the upper layer of soil. The different

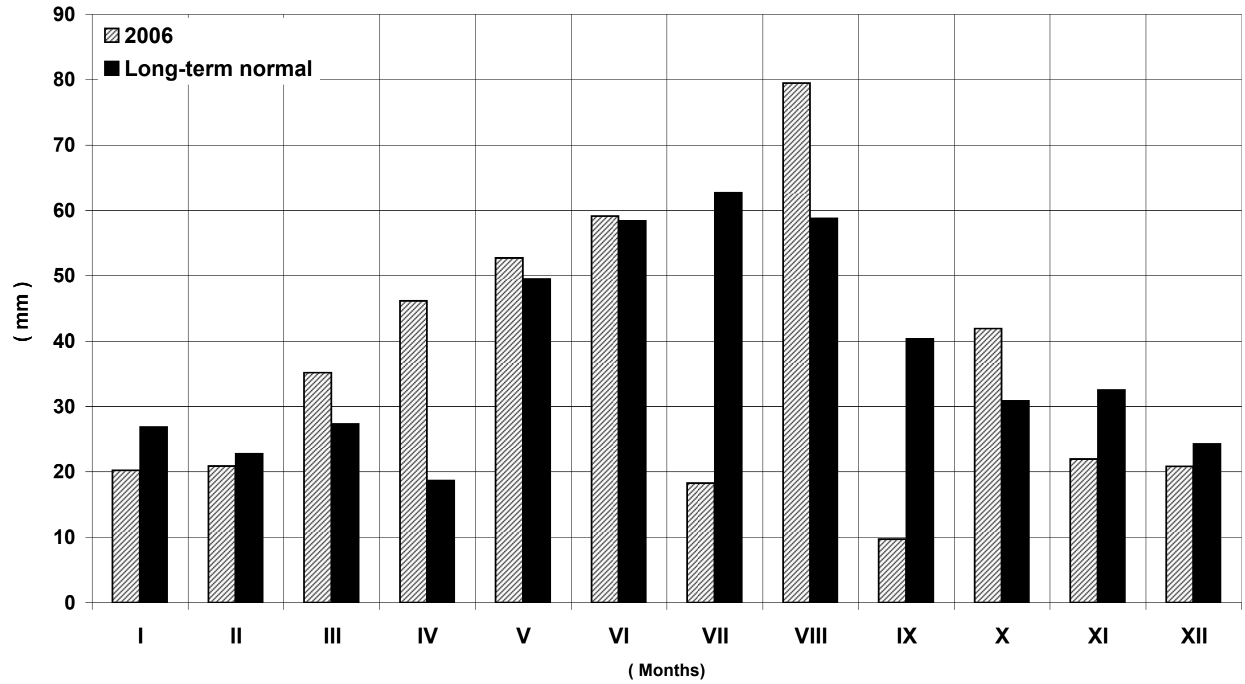

Fig. 3. Monthly sums of precipitation at site Klapý

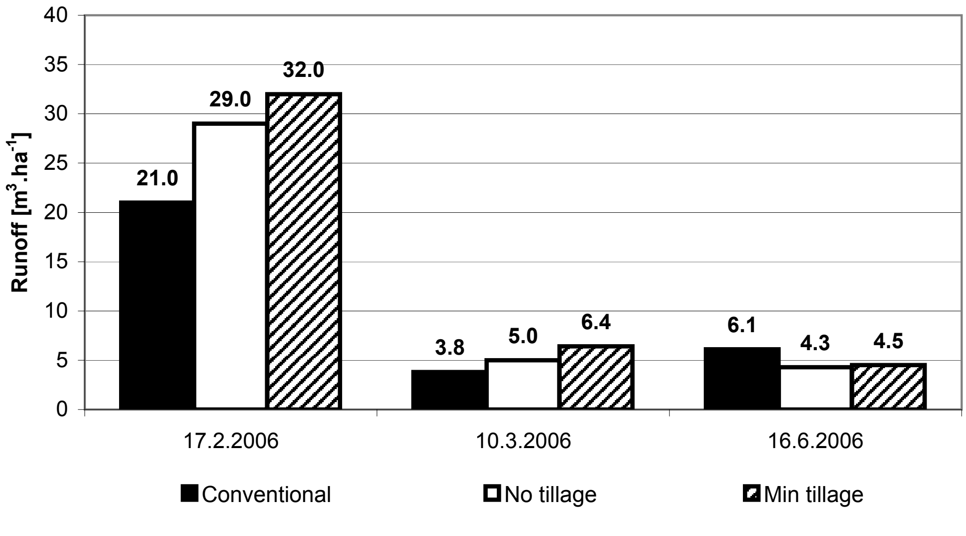

Fig. 4. Total runoff volume, within three erosion events in 2006

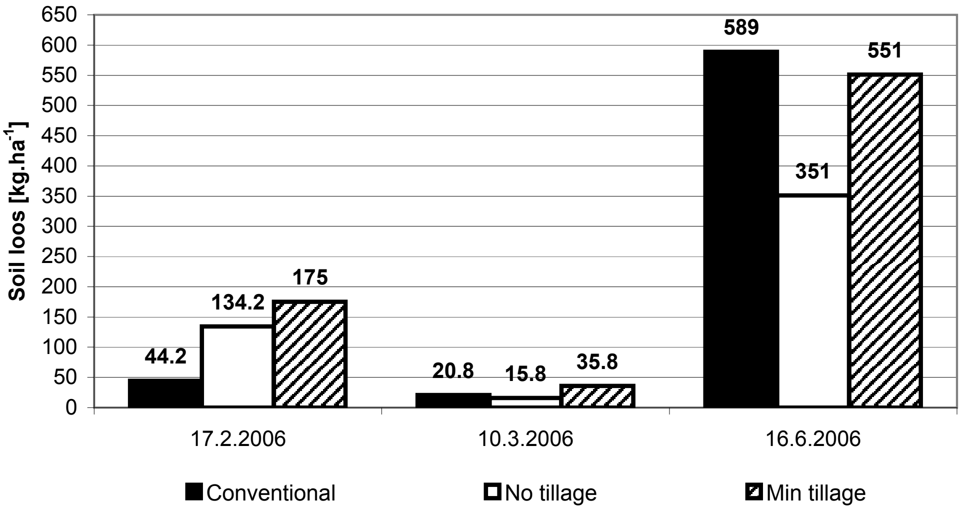

Fig. 5. Soil loss within three erosion events in 2006

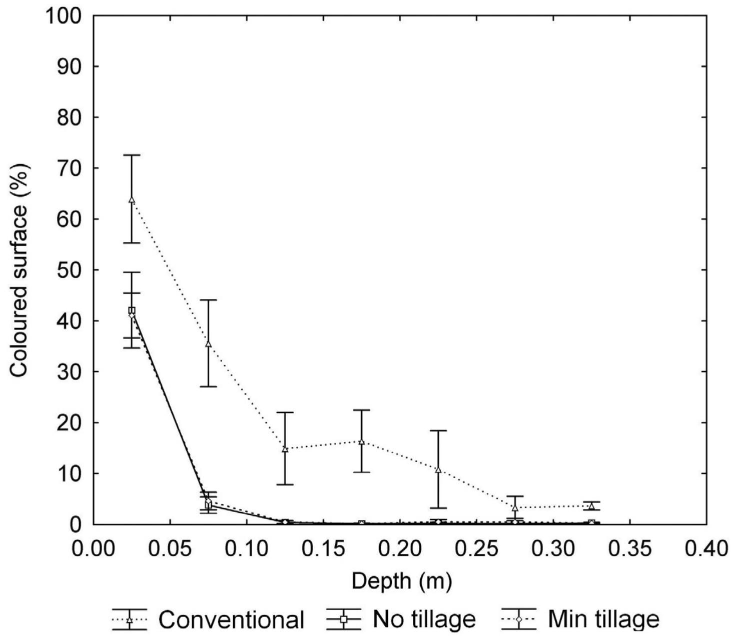

Fig. 6. Flow patterns measured by determining the percent blue dyed surface area (%) for three different tillage methods in Klapý site (17. 3. 2006). Error bars indicate ± 1 S.E.

results from the erosion events mentioned above, were found after the erosion event during the vegetation period in June (34 mm of rainfall) (Fig. 3). As for the runoff, no significant differences were found among individual treatments; however, larger runoff than in both conservation variants was recorded in the conventional treatment. This means that the soil in the conservation variants has more retention capacity for water than soil under conventional tillage. The highest soil losses (Fig. 5) were recorded in conventional treatment – P (100%); the lowest ones in the NT treatment (only 59.6%). No significant differences were found between the conventional and farm treatment (93.6%). Our findings correspond with the results of other authors concerning the impact of conservation soil tillage upon water erosion. These similar results include Schuller et al. (2007), where they conclude that no tillage practices, including crop residue management, reduce erosion from 100% to 57%, and therefore significantly decrease soil and nutrient loss. Bhatt and Khera (2006) compared the erosion effects during monsoon seasons on plots under conventional and minimum tillage, combined with straw mulching. He found the high impact of min. tillage with mulch in reducing soil erosion losses. Basić et al. (2004) also confirmed the favourable effect of no tillage technology that reduces erosion losses from maize and soybean crops 40 and 65%, compared to ploughing tillage.

Comparing the results from winter and vegetation erosion events, we found the basic differences in these erosion processes. Lower erosional effects in winter, on soils

Table 1. Tillage effects on blue colour infiltration (%) at the different depths in Klapý site during early spring period

Depth (m)	Tillage variants		
	Conventional	No-tillage	Min tillage
0.05	63.94 (b)	42.13 (a, b)	41.09 (a)
0.10	35.6 (b)	3.82 (a)	4.64 (a)
0.15	14.92 (a)	0.41 (a)	0.46 (a)
0.20	16.37 (a)	0.16 (a)	0.16 (a)
0.25	10.83 (a)	0.21 (a)	0.54 (a)
0.30	3.36 (a)	0.16 (a)	0.47 (a)
0.35	3.66 (a)	0.31 (a)	0.25 (a)

Significant differences at α = 0.05 are indicated by the different letters (a, b, c)

under conventional technology than on conservation ones are caused by a rough soil surface after the autumn ploughing that blocks fast water flow along the slope; decreasing the water speed and its ability to transport soil particles. Freeze-through of the soil profile is a further significant factor, allowed only minor infiltration. The runoff waters only partly infiltrate into conventionally tilled soil, probably due to higher amounts of macropores without frozen water, which was confirmed by results of the blue infiltration method (Fig. 6).

Results of blue water colour infiltration show differences in the soil infiltration intensity for various technology of soil tillage. The frozen topsoil saturated with water has prevented the deeper water penetration into soil for the shallow soil tillage and no-tillage variants during the measuring time (Table 1). The graph and the table show decrease of the blue colour concentration until the zero value. The topsoil tilth layer in the variant with ploughing enables the water infiltration into the ploughing depth.

CONCLUSIONS

In regions where the land freezes very deeply during winter, especially on clay soils, water erosion proceeds under other set of rules than in the vegetation period (after ploughing the furrowed soil surface). Higher surface roughness of ploughed soils and higher retention capacity, due to higher amounts of macro-pores (as a result of the more intensive loosening) play a significant role in the erosional effect mitigation during winter erosion events. Assessment of the erosion effect in the vegetation period has shown that the no tillage system with mulch can be a very effective defence against soil losses caused by water erosion.

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Vliv různých technologií zpracování půdy na zmírnění účinků půdní eroze.

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V roce 2004 byl na stanovišti Klapý u Litoměřic, asi 60 km severozápadně od Prahy, založen polní pokus s cílem studovat vliv půdoochranných technologií zakládání porostů polních plodin na průběh a účinky vodní eroze půdy. Stanoviště se nachází na černozemní, jílovitohlinité půdě se svahem kolem 10°. Na stanovišti byly vytýčeny tři erozní parcely s rozměry 75 x 16 m, které jsou ohrazeny plechovými zábranami tak, aby dosahovaly do výše 0,15 až 0,18 m nad povrch půdy. Pro měření erozního smyvu a ztrát půdy byly vybudovány na spodní straně parcel záchytné žlaby, které vedou po povrchu tekoucí vodu do tanků, umístěných v jámách pod erozními parcelami. Dataloggery přenášejí údaje o výšce hladiny v tancích na webové stránky projektu. Na erozních parcelách se využívají následující technologie: 1. konvenční (srovnávací), 2. přímý výsev do nezpracované půdy, 3. minimální zpracování půdy, tj. mělké kypření talířovým kypřičem a současně zapravení drcené slámy a posklizňových zbytků do půdy. Pro následné jařiny se využívá strniskových vymrzajících meziplodin, jejichž zbytky se likvidují před setím hlavní následné plodiny glyphosatem. Glyphosat je aplikován rovněž na variantu č. 2 v době před setím pro likvidaci plevelných společenstev. Dusík a ostatní živiny byly aplikovány v dávkách obvyklých pro vyšší intenzitu pěstování v dané oblasti. V roce 2005 byla na erozních parcelách pěstována slunečnice, v roce následujícím kukuřice na siláž.

V tomto příspěvku jsou hodnoceny dvě zimní erozní události v důsledku prudkého tání sněhu a jedna erozní událost během vegetace po intenzivním dešti, obě v roce 2006. Výsledky měření objemu erozní vody a splaveného půdního sedimentu ukázaly významné rozdíly v průběhu a důsledcích vodní eroze během zimy a za vegetace. Konvenčně zpracovaná půda v hrubé brázdě redukovala rychlost proudění povrchové vody, čímž se snížil odnos půdních částic a projevila se i vyšší retenční kapacita v důsledku intenzivnějšího kypření (vyšší objem makropórů). Byla tak efektivnější ochranou proti účinkům eroze z tajícího sněhu než relativně rovný povrch půdy parcel s půdoochranným zpracováním, přestože jejich povrch byl pokryt posklizňovými zbytky. To potvrzují výsledky uvedené na obr. 4 a 5. Promrzlý profil půd s redukovaným, nebo nulovým zpracováním neměl na rozdíl od zorané půdy téměř žádnou retenční kapacitu. To potvrdila také infiltrace obarvené vody, jejíž výsledky jsou znázorněny na obr. 6. V průběhu vegetace byl zaznamenán opačný jev – bezorebné technologie, charakteristické vyšším pokrytím povrchu půdy rostlinnými zbytky, zmírnily účinky vodní eroze v porovnání s konvenční technologií (obr. 5).

vodní eroze; konvenční zpracování půdy; půdoochranné zpracování; erozní smyv; ztráty půdy

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