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Review

Influence of agricultural development and climate changes on the drainage valley density of the southern half of the Russian Plain

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ABSTRACT

The southern half of the Russian Plain is characterized by a relatively short history of intensively ploughed lands. The duration varies from approximately three centuries in the southern part of the forest zone to less than one century in some parts of the steppe zone. It was found that after cultivation, on more than 40% of lands in river basins the drainage valley density (D_{dv}) decreased by 15–58% in all landscape zones. In the first stage, the D_{dv} decrease was mostly associated with increasing surface runoff coefficient after cultivation of virgin lands with proportional decreases in groundwater runoff. In the second stage, usually after reaching areas of arable lands in river basins $>60\%$, the volume of eroded sediments entering small river channels exceeded the transport capacities of the permanent water-courses. As a result, the river channels completely silted. In later stages, the sediment redistribution cascade within the small river basins of the Russian Plain stabilized because of the increasing proportion of sediment eroded from the basin areas and re-deposited before entering the river channels because of the increasing area of sediment sinks due to the increase in dry valley lengths and total areas. The morphological parameters of small valleys and groundwater discharges are the key parameters that affect the intensity of small river aggradation on the regional scale.

1. Introduction

The historical intensification of anthropogenic influences on river basins in plains and lowland areas has usually been associated with an increase in the area of cultivated lands. The most evident examples are the consequences of the intensive ploughing of the Great American and Russian Plains during the last two to three centuries. Tremendous volumes of soil material were removed from the cultivated slopes because of accelerated sheet, rill and gully erosion. Erosion occurred in conjunction with intensive sediment deposition at the base of cultivated slopes and within first-order valleys adjacent to cultivated fields and land traditionally used as pastures (Golosov et al., 1997; Trimble, 1974; Walling & Collins, 2008; Walling et al., 2011), but some sediments were transported to river streams. These land use changes resulted in the 5–7-fold increase in sediment discharge in some disturbed river channels (Dedkov & Moszherin, 1984; Wilkinson & McElroy, 2007). A number of sediment redistribution models can describe soil losses and sediment deposition at the hillslope or slope catchment scale (Tucker et al., 2001; Verstraeten, 2006), but upscaling sediment transport models to the landscape scale is difficult (Fryirs & Core, 2014). The main problems are associated with the verification of the models for new landscape conditions. The assessment of small river aggradation dynamics in association with intensifying anthropogenic influence on their catchment areas provides a good opportunity for understanding the sediment fluxes in river basins of diverse landscape zones with varied durations of intensive agriculture activities.

Trimble and Lund (1982) showed for the Coon Creek basin that the intensification of erosion from initially cultivated fields produced huge amounts of sediments that were partly delivered to valley bottoms with an extremely high intensity of sediment deposition because of the limited transport capacity of river channels. A similar intensification of sediment redistribution was observed in other parts of the Great Plains immediately after the initial tillage of virgin lands (Phillips, 1991, 1993). It is also possible to find some clear indicators of intensive erosion and deposition in areas with a longer history of intensive agriculture around the globe (Dotterweich, 2013; Hoffmann et al., 2007, 2009; Houben, 2012; Notebaert & Verstraeten, 2010). In addition, changes in river

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