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# Soil tillage systems in maize as a key factor in soil protection against erosion in the Czech Republic

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**Abstract**

Grain and silage maize are crops, where acreage increased in last years. Successful soil management system is based on improving soil properties. In lowlands, especially in dry areas, water saving soil tillage technologies can be enough efficient against a lack of suitable water for maize plants during vegetation. On the other hand, the systems, which are preserving soil erosion, could be used on slope areas. According to Czech legislatiton connected with protection of soil against erosion, different types of conservation tillage methods are applied by farmers. The results have shown that conventional and also minimum soil tillage can be suitable for maize growing, especially in lowlands. For areas endangered by water erosion, different modifications of conservation tillage are used. Suitable soil tillage management has to create good conditions for germination, emergence a development of maize stands. Conditions for high yield productivity could be in relation with improvement of soil fertility and protection soil against erosion.

**Key words**: soil tillage, grain ans silage maize, water erosion, crop residues

## Introduction

Maize (*Zea mays*) is warm-requiring crop growing in the Czech Republic for silage maize (180 000 ha) and for grain (120 000 ha). Growing area for silage maize is in last years increased, when biomass is requested by biogas stations (total number 487, and from it 317 are agricultural; 1.7.2013). With increasing growing area of maize, some agronomic aspects are coming:

In general - maize:

- is a wide row crop, with slow growth at the beginning of vegetation period, sensitive to soil erosion,
- according to Czech legislation, there are valid rules for growing of maize in soil erosion areas,
- possibility to grow some years repeatedly in sequence, but with some risks; especially higher occurrence of pests – corn borer (*Ostrinia nubilalis*) and western corn rootworm (*Diabrotica virgifera virgifera)*.

Grain maize

- grown in warmer conditions, harvested in late autumn (October, November),
- high amount of crop residues, which is a source for diseases (*Fusarium sp*., etc.),
- almost only spring crops are possible to grow after.

Silage maize – as fodder for animals

- with a closed cycle based on usage of farmyard manure,
- suitable fore-crop for winter wheat.

Silage maize – as a source of energy for biogas production – new phenomenon

System is based on production and usage of digestate, by-product of anaerobic digestion. Makádi et al. (2012) note that quality of a digestate is determined by the digestion process used and the composition of ingestates therefore the agricultural use and efficacy of the nascent materials could be different. Nevertheless, some common rules can be found in the course of the digestion process which allows us to evaluate the results of a digestion process.

All above mentioned aspects in combination with soil characteristics, properties and current soil state, could be used as important information for modification of appropriate suitable soil tillage. Successful soil management system is based on improving soil properties. In lowlands, especially in dry areas, water saving soil tillage technologies can be enough efficient against a lack of suitable water for maize plants during vegetation. On the other hand, the systems, which are preserving soil erosion, could be used on slopes. Haberle and Mikyskova (2006) write, that yields of crops, in a long term view, are the result of interaction of farmer's skill and technical equipment with either conservative environmental conditions of sites (altitude, soil, climate). The yield and quality is affected by occurence of biotic and abiotic stresses in a year governed by weather course.

The aim of the work was to compare the effect of different soil tillage on yield of maize and to assess impacts on soil environment. In South Moravian region three soil tillage systems were compared (conventional, minimum and no-tillage). From the soil parameters, bulk density, soil moisture, porosity, minimum air capacity and water infiltration into soil were evaluated. In second part, approaches in soil tillage with the antierosion effect in conditions of the Czech Republic are decribed and explained valid legislation in this topic.

## Materials and methods

The effect of different soil tillage for grain maize was assessed in two field trials established in different soil-climatic conditions in South Moravian region. Both localities are in maize-production region. Locality Visnove is characterized with brown loamy soil, in comparison with clay-loamy fluvisol, which is in Zabcice. Average annual temperature is similar in both localities (8.9°C), annual sum of precipitations differed (480 mm in Zabcice and 557 in Visnove). Different variants of soil tillage were used: CT – conventional tillage - ploughing to the depth of 0.22 m; MT – minimum tillage included soil loosening (disking) to the depth of 0.15 m and NT – no tillage (direct drilling without any tillage). In Zabcice, grain maize was grown after winter wheat and two variants of soil tillage were used (CT and MT). In Visnove, there is grain maize monoculture, all three variants were assessed (CT, MT and NT). The grain yield was evaluated in both trials, in Visnove physical soil properties (bulk density, soil porosity, soil moisture, minimum air capacity and water infiltration into soil) were assessed as well. Kopecky's physical cylinders were taken from soil depth (0–0.10 m; 0.10–0.20 m; 0.20–0.30 m) in five replications, each year in June (2005 – 2010). A double ring infiltrometers with diameter of 0.28 m and 0.54 m in soil depth of 0.1 m were used for soil infiltrability measurement.

## Results and discussion

*Soil tillage and the effect on yield and soil properties*

The yield results in Zabcice (2008-2012) are shown in Figure 1. Within the five-year average, higher yield was by CT than MT (difference is 0.41 t $ha^{-1}$). It was found out, that higher yield was found out in four years from five (2011 is exception, when the yield on variant with MT was 0.17 t $ha^{-1}$ higher than CT). Differences are almost non-significant. Only in 2010, statistically significantly higher yield was on CT (differed 1.27 t $ha^{-1}$). It could be caused by a lack of air content in the soil linked with very wet soil (high amount of precipitations during vegetation). Air content could be limiting factor for development of roots and reduce mineralization of organic matter (lower accessibility for maize).

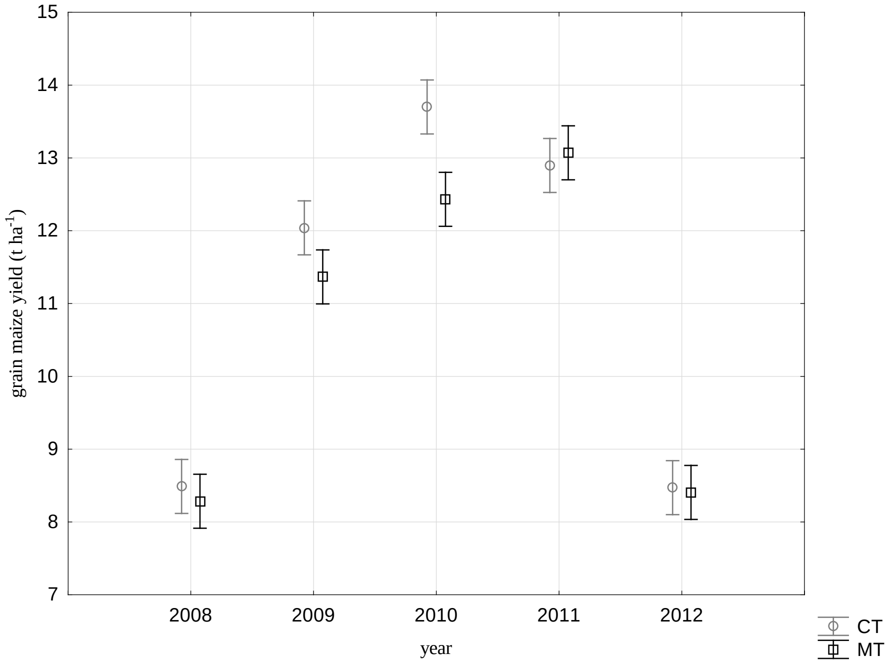


Figure1. Grain maize yield (t $ha^{-1}$, Zabcice 2008-2012)

Similarly, in Visnove, within the ten-years average (2002 – 2012, except 2009 when spring barley was grown), the highest yield was on CT (10.79 t $ha^{-1}$), following with MT (10.62 t $ha^{-1}$) and the lowest on NT variant (9.84 t $ha^{-1}$). Differences in yields between CT and MT were very low, differences among all variants statistically non-significant. Higher amount of crop residues on soil surface negatively affects maize stand establishment and often with higher weed infestation. The yield decrease of grain maize in no-tillage variant is mentioned by many other authors (Maurya, 1988; Borin and Sartori, 1995). No differences among various soil tillage systems found out Kosutic et al. (2005).

Table 1 includes the results from impact of soil tillage on soil properties. Values of bulk density increased with lower intensity of soil tillage and with soil depth. Values around 1.50 g $cm^{-3}$ were found out in variant MT and NT (except surface layer).

Table 1. Physical soil properties (Visnove, 2005 – 2010)

| Soil layer | Bulk density (g $cm^{-3}$) | | | Soil porosity (%) | | | Minimum air capacity (%) | | | Soil moisture (%) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Soil tillage | CT | MT | NT | CT | MT | NT | CT | MT | NT | CT | MT | NT |
| 0 - 0.10 m | 1.19 | 1.22 | 1.36 | 54.92 | 53.64 | 48.37 | 20.01 | 17.25 | 11.97 | 17.41 | 21.99 | 27.37 |
| 0.10-0.20m | 1.35 | 1.53 | 1.52 | 48.71 | 41.68 | 42.07 | 12.39 | 7.94 | 8.44 | 25.10 | 25.66 | 23.70 |
| 0.20-0.30m | 1.39 | 1.49 | 1.52 | 47.09 | 43.35 | 42.15 | 10.87 | 10.13 | 9.10 | 25.12 | 25.67 | 27.23 |
| Average 0 - 0.30 m | 1.31 | 1.41 | 1.47 | 50.24 | 46.22 | 44.18 | 14.42 | 11.77 | 9.84 | 22.54 | 24.44 | 26.10 |

The highest values of soil porosity were in CT (50.24% in average of 0-0.30 m), the lowest in NT (44.18%). Smaller differences in soil porosity were between layers 0.10 – 0.20 m and 0.10 – 0.20 m in all variants of soil tillage. Minimum air capacity decreased with intensity of soil tillage, in MT and CT. The values in deeper layers were lower than 10%. Soil moisture was the highest in NT, where surface and the deepest layers had the highest values. CT and MT variants had the driest layer close to the surface.

*Soil tillage and water infiltration rate*

The results from location Visnove shown, that the highest infiltration rate in first minutes was for conventional variant (CT) and the lowest for no tillage variant (NT). But this order was changing through time intervals (1, 10, 30 and 60 min) and the infiltration rate of NT was increasing to the level of CT variant. This corresponds to the review of Strudley et al. (2008), which describes the tendency of NT to increase macropore connectivity and deeper movement of water. Lipiec et al. (2006) noted that the differences in initial infiltration and reduction of infiltration rate with time among tillage treatments imply higher capability of conventional tillage pore system to increase amount of water infiltrating before filling macro-pores and reaching steady state. Kroulík et al. (2007) compared the differences between tillage practices at same locality in 2006. The results were similar – the highest infiltration rate was observed for CT and lowest for minimu tillage (MT) variant. Coloured water infiltration was used as well, and it showed a water saturation of CT in the top layer, while the variants with reduced tillage (MT, NT) were saturated deeper.

The above mentioned results have shown that conventional and also minimum soil tillage can be suitable for maize growing. These soil tillage systems, in differrent modifications, are based on inverting (ploughing) or loosening soil (chiseling or disking) and used in areas without problems with soil erosion. No-tillage system is extreme variant which is not appropriate to standard crop management practice for maize in Czech conditions.

**Soil tillage systems in areas threatened by soil erosion**

In the Czech Republic there is more than 50% of agricultural land exposed to water erosion (Janeček et al., 2002). It is a very urgent problem at present and mainly for the future. The problem must be solved now when there is still something to protect. Detailed data about area with water erosion risk in Czech Republic are in Table 2.

Table 2. Structure of areas treatened by water erosion

| Category of water erosion risk | Soil loss (t/ha/year) | % of arable land | Area (ha) |
|---|---|---|---|
| Very small danger | < 1.0 | 47.12 | 1 935 393 |
| Small danger | 1.1 – 2.0 | 16.90 | 694 090 |
| Medium danger | 2.0 – 4.0 | 17.19 | 706 021 |
| Great danger | 4.1 – 8.0 | 11.33 | 465 315 |
| Very great danger | 8.1 – 10.0 | 2.28 | 93 851 |
| Extreme danger | > 10.1 | 5.18 | 212 798 |
| Total | - | 100.00 | 4 107 468 |

Degradation results in limitation or loss of both the productive and non-productive functions of the soil. A significant risk associated with soil in the Czech Republic consists in the accelerated erosion of agricultural land that is conditioned anthropogenically. The erosion itself is a natural process and predisposition of soil to erosion depends on natural factors (climatic conditions, soil conditions, morphology of the area, vegetation conditions), which, however, may be secondarily influenced by anthropogenic factors. Therefore, human activity can be the start-up factor of the accelerated erosion also on plots that are not otherwise threatened by erosion.

*The Conception of the Agricultural Policy after the EU Accession for the Period 2004–2013 and the Strategic Framework for Sustainable Development in the Czech Republic* mentioned the risk of water and wind erosion and other ways of soil degradation (such as compacting) among the significant problems. Subsidies to agriculture also support sustainable management of agricultural land. The payment of direct support for farmers under the *Council Regulation (EC) 73/2009* and of other selected subsidies is made dependent on fulfilment of the *Statutory Management Requirements (SMR) and Good Agricultural and Environmental Conditions (GAEC),* while GAEC1 and GAEC 2 concern soil erosion. Emphasis is put on the protection of soil against erosion on sloping land, the soil protection against water erosion and on the effort to reduce the negative impact of the consequences of erosion (e.g. damage to roads and real estate). The GAEC and SMR standards are parts of the cross compliance system. The extension of GAEC 2, focusing on restrictions on the cultivation of wide-row crops on soils threatened with moderate erosion, is effective from 1st July 2011.

The Czech Republic pointed out, in particular, how the specific implementation of GAEC 1 and 2 is contributing to reduce soil loss, increase water retention and reduce the risk of extreme events such as floods: USLE equation (universal soil loss equation; Wischmeier and Smith, 1978), used for soil erosion allows quantifying the positive effects through 6 the Vegetation Protection Factor (Cp) identification. Soil use and type, erosion risk features, land sloping and annual precipitation patterns contribute to identify soil erosion risk maps which, if simplified and made available to farmers, can facilitate prevention activities, with reference to specific agricultural parcels concerned.

Combination of above mentioned data was used for definition of seriously and slightly endangered areas by erosion.

In *seriously endangered areas*, wide-row crops (maize, sugar beet, potatoes, sunflower, bean, soybean and sorghum) are not allowed to grow. Crop stands of cereals and oilseed rape must be established by conservation tillage technology, when crop residues cover on soil surface is at least 30% till emergence of crop.

In slightly *endangered areas,* growing of wide-row crops is allowed, but using conservation tillage. Limit for minimal crop residue cover is changing with developing of crop stand: 20% is requested during sowing, 10% till June, 30 and visual provability of usage of conservation tillage system after July, 1.

According to Czech legislatiton connected with protection of soil against erosion, different types of conservation tillage methods are applied by farmers. Conservation tillage technologies where ploughing is replaced by tillers and shallow soil loosening are increasingly used as soil treatment. It is typical for shallow soil tillage that all plant residues are left on the soil surface, or in the treated (tilled) upper soil layer. The plant residues can play a very important role by the next plant cultivation. Leaving crop residue on the soil surface year around, before and after planting provides soil surface protection at critical times to protect the soil against wind and water erosion. Reducing tillage operations improves soil surface properties, including improved soil aggregation accounting for increased infiltration and percolation; less compaction due to less usage of field implements; and more biological activity due to an increase in organic matter. Adding soil surface cover increases water infiltration, reducing soil drying and maintains more moisture for crop utilization. In the experimental section the aim of the research was described which is possible to summarize briefly as follows – evaluation of soil physical properties on the work quality of tillers, evaluation of sweep tillers and disc tillers work quality by stubble ploughing. Especially conservation tillage systems with their modification are increasingly being introduced under the economic pressure on the fields of the Czech Republic (Mašek et al., 2012).

Examples of conservation soil tillage methods:

- direct sowing (no-tillage) into postharvest crop residues,
- use of cover crops (intercrops) – sowing of winter rye or phacelia in autumn, direct sowing in spring (sometimes necessary to apply total herbicide),
- sowing of spring barley in spring, application of total herbicide, direct sowing of maize in spring.

Rules, which are based only on parameter of covering of soil surface by crop residues, are discussed and there is also space fore some modifications. Every soil tillage method has own advantage, but also disadvantage. It is important to choose soil management suitable to soil-climate conditions of some locations. Between farmers and research community there are a lot of negative remaks and recommendation, that these system evaluation of crop residues is very one-sided. In general, more complex system of evaluation is appreciate – with more broad view on the effect of soil tillage on soil properties parameters (content of soil organic matter, soil compaction, bulk density etc.). In soil tillage improvements, there are ideas about loosening soil profile in differed intensity in horizontal direction. Strip tillage is one the example of it.

Apart from above mentioned approches in soil tillage, new crop management practices are tested with potential effect against erosion. In maize, systems based on narrower rows and crop stand structure (distribution of plants in space) is evaluated in different locations of the Czech Republic. Practically, standard wide row (0.75 m) is compared with “narrow-row” in width 0.375 m between rows. Third system is called “twin rows”. In a twin-row configuration, maize is planted in paired rows, usually 0.2 m apart, on 0.75 m centers. The idea behind this system is to gain a more uniform spacing of plants, similar to narrow-row corn. The theory is reducing the amount of inter-row competition above and below ground allows the corn plant to maximize yield.

This approach is coming in USA, and the results showed, that maize grows, more and more of the sun light is captured by the leaves. The more nutrients that are captured, the more large healthy ears will be formed. That is why increasing the spacing between plants is the best way to encourage root development. Large healthy roots maximize nutrient retrieval and moisture absorption. All these results are concluding in higher yield level of biomass in comparison with standard wide-row systems. Also, twin-row’s larger stalks and increased root mass result in a plant that is stronger and better prepared to withstand high winds and storm damage.

**Conclusions**

The results have shown that conventional and also minimum soil tillage can be suitable for maize growing, especially in lowlands. For areas endangered by water erosion, according to Czech legislation, different modifications of conservation tillage are used. Suitable soil tillage management has to create good conditions for germination, emergence and development of maize stands. Conditions for high yield productivity could be in relation with improvement of soil fertility and protection soil against erosion.

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