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# Conservation tillage practices in the alpine forelands of Austria — Are they effective?

Rosemarie Hösl *, Peter Strauss

*Land is Water, Institute for Land and Water Management Research, Federal Agency for Water Management, Pollnbergstrasse 1, A-3252 Petzenkirchen, Austria*

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ABSTRACT

If it comes to the advantages of conservation tillage practices, a considerable amount of evidence supports positive effects towards reduction of surface runoff and soil erosion. However studies concerning arable land frequently are conducted under ideal laboratory conditions or "controlled" field conditions, meaning that the experimental approaches were not managed by farmers in the way they usually perform conservation tillage but managed towards an optimisation of the tested features. In addition, applicability of different existing conservation tillage techniques such as no tillage or mulching may be regionally different. The alpine forelands of Central Europe are dominated by small scale farming systems which frequently have limited access to special machinery which is needed to successfully implement no tillage treatments. We therefore carried out rainfall simulation experiments employing conservation tillage practices to test the effectiveness of actual real life conservation tillage methods under conditions prevailing in the alpine forelands of Central Europe. Experiments were carried out in the years 2011 and 2012 for testing the relative performance of different mulching and no tillage treatments on surface runoff and erosion. The tested treatments for the year 2011 were a) no tillage with prior rough seedbed (NT1), b) no tillage with prior fine seedbed (NT2), c) mulching with rotary harrow (M1), d) mulching with rotary harrow and disc harrow (M2) and e) conventional tillage (CT11). The tested treatments for the year 2012 were a) combined mulching (MC), b) mulching with loosened wheel tracks (M−T), c) mulching without loosened wheel tracks (M+T) and d) conventional tillage (CT12). In 2011, total surface runoff and total soil loss for the different treatments were ordered as follows: NT1 < NT2 < CT11 < M1 < M2. No significant differences for total soil loss could be identified. For total surface runoff differences were significant ($p < 0.05$) between all treatments, except for NT2 and CT11. The treatments also differed with respect to runoff initiation, sediment concentrations and shear stress. As a main reason for the unexpected bad performance of the mulching treatments M1 and M2 lack of sufficient soil cover (M1: 6%, M2: 11%) together with shallow surface cultivation were identified. In 2012, total surface runoff and total soil loss for the different treatments were ordered as follows: MC < M−T < CT12 < M+T. Although there were a visible trend in these results, significant differences could only be observed for total surface runoff between treatments MC and M+T ($p < 0.05$). We attribute the good performance of treatment MC to the improved soil cover (25%). Wheel tracks of treatment M+T obviously had influenced soil erosion and surface runoff. Under real life conditions of agricultural conservation practices in small scale farming systems, a sufficient soil cover was not obtained for mulching treatments in 2011 and only partially in 2012. In contrast to the vast majority of literature that stresses the positive and even dramatically positive effects of conservation tillage treatments compared with conventional agricultural management techniques, our results reveal possible problems when applying these best management techniques in small scale farming systems.



## 1. Introduction

Conservation tillage methods in agriculture are commonly seen as effective measures to protect soil against erosion (Gaynor and Findlay, 1995; Harrold and Edwards, 1974; Holland, 2004; Langdale et al., 1979). According to Potter et al. (1995) and Torbert et al. (1996), a 30% soil cover is usually used to define tillage systems as "conservative".

Kassam et al. (2009) defined conservation agriculture as a concept for resource-saving agricultural crop production which must meet the following conditions: (1) minimal soil disturbance, (2) soil cover in one of three categories: 30–60%, 61–90% and 91+% ground cover, measured immediately after the planting operation; ground cover of less than 30% is not considered to be conservation agriculture and (3) crop rotation should involve at least three different crops. These definitions for conservation agriculture are also used in Naudin et al. (2010) and Prasuhn (2012). Conservation tillage methods are able to save costs and increase effectiveness of machinery input (Rosner et al., 2008;

* Corresponding author at: Pollnbergstrasse 1, 3252 Petzenkirchen, Austria.
*E-mail addresses:* rosemarie.hoesl@gmail.com, rosemarie.hoesl@georaum.at (R. Hösl).

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Van den Putte et al., 2010) even for small scale farming systems which are prevailing in Central Europe. As soil erosion negatively influences crop yields (Strauss and Klaghofer, 2001) conservation tillage methods also contribute to maintain yield levels.

When it comes to evaluating the effectiveness of conservation agriculture, the most critical issue is the crop residue cover on the soil surface (Smets et al., 2008). Crop residues are known to increase organic matter content, and improve aggregate stability and infiltration. A significant correlation between the percentage of soil cover (crop residues, organic or synthetic mulch) and soil loss is also presented in the literature (Armand et al., 2009; Mostaghimi et al., 1988; Myers and Wagger, 1996; Poesen and Lavee, 1991). Despite the importance of soil cover for conservation agriculture, there is limited data available that quantitatively evaluates the effects of conservation agriculture, and the factors that influence it. Quinton and Catt (2002), Rhoton et al. (2002) and Shipitalo and Edwards (1998) for example all showed reduced soil loss from no tillage systems in contrast to conventional tillage systems, but provided no information about percentages of soil cover. A common approach is to evaluate the effectiveness of conservation agriculture based on well-defined percentages of soil cover which are applied to the experimental plots. Examples of this approach are the work of Cogo et al. (1984), Mostaghimi et al. (1988) or Meyer et al. (1970), who all examined the effectiveness of conservation agriculture by employing different predefined mulch rates. Numerous other studies employ a similar methodology (Adekalu et al., 2006; Atreya et al., 2008; Bhatt and Khera, 2006; Cruse et al., 2001; Edwards et al., 2000; Jordán et al., 2010; Leys et al., 2010; Singer and Blackard, 1978; Smolikowski et al., 2001).

Relatively few studies deal with field experiments without predefined soil coverage. Gaynor and Findlay (1995) compared conventional, mulching and no tillage treatments over three years under field conditions and found that conservation tillage reduced average soil loss. In a two-year field study, Myers and Wagger (1996) measured reduced soil loss under no tillage systems with surface residues in contrast to conventional tillage; however, they did not find reduced runoff rates for no tillage systems.

In summary, most studies, independent of the methodology employed, show improved soil protection when using conservation agriculture measures. Negative effects of conservation agriculture on soil loss were detected in only few studies such as Singer and Blackard (1978), who measured higher soil loss from a mulching treatment (31% soil cover) compared with a conventional tillage system. Shelton et al. (1983) presented an experiment using conventional tillage, no tillage and mulching management systems. The mulching treatment showed higher soil losses compared with the conventional tillage treatment due to similar residue cover percentages for mulching and conventional tillage treatment. Prasuhn (2012) presented results of a long-term field study concerning soil loss under real life field conditions and found lower soil erosion values for fields under mulching or no tillage systems compared with conventional tillage systems. Prasuhn (2012) also demonstrated that without an idealized experimental layout, protection may decrease considerably due to insufficient soil cover under reduced tillage systems.

In light of this, we hypothesize that field conditions in the real life context of conservation agriculture work may be quite different from the idealized situation of a controlled experiment. In addition, the way farmers actually perform conservation tillage may depend very much on regional characteristics, not only in terms of environmental conditions but also in terms of farming structures and the socioeconomic status of farms (Knowler and Bradshaw, 2007). In Austria as well as in other regions of Central Europe (e.g. Bavaria, Switzerland) relatively small scale farming systems are widespread. However expensive machinery for no tillage (direct drilling) treatments is not present in this agricultural environment. In contrast, mulching techniques are implemented with machinery which is available at almost every farm (chisel, rotary harrow).

Information on the actual effectiveness of conservation agriculture measures, as opposed to idealized results, could also be important for evaluating and improving current subsidy programmes to promote soil and water protection. In order to narrow the information gap between work focussed on idealized conditions for conservation agriculture and the actual effectiveness of conservation agriculture under real life agricultural management, we studied a set of conservation tillage practices which are common at regional scale representative for small scale farming systems in the European alpine forelands. As a test region the alpine forelands of Upper Austria were chosen. This is one of the areas in Austria which are at highest risk of soil erosion due to water (Strauss, 2007). The main reason for this is a combination of undulating land, soils with high silt contents and the cultivation of crops with high erosion risk such as maize. We therefore focussed our experiment on conservation tillage methods for the management of maize. There are several reasons which cause high soil erosion risk for this crop. First no sufficient soil cover for erosion protection is produced at least for 2 months after seeding where soil is bare and hence erodibility is high. Another reason is the climatic condition in the tested region, the period between May and June can be identified as very storm intensive. Most of the total annual precipitation comes within this period (ZAMG, 2013).

The objectives were to evaluate the actual effectiveness of regionally typical soil conservation measures under real life management conditions of small scale farming systems, and to find out if and how those measures differ from the idealized situation of controlled trials. The main purpose of choosing rainfall simulation as an experimental setup was to identify relative rankings of the performance of different tillage treatments with respect to surface runoff and soil erosion. Recent examples for using rainfall simulator studies to demonstrate relative differences of management on surface runoff and soil erosion are for instance Davidson et al. (2014), Montenegro et al. (2013) or Rimal and Lal (2009).

## 2. Methods and materials

### 2.1. Study site

The Innviertel region is part of the Central European alpine forelands (Fig. 1). It is a rather hilly region with mean slopes of 12% and altitudes between 350 and 500 m asl (48° 18′56″ N, 13° 26′5″ E). The underlying geology is indigenous molasse (tertiary sediments) with fine-sandy, silty marl. Typical soils are Gleysols, Regosols, Cambisols and Planosols (World Reference Base for Soil Resources). Regional long-term annual precipitation is 950 mm$^{-1}$, mean annual temperature is 8.3 °C (ZAMG, 2013). The Innviertel region is typical for intensive corn and root crop production; typical crops are maize, wheat, barley and rape.

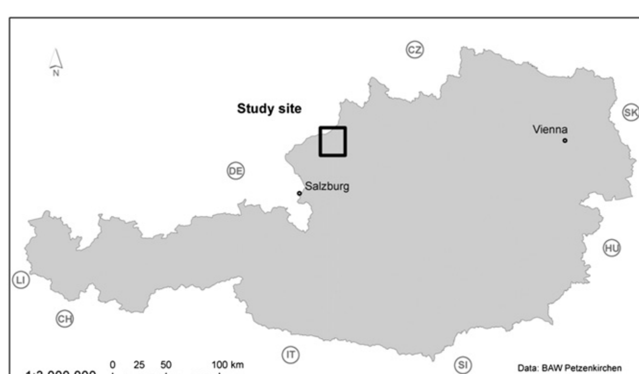


**Fig. 1.** Study site location.