Conservation tillage: impacts on soil erosion, runoff and pesticide losses

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Soil erosion by wind and water is the major threat to the soil resources worldwide. Although erosion is a natural geological process, some human activities like inadequate agricultural and forestry practices, including tourism can dramatically exacerbate erosion rates. An estimated 115 million hectares or 12% of Europe´s total land area are subject to accelerated water erosion, and 42 million hectares are affected by wind erosion.

Modern agriculture needs to achieve high crop yields with decreasing equipment and labour inputs while also reducing negative environmental impacts. Improved soil management practices, including reduced tillage are often reported as a potential solution. These practices are not yet widely used in Europe with adoption rates at only 15%. Conservation tillage is a method which reduces the intensity and the depth of soil cultivation and leaves the previous year's crop residue (such as corn stalks or wheat stubble) on fields before and after planting the next crop. To provide these conservation benefits, at least 30% of the soil surface must be covered with residue after planting the next crop.

In 1994 field experiments started at two sites in the eastern part of Lower Austria (Mistelbach and Pyhra) to investigate the effects of different tillage practices on soil erosion, surface runoff and erosion associated nutrient and pesticide losses. In 1997 the Pixendorf site was added to the trial. Three soil tillage/management systems were compared: 1) conventional tillage (CT), mulch seeding with cover crops during the winter season (CS), and 3) direct seeding with cover crop during the winter season (DS).

The soils in Mistelbach and Pyhra are classified as Typic Argiudolls while the soil in Pixendorf is an Entic Hapludoll. Soil textures range from silt loam to loam. Mean annual precipitation at the sites ranged from 645 to 947 mm with average mean annual air temperatures between 9.4 and 10.4 °C. Crop rotations included corn, winter wheat, sunflower, canola and sugar beet. Soil erosion, surface runoff and nutrient and pesticide losses due to erosion processes were determined at all sites for each tillage system by using 4 m wide and 15 m long runoff plots. All fields and plots were managed up-and-down the slope.

Long-term average results show a significant reduction in soil erosion due to conservation tillage (Fig.1). Compared to conventional tillage mulch seeding (CS) decreased soil loss by 38-86% while direct seeding (DS) led to reductions between 65 and 92%. On average, CS and DS decreased soil losses by 75 and 86%, respectively.

Runoff results do not show a uniform pattern (Fig.1). Soils with low clay contents like Mistelbach and Pixendorf show a positive response to conservation tillage which results in improved infiltration and reduced surface runoff. Heavy soils like Pyhra with clay contents >50% may tend to soil compaction under conservation tillage which leads to higher runoff. Nevertheless, runoff velocity from conservation tilled soils is much lower due to the high amount of residues and organic material on the soil surface which reduces the kinetic energy of runoff and therefore its erosive force.

Reduced surface runoff and soil loss under CS and DS lead also in lower amounts of nitrogen and phosphorus washed off the field (Table 1). The amount of erosion induced losses of applied pesticides is mainly driven by the time elapsed between the pesticide application and the first erosive event. In addition, the losses depend also on some pesticide characteristics like half-life, adsorption coefficient and solubility (Table 1).

Field observation of soil moisture during growing seasons 2002 and 2003 showed positive effects of conservation tillage on soil water contents. In both years the treated fields had higher soil water contents in the root zone (0-100 cm) which can be attributed to higher infiltration in these plots.

In Pyhra and Pixendorf conservation tillage systems had no or positive impacts on crop yields. Compared to conventional tillage CS affected crop yield by +4 (Pyhra) and +10% (Pixendorf), and DS by +/-0 (Pyhra) and +8% (Pixendorf). In Mistelbach both conservation tillage systems had a slightly negative effect on crop yield (-6% for CS and -8% for DS). When considering lower inputs into the system a positive economic evaluation was obtained.

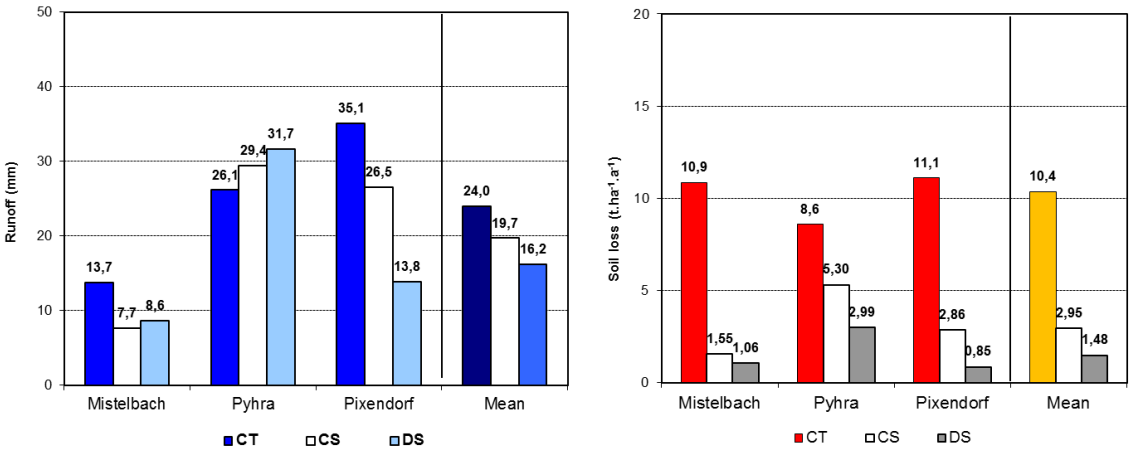

Figure 1: Long-term average annual runoff and soil loss from fields with conventional (CT), conservation tillage (CS) and direct seeding (DS) (1994-2015)

Table 1: Long-term average nutrient and pesticide losses due to soil erosion

Parameter	CT	CS	DS
Total nitrogen (kg.ha^{-1})	24.0	9.4	5.1
Total phosphorus (kg.ha^{-1})	14.3	3.4	1.9
Organic carbon (kg.ha^{-1})	180.3	53.2	29.0
Pesticide losses (in % of applied amount)	2.2	1.0	0.6

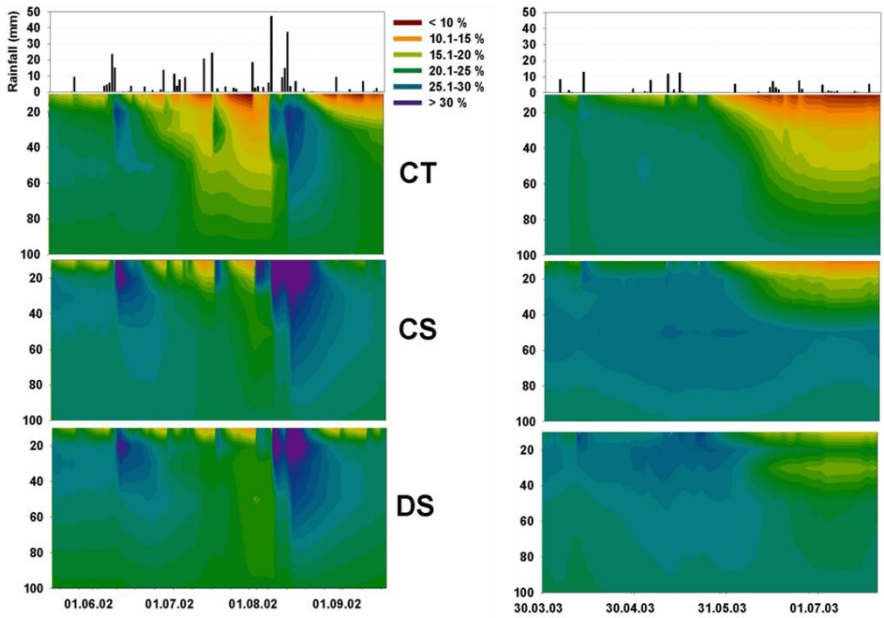

Figure 2: Temporal distribution of soil moisture content in the root zone for corn (growing season 2002, left) and winter wheat (growing season 2003, right)