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The distribution of and factors influencing the vegetation in a gully in the Dry-hot Valley of southwest China

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ABSTRACT

The Dry-hot Valley of the Jinsha River in southwest China is an ecologically fragile zone in which gully erosion is one of the most important environmental problems due to the high sediment yield from the gully. The vegetation, which impacts the erosion processes of the gully, is important to the ecological environment. In this study, we investigated the vegetation in gully n1 of Yuanmou County, which is a typical area of the Dry-hot Valley. A total of 82 vegetation quadrats on a relatively gentle section of gully n1 (slope was mostly less than 45°) and nine points on a steep slope (slope higher than 70°) were investigated in 2012. The vegetation indices, in addition to the soil conditions and topography, were measured through field investigations and the gully Digital Elevation Model (DEM). On the gully sidewall, almost no vegetation grew in the steep slope, whereas the slope gradient and the slope aspect exhibited a weak relationship with the vegetation indices when the slope was less than 45°. On the gully bed, the runoff path was the most important factor that affected the vegetation. The average vegetation cover inside the runoff path was 5.2%, whereas the average vegetation cover outside the runoff path increased to 56.3%. The vegetation strongly impacted the soil moisture during the rainy season. However, this relationship was not observed during the dry season, which indicates that the water conservation effects exerted by the vegetation cannot last a long time in the Dry-hot Valley. The active part of gully n1 has a vegetation cover (average 16.9%) that is significantly lower compared with the stable parts of the gully (55.1%). This finding indicates that the vegetation in the gully is not only impacted by the soil and the topography in the area of vegetation growth but also influenced by the runoff processes upstream of the gully heads.

1. Introduction

Vegetation, which can purify air, filter water, and protect soil, is often impacted by the soil condition and topography in a region (Florinsky and Kuryakova, 1996; Poulos et al., 2007; Xu et al., 2008). The topography can influence the vegetation by affecting the development of roots, the microclimate, and the solar radiation (Alday et al., 2010; Bennie et al., 2006; Li et al., 1991). The vegetation is also affected by various soil properties, such as soil moisture, acidity (pH), and nutrient content. In addition, the growth of vegetation may affect the topography and soil properties through various processes, including respiration, hydrologic control, and soil conservation (Jiao et al., 2009; Osterkamp et al., 2011). The relationship between vegetation, topography, and soil, which may change at different spatial scales, is an important subject of ecological and geographic studies (Solon et al., 2007; Xu et al., 2008).

Gully erosion is an important type of soil erosion, and gully itself is a main source of sediments, which contributes 10% to 94% of the total sediments in different areas of the world (Poesen et al., 2003). The vegetation has beneficial effects in controlling of gully erosion (Munoz-Robles et al., 2010; Rey, 2003), which could result in the reinforcement of steep gully sidewalls and the interception of sediment transport processes on the gully beds. The topography of the gully investigated in this study was quite different from that reported in previous studies. The slope gradient of the vegetation were often reported to be below 30° in previous studies (Solon et al., 2007; Wang et al., 2011; Xu et al., 2008), while slopes reached 35° to 45° thus were described as steep slopes (Wang et al., 2008b). The slope gradient of the gully changed significantly: the gully sidewall was often close to or even more than 90°, whereas the gully bed was often below 5°. The soil composition of the gully was often complicated because it cut deeply into the earth surface, which made the soil type to vary in the longitudinal direction. Thus, the special topography and soil conditions of the gully create a complex environment for vegetation growth. Furthermore, the erosion processes that occurred in different parts of the gully also varied (Leyland and Darby, 2008; Martinez-Casasnovas, 2003; Poesen et al., 2003), and the vegetation conditions, which are strongly correlated with erosion processes, may also be different. However, few studies have focused on

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the vegetation distribution and the factors that influence this distribution in a gully.

The Dry-hot Valley of the Jinsha River is an ecologically fragile zone in southwest China that covers an area of approximately 1.2×10^4 km^2 (Xiong et al., 2010), and gully erosion is a serious problem in this area. According to previous studies, the distribution density of most gully area ranged from 3 to 5 km/km^2, with the highest density being 7.4 km/km^2 (Cheng et al., 2011; Wang et al., 2008a). This distribution results in a high sediment yield and a rapid degradation of land. The revegetation of the gullies is very important for the improvement of the ecological environment of this region, although the gullies in this region are often large in scale with a deep incision, steep gully sidewall and a complex soil composition. These special characteristics may influence the vegetation distribution and growth in the gully. The aim of this study was to investigate the vegetation conditions in conjunction with the topography and the soil conditions in the gully and to analyse the distribution of vegetation in different parts of the gully.

2. Materials and methods

2.1. Study area

The Yuanmou Dry-hot Valley, which covers an area of more than 2000 km^2, is located in the upper and middle reaches of the Jinsha River (an important tributary of the Yangtze River) in Yunnan Province (Fig. 1a) in southwest China (Xiong et al., 2009). The region exhibits a typical southern subtropical climate with an annual average temperature of 21.8 °C. The annual precipitation is 615 mm, and the annual potential evaporation is 3569 mm, which results in the extreme aridness of this region (Wang et al., 2008a). The rainy season, which often lasts from June to early October, accounts for more than 85% of the annual precipitation. Gullies often developed at the quaternary fluvial–lacustrine deposits with a loose structure at an elevation of in the range of 1000 to 1350 m above sea level, and the main soil types at the surface of the region were dry red soil (classified as Ustic Ferrisols in Chinese Taxonomy) and vertisols. Dry red soil has a high sand content (often above 50%) and contains iron and manganese, whereas vertisols are mainly composed of clay (often over 50%) with a strong expansibility. In addition, a sandy soil layer, which could easily be eroded by water, often develops under these two types of soil, and a large amount of sediments are deposited in the middle and downstream of the gully bed. The vegetation in the gully is dominated by the herbs *Heteropogon* and *Bothriochloa pertusa*, and a few *Dodonaea viscosa* (L.) Jacg. shrubs grow in some parts of the gully (Zhang et al., 2003).

2.2. Quadrat investigation of the vegetation

We randomly selected 82 1 m × 1 m quadrats in gully n1 (Fig. 1b) at the beginning of the rainy season (June 22th) in 2012, which was the very next day after a three-day period of continuous rainfall (about 15 h after the rainfall stopped). The vegetation indices, including the plant species, the percentage of vegetation cover, the number of plants, and the height of the plants, of each quadrat were determined. According to previous investigation and studies, the length of the herb roots in gully area was mainly ranged between 5 and 30 cm. So a soil depth of 0 to 30 cm was sampled in each quadrat which was mainly concerned with the vegetation condition. A total of 82 samples were oven-dried at 105 °C for 12 h to test the soil moisture by mass in the rainy season. The location of each quadrat was recorded by high-precision RTK GPS (Trimble R8, the horizontal and vertical positioning accuracy were 1 cm ± 2 ppm and 2 cm ± 2 ppm, respectively).

During the dry season (November 6th, 46 days without any precipitation) in 2012, we used the lofting function of the RTK GPS to find the locations of the quadrats investigated in June; the navigation accuracy reached the centimetre level. The vegetation indices and the soil moisture were measured in the dry season to obtain the changes in the vegetation conditions and the soil moisture in the same quadrats. In addition, the vegetation conditions at nine points on the steep gully sidewall (slope over 70°) of gully n1 were also investigated.

2.3. Gully topography measurement and data processing

Gully n1 was located in the valley floor of a small catchment in Yuanmou (Fig. 1c) and was measured using an RTK GPS in April 2012. A total of 11,280 high-precision topographic points were monitored along the boundary of the gully sides, the edge of the gully bottom where the gully sidewall changes abruptly into a flatter gully bed, and randomly distributed on the sidewall and the bottom of the gully. These data were transferred to ArcGIS 9.3, used to create Delaunay triangulated irregular networks (Tins) using the 3D Analyst tool, and then converted into a DEM grid with 1-m cell size (Wu et al., 2008).

The elevation and depth of each cell could be extracted from the DEM grid. The slope gradient and the slope aspect of each cell could be calculated using the Spatial Analyst tool of ArcGIS, and the topography information of each quadrat could be obtained according to its location cell in the DEM grid. According to the results, the area and volume of gully n1 were 16,939.4 m^2 and 124,514.5 m^3 respectively. The mean depth of the gully was 7.6 m, and maximum depth was 15.9 m. The elevation ranged between 1060.4 m and 1090.9 m, and the slope gradient ranged from 0.45° to 87.8° with an average of 34.3°.

3. Results

3.1. Vegetation, soil, and topography of the quadrats in the gully

Herbs were observed to be the major vegetation type in the gully. All of the quadrats with vegetation contained herb plants: 94.7% of the quadrats contained *Heteropogon* and 37.3% of the quadrats contained *B. pertusa*. In addition, 4.9% of the quadrats contained shrubs, and the species was *D. viscosa* (L.) Jacg. The vegetation conditions in November were slightly better than those in June because the herbs in the gully, which had just begun to grow in June and were thus fully grown after the rainy season, were tolerant to drought and had therefore not completely wilted in November (after more than 1 month without precipitation). A total of 12 of the 82 quadrats did not have any vegetation in June, and 5 of these 12 quadrats contained herb plants in November; however, the average vegetation cover in these quadrats was 3.6%, and only one of the five quadrats exhibited a vegetation cover of more than 5%. The average vegetation cover in the 82 quadrats increased by 6.0% from June to November. Although the number of plants did not significantly change, the height of the plants increased by 38.6% (Table 1). The height of the plants enhanced in November, but the leaves of the herbs began to wilt and the colour of the herbs was mostly turned into yellow already. The high coefficient of variation (*Cv*) of the vegetation cover revealed that the vegetation distribution varied between different locations of the gully, likely due to the complex topography and soil conditions. Because the growing season of the plants was mainly during the rainy season and the vegetation was not fully grown at that point, the vegetation indices in the rest of the manuscript indicate the results obtained in the dry season (November) unless otherwise noted.

The analysis of the 82 quadrats revealed a significant relationship between the vegetation indices, including the vegetation cover and the number and the height of the plants (Fig. 2). The soil water content (by mass) in June (*SWC1*) was significantly higher than that in November (*SWC2*); the average *SWC1* was 7.45%, whereas the *SWC2* was only 3.78%. The slope of the quadrats ranged from 1.25° to 61.35° with an average of 22.05°. The slope aspect was converted using the cosine function to a range from −1 to 1, which indicates south to north (Xu et al., 2008), and the average was −0.27. The depths of the quadrats ranged from 1.28 m to 15.50 m, and the elevation ranged from 1060.70 m to 1088.44 m (Table 2).