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Grass hedge effects on controlling soil loss from concentrated flow: A case study in the red soil region of China

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ABSTRACT

Grass hedges are widely applied on sloping croplands as a low-cost measure to reduce soil and nutrition loss. Therefore, it is important to understand the role of hedgerows in runoff and sediment processes. In this study, 36 field runoff simulation experiments were conducted in the red soil region of China to determine flow hydraulics and soil loss processes under 12 different hedgerow conditions. Specifically, two types of hedgerow widths (two-row and three-row) were planted for each of three species of vegetation (Bahia grass (*Paspalum notatum*), Vetiver (*Vetiveria nigritana*) and Daylily (*Hemerocallis fulva*)), and these plots were tested both before and after the removal of the grass stems. Grass stems played an important role in decreasing the flow velocity and filtering sediment. For the three selected vegetation types, the final flow velocities (V3) were ranked in the following order: Bahia grass (0.12 m/s) < Vetiver (0.17 m/s) < Daylily (0.19 m/s). There was no significant difference between the three grass species in trapping sediment under the condition of this study. A comparison between the two different hedgerow widths revealed that the three-row hedges were more effective (decrease ratio >30%) than the two-row hedges (decrease ratio <20%) in reducing the flow velocity ahead of the grass barriers (V2). Nevertheless, soil losses from the grass hedges were mainly related to the final flow velocity (Pearson's $R = 0.66$, $N = 36$) rather than the V2. The final flow velocity and the total soil loss rate did not decrease remarkably when using the three-row hedges. These results could be used to provide sound field recommendations for designing and managing hedges in the red soil region of China.

1. Introduction

Soil erosion from croplands has long been recognized as one of the most serious causes of soil degradation. In China, 28.3% of soil loss is generated from croplands, which only account for 6.8% of the total area that suffers soil loss Ministry of Water Resources of the Peoples Republic of China ((MWR, 2007). Large areas of sloping croplands, particularly in the hilly red soil region of China, are suffering from severe soil erosion due to intensive cultivation (Liang et al., 2010). Soil erosion is a serious challenge for local agricultural development that should be controlled. Among soil and water conservation measures, grass hedges have been widely used as a low-cost approach for reducing soil erosion on sloping land in China and other regions (Gilley et al., 2000; Herbst et al., 2006; Cullum et al., 2007; Lin et al., 2009; Huang et al., 2010; Wu et al., 2010; Xiao et al., 2011).

Recently, studies on the effects of grass hedges on soil conservation have been reported worldwide. Grass hedges can slow concentrated flow and promote the deposition of sediment in the ponded backwater area above the hedges (Meyer et al., 1995). Therefore, hedges can be used as a conservation practice for reducing soil loss and dispersing runoff in agricultural fields (Ritchie et al., 1997). When grass hedges are used in conjunction with conservation practices, such as no-till or reduced-till farming systems, the conservation benefits are especially effective (Gilley et al., 2000; Cullum et al., 2007). By reducing runoff and capturing eroded material, grass hedges can control nutrient loss and enhance soil fertility (Eghball et al., 2000; Owino et al., 2006; Gilley et al., 2008; Mutegi et al., 2008; Lin et al., 2009). The conservation efficiency of grass hedges is influenced by multiple factors, such as the width of the grass strip, the grass density and the grass height (Van Dijk et al., 1996; Donjadee et al., 2009). Thus, hedgerows should be composed of competent grass species and implemented correctly. For example, in northern China, researchers evaluated the benefits of various grass hedges and proposed suitable species for application in the study area (Huang et al., 2010; Wu et al., 2010; Xiao et al., 2011).

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It is important to understand how grass hedges work to control soil loss when developing efficient measures. Therefore, the grass-hedge conservation system has been studied frequently. Specifically, changes in surface runoff hydraulics and soil hydrologic characteristics are essential aspects of the grass-hedge effect (Meyer et al., 1995). When grass hedges are planted on contours, the hydraulic resistance of the vegetation slows runoff, creates ponding, and promotes sedimentdeposition (Rose et al., 2003; Vieira and Dabney, 2012). By conducting laboratory flume experiments, soil loss processes through grass hedges or strips can be simulated (Tadesse and Morgan, 1996; Hussein et al., 2007a,b; Pan et al., 2010). Laboratory flume experiments can be used to reveal surface flow depth upstream and downstream of the grass hedges. In turn, the maximum hedge spacing can be calculated (Dalton et al., 1996). The dynamic profile of the water that passes through the grass hedges can be quantified (Rose et al., 2003; Akram et al., 2014), and the formation processes of the backwater ahead of the hedges can be simulated (Hussein et al., 2007a,b). In addition to runoff hydraulics, soil hydraulic characteristics are important and have been studied. Previously, grass hedges were reported to affect soil hydraulic properties, such as saturated soil hydraulic conductivity, bulk density, and soil water retention (Rachman et al., 2004a,b,b). Detailed measurements of soil physical properties showed a significant increase of soil macropores in grass buffers relative to traditional treatments (Udawatta and Anderson, 2008). Furthermore, the infiltration capability improves and more soil accumulation occurs when grass hedgerows are present (Oshunsanya, 2013). Based on data from field or laboratory experiments, soil erosion models were adopted to simulate grass hedge system effects on soil and water conservation (Hussein et al., 2007a; Rachman et al., 2008; Xiao et al., 2012).

The above mentioned studies report the benefits of grass hedges and their associated soil erosion control mechanisms. However, most of these experiments were conducted under laboratory conditions, which differ from field conditions with respect to surface roughness and vertical soil water movement. Furthermore, different grass species and hedgerows have unique stem stiffness and density characteristics that alter flow hydraulics

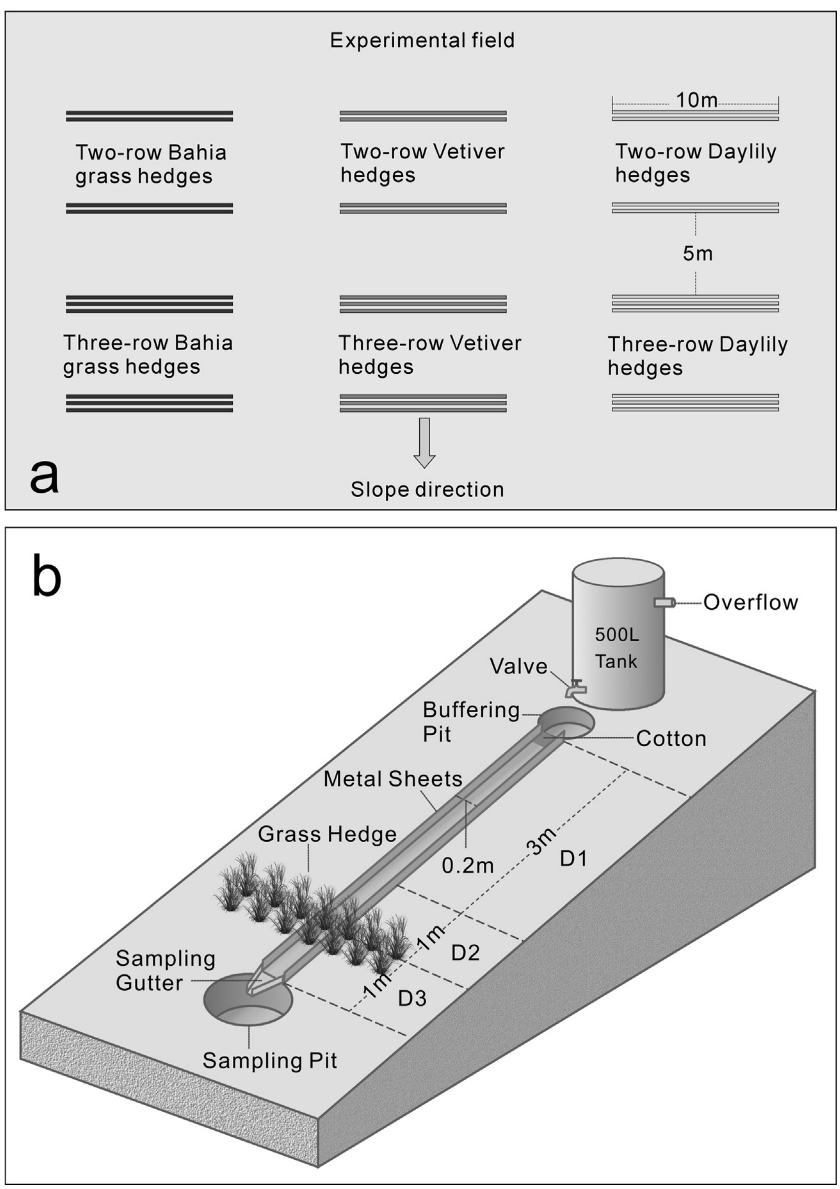

Fig. 1. Location of the hedgerows within the field (a) and the experimental design (b).