Catena 147 (2016) 463–468

Contents lists available at ScienceDirect

Catena

journal homepage: www.elsevier.com/locate/catena

A study of erosion control on expressway embankment sideslopes with three-dimensional net seeding on the Qinghai-Tibet Plateau

Lin Hu [a,b,*], Yongti Shan [b], Ruihua Chen [b], Wen Guo [b], Qi Wang [b], Zhanbin Li [a,c]

[a] State Key Laboratory Base of Eco-hydraulic Engineering in Arid Area, Xi'an University of Technology, Xi'an, Shaanxi 710048, PR China
[b] Institute of Environment and Landscape Planning, CCCC First Highway Consultants Co., LTD., Xi'an, Shaanxi 710075, PR China
[c] State Key Laboratory of Soil Erosion and Dryland Farming on the Loess Plateau, Institute of Soil and Water Conservation, CAS & MWR, Yangling, Shaanxi 712100, PR China

ARTICLE INFO

Article history:
Received 10 January 2016
Received in revised form 26 July 2016
Accepted 27 July 2016
Available online 4 August 2016

Keywords:
Soil erosion
Expressway sideslope
Cover percentage
Three-dimensional net seeding
Qinghai-Tibet Plateau

ABSTRACT

Soil erosion on expressway sideslopes affects hillslope stability and adversely influences expressway conditions. However, few attempts have been made to quantitatively study soil erosion processes and control the effectiveness of these processes on expressway sideslopes. The objectives of this study were to investigate the effects of *Elymus dahuricus* cover on soil erosion processes and effectiveness. Experiments using three *Elymus dahuricus* cover percentages (0%, 37% and 74%) and two inflow rates (3.0 and 8.0 L min^{-1}) were conducted in 3-m-long by 1-m-wide plots on expressway embankment sideslopes with three-dimensional net seeding on the Qinghai-Tibet Plateau. The results showed that when the cover percentage was increased from 0 to 37%, the mean runoff velocity decreased by 35.3–45.9%. Soil loss was also significantly lower. Compared with the soil loss from bare sideslopes, the soil loss from sideslopes with 37% cover decreased by 92.6–95.4%. Although expressway construction and maintenance are expensive and difficult in this region, at least 37% *Elymus dahuricus* cover on expressway embankment sideslopes with three-dimensional net seeding should be required. A soil loss equation, which was based on the cover percentage and the inflow rate, was established and evaluated for expressway embankment sideslopes in the region. The effects of the cover percentage on soil erosion were greater than those of the inflow rate. Therefore, preventing runoff-induced erosion through effective cover measures, such as three-dimensional net seeding, is critical for soil erosion control on expressway embankment sideslopes on the Qinghai-Tibet Plateau of China.

1. Introduction

Soil erosion is an important environmental concern because it directly affects sustainable development (Girmay et al., 2009; Wen et al., 2015), especially on the Qinghai-Tibet Plateau, which has a fragile ecosystem (Ma et al., 2009). With rapid economic development and growth, road construction on the Qinghai-Tibet Plateau in China has created extensive surface disturbances that have had adverse impacts on the surrounding environments, such as severe soil erosion (Xu et al., 2006). Runoff and inflow from road surfaces generally result in severe erosion of embankment sideslopes even during small rainfall events because of runoff erosivity, which is the shear stress to the soil surface induced by runoff (Ziegler et al., 2001). It is an important source of soil loss around roads. This process can also affect hillslope stability and further influence expressway conditions (Li et al., 2013). Therefore, a detailed study of soil erosion control on highway embankment sideslopes in this region is essential.

Soil erosion is a natural process and cannot be completely eliminated. However, best management practices can be determined to control and manage soil erosion (Bakr et al., 2012). There are several suitable management practices on the Qinghai-Tibet Plateau because of its high elevation, unique geomorphology and extremely severe weather conditions. Engineering measures are effective for soil erosion control in the short term, and vegetation measures on road sideslopes are effective in the long term (Xu et al., 2006). Along expressways on the Qinghai-Tibet Plateau, the management practices for runoff and erosion control are three-dimensional net seeding, turfing, etc. (e.g., Cheng et al., 2010). Three-dimensional net seeding technology has been widely applied in this region. However, the effectiveness of three-dimensional net seeding, such as the magnitudes of runoff and soil loss processes, is seldom investigated.

Forman (2000) noted that approximately 19% of the total land area had been affected by the public road system. Numerous studies of soil erosion on expressway embankment sideslopes have been conducted in humid and warm regions. However, in cold regions, few studies have been conducted. Furthermore, most studies focused on the effectiveness of control measures for small or intermediate slope gradients (normally <30°). However, expressway embankments with steep sideslopes also require protection (Álvarez-Mozos et al., 2014),

* Corresponding author at: No. 205, Keji 4th Road, First Highway Consultants Co., LTD., Xi'an, Shaanxi 710075, PR China.
E-mail address: 27430166@qq.com (L. Hu).

http://dx.doi.org/10.1016/j.catena.2016.07.050
0341-8162/

especially on the Qinghai-Tibet Plateau. High flow exacerbates soil erosion and amplifies this risk on steep sideslopes. Thus, it is imperative to study the effectiveness of soil erosion control on steep expressway embankment sideslopes.

Monitoring soil loss using runoff plots is a suitable, cost-effective and useful approach that helps decision makers identify soil erosion risks and improve their management practices (Hartanto et al., 2003). The most important factor that influences soil erosion is the percentage of vegetation cover (Block, 2000). For these reasons, a study of inflow simulation was conducted under controlled conditions on field expressway embankment sideslopes with three-dimensional net seeding on the Qinghai-Tibet Plateau. The objectives of this study are to quantify the total runoff and soil loss, analyze soil erosion processes, study the erosion control effectiveness of three-dimensional net seeding under three vegetation covers and propose an optimal soil erosion control measure for expressway construction in this region.

2. Materials and methods

2.1. Experimental area and materials

The experiments were conducted on embankment sideslopes in the D5 Section of the Gong Yu (Gonghe to Yushu) Expressway on the Qinghai-Tibet Plateau, China. The elevation of the expressway is 4380 m. The research site (33°38′4″N, 97°11′30″E) has a typical plateau continental climate. The annual precipitation is between 262.2 and 772.8 mm. Rainfall is generally concentrated during the months of June through September. The study focused on 12 individual sideslope plots to conduct inflow simulation experiments. Each sideslope plot was 3 m long and 1 m wide, with a slope gradient of 70° (Fig. 1). The plot was surrounded by galvanized sheet iron with a thickness of 0.45 mm. The height of the galvanized sheet iron was 35 cm (20 cm under the ground and 15 cm above the ground).

The overflow tank that supplied the inflow was attached to the upper end of the plot (Fig. 2). A runoff collector was installed at the bottom of the plot and was used to collect the runoff samples. The water was provided via a 4500-L sprinkler.

The soil in this study was alpine meadow soil, classified as an *Entisol* (USDA Taxonomy), with 34.8% sand (>50 μm), 64.8% silt (50–2 μm), 0.4% clay content (<2 μm) and 11.3% soil organic matter. The pipette method and the potassium dichromate oxidation-external heating method were used to analyze the soil texture and soil organic matter, respectively.

The re-vegetation measure applied was three-dimensional net seeding. The method first involved adding 20 cm of soil to the plot, then covering the three-dimensional net (Fig. 3) with grass seeds.

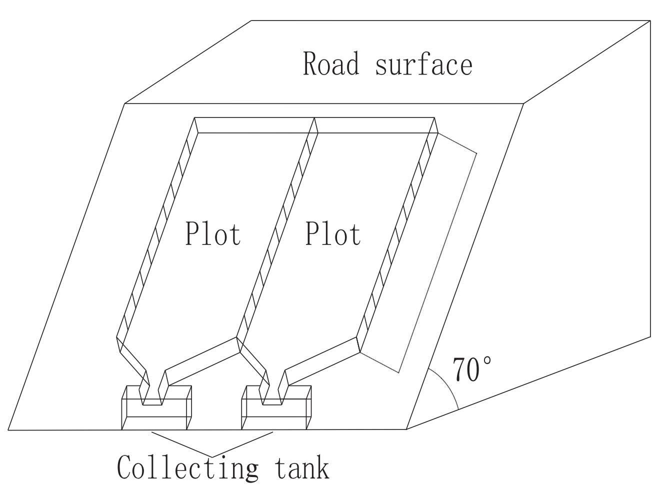

Fig. 1. Map of the experimental plots.

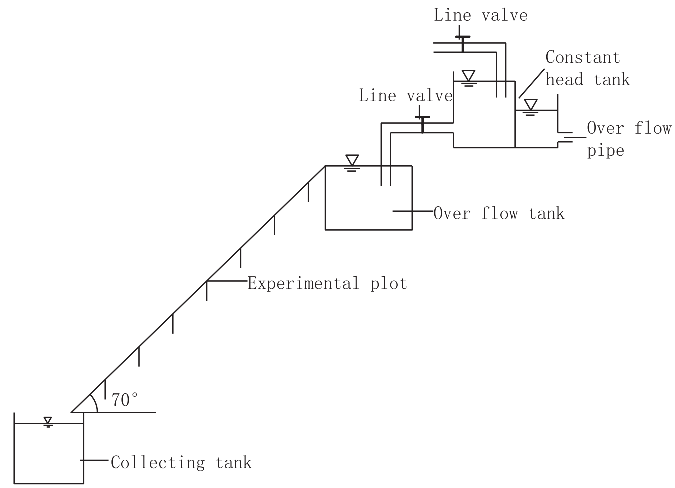

Fig. 2. A schematic representation of the experimental inflow setup.

Then, another 10 cm of soil was added. The three-dimensional net allowed the plant roots to cross and promoted growth evenly. Three-dimensional net seeding also held the gauze pad, turf and soil surface together. Then, a solid composite protective layer was formed. Grace (2002) suggested that the local species should be used for soil erosion control. By evaluating the characteristics of the local grass species, we chose the tufted perennial *Elymus dahuricus* Turcz. as the representative grass because it has been commonly used in vegetation regeneration (Zhang et al., 2012).

2.2. Experimental procedures and design

The experiments were conducted from June to July 2015. Before the inflow experiments, the bulk densities and soil water contents of the 12 plots were measured. For the plots with and without *Elymus dahuricus*, the average bulk densities were 1.01 and 1.04 g cm^{-3}, and the average soil water contents were 25.4% and 21.2%, respectively.

Plateau rainfall is mainly convective, resulting from vertical instabilities. The maximum rainfall intensities over 30 and 10 min for summer rainfall on the Qinghai-Tibet Plateau were approximately 0.10 and 0.30 mm min^{-1}, respectively (Li and Tao, 2005). Furthermore, the runoff and inflow from the expressway surfaces generally converged and resulted in strong scouring erosion of the expressway embankment sideslopes, even during low rainfall events (Ziegler et al., 2001). Thus, following the normal and extreme local rainfall conditions and steep sideslope characteristics, we designed inflow rates of 3.0 and 8.0 L min^{-1} to simulate the runoff scouring processes. Because the Gong Yu Expressway is under construction and will be completed in 2017, the re-vegetation measures have not been completed. Therefore, there were different three-dimensional net seeding covers. We chose

Fig. 3. Three-dimensional net.