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Influence of three plant species with different morphologies on water runoff and soil loss in a dry-warm river valley, SW China

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ABSTRACT

Understanding of the effects of isolated plants with different morphologies on water runoff and soil loss is important for vegetation restoration in arid environments. We selected three representative species (*Artemisia gmelinii*; *Ajania potaninii*; *Pulicaria chrysantha*) of the dry-warm river valley of the upper reach of Minjiang River, SW China to examine these effects. Twenty-five runoff events were recorded using runoff plots at micro scale ($<$40 cm $\times$ 40 cm) on a south facing slope from July through October 2006. *A. potaninii* had sparse canopy, the smallest leaf area (0.49 $\pm$ 0.25 cm^2) and specific leaf area (67.8 $\pm$ 16.5 cm^2/g), and the highest leaf relative water content (27.1 $\pm$ 4.4%). It is the most resistant to drought stress. *A. gmelinii* was the shortest, and had relatively small leaf area (0.55 $\pm$ 0.50 cm^2) and the densest canopy. *P. chrysantha* had the greatest leaf area (1.41 $\pm$ 0.49 cm^2) and most extended canopy (4450 $\pm$ 1646 cm^2). Dead branches and leaves of *A. gmelinii* and *P. chrysantha* commonly fall and collect on the soil surface. Thus they had greater improvements on soil porosity and soil water content, and higher effectiveness in controlling soil loss. However, *A. gmelinii* had more stable effectiveness in controlling runoff as compared with *P. chrysantha*. The characteristics such as relatively small leaf area but low height and dense canopy might be one criterion for selecting species to improve soil properties and controlling runoff and soil loss. Differences in soil environments, and runoff and soil loss production capacity for micro-surfaces regulates water and materials redistribution, which emphasizes the importance in designing vegetation restoration pattern.

1. Introduction

Vegetation and water erosion processes can strongly interact in landscapes. One particularly important interaction between these processes in patchy semiarid lands is how vegetation patches serve to control water erosion and then how this retained water runoff and soil material increase vegetation growth that, in turn, provides feedbacks to the system (Ludwig et al., 2005). These interactions could also lead to microtopography change that could further affect water runoff and soil loss processes (Bergkamp, 1998). Many studies have proved increasing vegetation cover is an important measure to control water erosion, and to improve soil environments (Hidalgo et al., 1997; Cerda, 1998; Martinez-Mena et al., 1999; Sanchez et al., 2002; Durán Zuazo, 2004; Xu et al., 2006b). However, few were conducted at individual plant scale (De Baets et al., 2007), on which we could relate such effects to plant morphology and thereby provide necessary information to select suitable plant species in terms of plant morphology for vegetation restoration in arid and semiarid environments. Moreover, the existing studies at individual scale were mainly concentrated in Mediterranean landscapes (Bochet et al., 1998, 2006; Casermeiro et al., 2004). In these studies of individual plant scale, small runoff plots ($<$1 m^2) was often used to monitor runoff and soil loss. These plots are very efficient at representing the hydrological behaviors of different surfaces to allow comparisons between them (Boix-Fayos et al., 2008).

The dry-warm river valley of upper reach of Minjiang River in mountainous area, SW China, experienced much disturbance (Yan et al., 2006), which caused sparse vegetation distributing in a mosaic of vegetated patches or isolated plants and bare surfaces, and therefore resulted in severe soil degradation and soil loss. Estimated by Lu et al. (2003), sediment delivery from this area is between 1000 and 5000 t km^{-2} year^{-1}. This area has become the key region for eco-environmental rebuilding under the National Eco-environmental Renovating Scheme of China (Li et al., 2006a). Many restoration studies have been conducted in this area (Li et al., 2005, 2006b), however, most of which mainly focused on the

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response and adaptation of certain plant species to environmental stresses, and scarcely related vegetation to water runoff and soil loss. Especially, few studies paid attention to the effects of plant morphology on water runoff and soil loss (Xu et al., 2006a).

Based on the analysis above, this paper aimed to (i) examine the differences in some plant characteristics of three representative species of this arid environments as well as relate these characteristics to water runoff and soil loss, and some soil properties at individual scale, (ii) investigate the relationships between slope gradient and water runoff and soil loss at micro scale.

2. Site descriptions

The study site is located at Maoxian county (31°37′20″–31°44′53″N, 103°54′04″–103°56′52″E), which belongs to Aba prefecture of Sichuan Province in southwest China (Fig. 1). This area is part of the dry-warm river valley of upper reach of Minjiang River, which is one of the four principal tributaries of the Yangtze River. Mountain peaks 1500–3500 m above the deep river valley are the prominent local topographical features of the area. The mean annual temperature is 11.2 °C, and mean annual precipitation is 494 mm with about 83% of this occurring throughout April–October (wet season). Two peak rainfall occurrences are during the wet season with one from April–June, and the other from August–September. Mean annual evaporation is 1332 mm. The aridity index (the ratio of potential maximum evaporation to rainfall) for this area is within 1.5–3.49, which is typical of semiarid environments (Zhu and Li, 1989). Brown soil is the predominant soil type—shallow depth (10–30 cm) and coarse texture (sand, 28.7%; silt, 68.7%; clay, 2.6%, percent by volume). Grassland and shrubland cover above 48% and 40% of the area, respectively. The vegetation mainly comprise drought-tolerant species, e.g., *Sophora davidii*, *Cotinus coggygria*, *Bauhinia faberi* var. *microphylla*, *Jasminum nudiflorum*, *Ostrypsis davidiana*, *Cotoneaster* spp., *Convulus tragacanthoides*, and *Ajania potaninii* are the predominant shrub species; *Artemisia gmelinii* and *Pulicaria chrysantha* are the predominant herbaceous species. In this study, we selected three species (*A. potaninii*, *A. gmelinii* and *P. chrysantha*) for the following reasons: (1) the three species are common in this area; (2) the three species include both shrub and herbaceous species, and (3) they each have unique morphologies and grow in the same area, which facilitates sampling. *A. potaninii* is a small perennial shrub widely distributed throughout the entire river valley. Its stems and branches grow separately and erectly, thus creating a sparse canopy. Its leaves are relatively thin, small, and sclerophyllous (Fig. 2c); *A. gmelinii* is a perennial tussock, which is widely distributed in semiarid ecosystems associated with the river valley. It is relatively short with a dense, umbrella-shaped canopy, with branches and leaves that often reach the ground (Fig. 2b). Dead branches and leaves commonly fall and collect on the soil surface; *P. chrysantha* is a perennial grass that is widely distributed in the semiarid ecosystems of the river valley. It is highly branched, and the branches grow outwards so that the canopy resembles an inverse cone. It has relatively large leaves that resemble feathers (Fig. 2d). Dead branches and leaves commonly fall and collect on the soil surface. Note that Latin names are used for all plant species in this study.

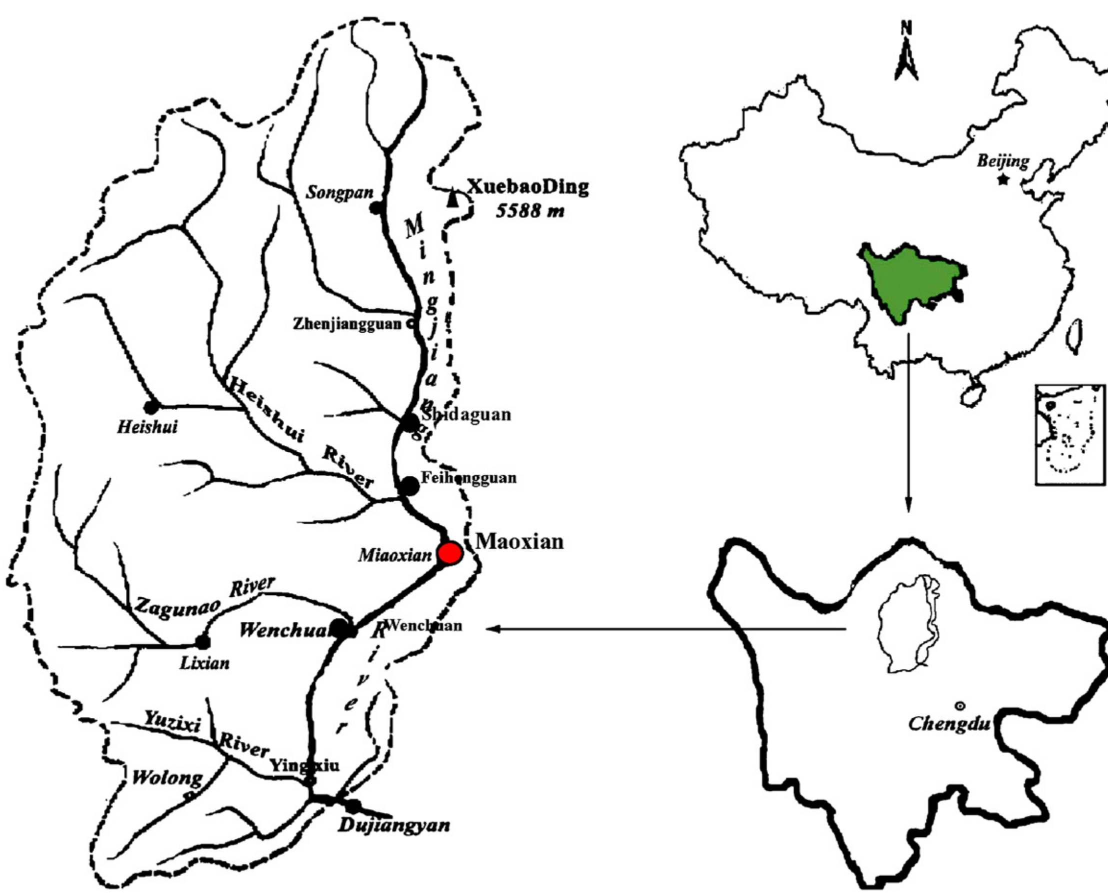

Fig. 1. The location of the study site.