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Effectiveness of conservation tillage, tied-ridging, and winter cover crops at controlling runoff and soil loss in the Western European context: a meta-analysis

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As a result of intensive agricultural practices, cultivated soils of the European loess belt can experience high levels of degradation by erosive runoff. Given the sometimes severe and costly on- and off-site impacts, the agricultural community is urged to adopt alternative cropping techniques to mitigate runoff and erosion. Several cropping practices related to conservation agriculture are known for their ability to mitigate surface flows, but the magnitude of their effectiveness is associated with a wide variability due to environmental or management factors. The influence of these factors on the practices' effectiveness is still poorly understood in quantitative terms. We therefore quantitatively reviewed the effectiveness of three common conservation farming practices at controlling runoff and soil loss. A systematic search was performed, focused on the plot scale and the Western European context, and meta-analyses were carried out on the 35 collated relevant studies involving 239 individual trials (plot-years). Two different approaches suitable for hierarchically structured datasets were used for the meta-analyses: hierarchical nonparametric bootstrapping and linear random effects models. Both methods yielded very similar outcomes, but the lack of primary data sometimes restricted the ability to account for all hierarchical levels of the dataset in the random effects models. We found that, on average, winter cover crops decrease cumulative seasonal (autumn-winter) runoff by 68% and soil erosion by 72% compared to a bare soil. The level of stubble tillage on the control plot, the number of successive years of cover cropping, and the maximum vegetation cover reached are three key variables explaining the mitigation effect of winter cover crops. In potato crops, tied-ridging (=(micro)basin tillage) cut cumulative seasonal (spring-summer) overland flow by a mean of 70% and soil loss by 92% compared to conventional furrows, but no moderators could be identified to explain the variability across studies or trials. Conservation (non-inversion) tillage techniques alleviate cumulative seasonal runoff by 27% and associated sediments losses by 66% on average, but a publication bias is strongly suspected for this meta-dataset. These mitigation effects are much greater for spring crops than for winter crops, and increase over time since ploughing stopped. The type of conservation tillage schemes also affects the capacity to attenuate surface flows. Intensive non-inversion tillage schemes based on multiple (powered) tillage operations turns out to be the least effective at reducing both water and soil losses. The best performing scheme against runoff appears to be a deep non-inversion tillage (-61%), while against

erosion it would be a direct drilling system (-82%). Coarser-textured soils (sandy loam) also respond slightly better to conservation tillage than (clay-)loams. Although several factors could partly explain the effectiveness of two of the three conservation practices considered in this study, there remains a high (unexplained) variability between trial effect sizes, thus not attributable to sampling variability. Meanwhile, this review provides farm advisors or policy makers with guidance on the conditions in which such conservation practices are expected to achieve the greatest benefits.