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Assessment of soil erosion and conservation on agricultural sloping lands using plot data in the semi-arid hilly loess region of China

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ABSTRACT

Study region: Semi-arid hilly loess region of China.
Study focus: The objectives of this study were to investigate soil and water loss on agricultural sloping lands and to evaluate the effectiveness of soil conservation practices in controlling erosion using plot data.

Runoff and soil loss were measured from the short slope plots (SSP) (7 m long) and the long slope plots (LSP) (20 m long) at various slope angles as well as from cropland and soil conservation plots (SCP) under natural rainfalls.

New hydrological insights for the region: The results revealed that runoff per unit area slightly increased with slope angle on SSP, but reached a maximum at 15° and then decreased with slope angle on LSP. Soil loss per unit area increased with slope angle on both SSP and LSP. An average of 36.4% less runoff but only 3.6% less soil loss per unit area was produced on LSP than on SSP. The *S* factor calculated using the slope factor equations in USLE/RUSLE was significantly greater than that estimated from the measured soil loss on the plots. Rainstorms with recurrence intervals greater than 2 years were responsible for more than two thirds of the total soil and water loss. The effectiveness in reducing surface runoff by five types of conservation practices was mixed. However, all the conservation practices yielded much less soil loss than cropland.

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1. Introduction

Soil erosion remains one of the biggest environmental problems worldwide, threatening both developed and developing countries (ISCO, 2002). Erosion by rainstorms in agricultural areas not only strips the fertile topsoil on site, but also degrades water quality and clogs streams, rivers, and reservoirs off site (Zhu et al., 2013). As a result of increasing population, cultivation has been expanded to steep sloping lands in many developing countries in the world (Liu et al., 1994, 2000; Turkelboom et al., 1997; Rumpel et al., 2006; Podwojewski et al., 2008; Mugagga et al., 2012), which causes major types of environmental damage with dramatic consequences in terms of soil fertility decrease and water availability (Lal, 1998). This is particularly so in semi-arid areas which are characterized by intense rainstorms and medium to poor soil fertility.

The Universal Soil Loss Equation (USLE) (Wischmeier and Smith, 1978) and its revised version (RUSLE) (Renard et al., 1997), originally developed in the US, have been employed in many countries for the assessment of soil loss from agriculture because of their simplicity and low requirements for input parameters (Fox and Bryan, 1999). The intimate integration with land use and soil conservation measures in the models can also provide guidance in land use management and planning (Laflen et al., 1978). However, the models are typically applicable to areas with gentle slope gradients between 3% and 18%, a normal probability distribution of annual rainfall, and cropping management systems similar to the US (Wischmeier and Smith, 1978; McCool et al., 1987; Mannaerts and Gabriels, 2000; Kinnell, 2010). When applied to areas where environmental conditions and farming techniques, as well as soil conservation practices significantly differ from the U.S., variables in the USLE/RUSLE models need to be modified to accommodate local characteristics (e.g., Lu and Higgitt, 2001; Hoyos, 2005; Zhu et al., 2013).

In semi-arid areas, most of rainfall events are non-erosive and often relatively few storms generate runoff and cause soil loss each year. Thus it is important to evaluate the relative contributions of large and small storms to total soil loss. From the practical standing point, it is essential to design conservation measures and strategies that are effective in controlling soil losses in those large events. For examples, Larson et al. (1997) suggested that conservation systems should be designed for limiting soil loss (namely, tolerance) to the value corresponding to a return period variable from 10 to 20 years. Mannaerts and Gabriels (2000) emphasized that adding a probability of recurrence to erosion events is essential for successful erosion assessment in semiarid zones.

The present study was conducted in the hilly region of the Loess Plateau in China, which is among the most severely eroded regions in the world, with a mean erosion rate of 150 Mg ha^{-1} yr^{-1} (Chen and Luk, 1989). The region has a semi-arid climate, characterized by strong spatiotemporal variability of rainfall occurrence. The rainfall in the region shows a pronounced skew instead of normal probability distribution (Zhu, 2013). Due to the high density of population and the rugged terrain conditions in the region, the cropland parcels owned by individual households are characterized by short slope lengths and a wide range of slopes up to more than 30°. The lands are also ploughed by animals instead of tractors. The various types of field boards between land parcels (i.e. earth banks, small ditches, etc.) interrupt storm flows on slopes. The profound difference in climates, terrain conditions, and farming techniques between this region and the US has become a major barrier to a wide application of the USLE models in the region.

The objectives of this study include: (1) to examine runoff and soil loss at slope angles of 5°, 10°, 15°, 20°, 25°, and 30° on short and long slope plots; (2) to evaluate the relative contributions of storms with various recurrence intervals to total soil loss; (3) to test the validity of the slope equations used in the USLE/RUSLE models; and (4) to assess the effectiveness of different soil conservation measures in reducing runoff and soil loss.

2. Study site and field settings

The study was conducted at the experimental watershed of the Shanxi Institute of Soil and Water Conservation (SISWC) in Lishi, Shanxi Province of China (Fig. 1). The watershed, Wangjiagou, is located in the hilly region of the Loess Plateau, with a drainage area of 9.1 km^2. The climate is semi-arid warm temperate, with mean annual precipitation of about 500 mm, of which about 80% falls in the rainy