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# Effects of grass contour hedgerow systems on controlling soil erosion in red soil hilly areas, Southeast China

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ABSTRACT

Soil erosion by water is a well-recognized serious environmental problem in the world. While contour hedgerow systems are an effective method for soil water conservation, there are a few studies on its effect in the red soil hilly areas in Southeast China. With a fixed field experiment, we constructed a runoff plot at hilly area in Zhuji County, Zhejiang province, to evaluate the effect of the grass hedgerows in soil water conservation, and to determine the optimized hedgerow patterns. Hemerocallis citrine (HC) and Ophiopogon japonicas (OJ) were selected to build the hedgerows in patterns of one row and two rows. The REE method was used to trace the source of the sediment for a better understanding of the characteristic and mechanism of erosion with hedgerows control. Our results showed that (1) hedgerows reduced erosion and surface runoff by 31.99–67.22% and 15.44–45.11%, respectively; (2) hedgerows delayed the development of rills; (3) hedgerows reduced the soil nutrients loss; (4) hedgerows reshaped the soil physical properties, especially in increasing $>0.25$ mm water-stable aggregates. Taken together, our results suggest that two-row OJ is the optimized contour hedgerow pattern in the experiment condition, and downward sloping land should have the highest priority to take measures for soil water conservation. This research comprehensively studied the effects and mechanism of contour hedgerows in controlling soil and water loss in red soil hilly areas, Southeast China, so that the practice of soil and water conservation can be implemented more effectively in these areas.



## 1. Introduction

Soil erosion by water is a well-recognized serious environmental problem in the world (Beskow et al., 2009, Blavet et al., 2009, Chen et al., 2012). It leads to a series of negative effects, such as soil deterioration, declining land productivity, contamination of local hydrology systems and reduction of water storage capacity with transported sediments and pollutants (Cerdan et al., 2010). Moreover, since soil is the largest terrestrial C pool, soil erosion even increases the threat of global warming via loss of soil organic carbon (Lenka et al., 2013). In hilly areas, soil erosion is often a more serious problem than that in plain areas (Lin et al., 2009). Conserving soil from being eroded by water is very important to retain the tillage and maintain sustainability in hilly areas. In the coastal areas of China, like Zhejiang Province, with fast economic development, there is more pressure on soil erosion from intensive cultivation.

Planting hedgerows along the contour on steep lands is an effective soil conservation technology in hilly areas. Research has pointed out that contour hedgerows could reduce runoffs, soil erosion (Cullum et al., 2007; Salvador-Blanes et al., 2006) and control non-point source pollution by reducing soil nutrients' loss (Agus et al., 1997; Agus et al., 1999; Chaubey et al., 1995; Lin et al., 2009; Wu et al., 2011). It has also been reported that contour hedgerows can reduce investment on slope farmland (Lin et al., 2007; Wu et al., 2011). Under certain conditions, contour hedgerows could reduce runoffs and sediments by 60–80% and 80–95%, respectively (Lal, 1989; Lin et al., 2009). In the recent two decades, several studies also particularly focused on the hedgerows' influence on reshaping the micro-topographic features of the slope (Dabney et al., 1999; Lin et al., 2009; Zheng, 2006) and its impact on redistributing soil nutrients on the slope (Lin et al., 2009).

While several studies have been done on the controlling effect of contour hedgerow on soil erosion in other areas of China

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(Bu et al., 2008; Lin et al., 2009, Tang et al., 2003), there are still no studies in red soil hilly areas of Southeast China so far. It is important to understand contour hedgerow's soil erosion controlling effect specifically in red soil hilly area since depending on hedgerow species, management methods, weather conditions and soil properties, the controlling effects vary. For instance, Bu Chongfeng et al. studied effects of contour hedgerows and found that it increased soil organic matter, total nitrogen, and total phosphorus 5–9 times higher in the soil in Three Gorges Dam area, China (Bu et al., 2008). But results of Agus et al. showed that the concentration of P in the soil reduced from 20 mg/kg to about 14 mg/kg, exchangeable K increased from 0.24 cmol(+)/kg to 0.29 cmol(+)/kg, in the Philippines (Agus et al., 1999). The strong climate fluctuation, especially in rainfall quantity, affects the vulnerability of a region to erosion (Imeson & Lavee, 1998). Since Southeast China is covered by subtropical ridges in summer, it often experiences dry weather during that period, and storm events brought by typhoon cause high risk of erosion in this area. Thus, it is important to understand the effects of soil conservation in hilly areas of Southeast China, and find an effective mitigation method.

The objectives of this study are: (1) investigating the effects of grass hedgerows on controlling soil erosion in red soil hilly areas of Southeast China; (2) investigating the effects of grass hedgerows on reducing the soil nutrients loss; (3) evaluating the impacts of grass hedgerows on redistributing sediment on the slope and reshaping in the same area; (4) selecting the optimized hedgerow pattern for soil conservation in the area.

## 2. Materials and methods

### 2.1. Background of the study area

Zhejiang Province is one of the provinces which are most lack of arable lands in China (Ding Xiaodong, 2008). According to the soil monitoring report of Zhejiang Province (2004), there is 13,654.13 km$^2$ land impacted by soil erosion, which equals to 12.95% of total province area. About 89.6% of the erosion area in Zhejiang province is in the terrain with slope more than 8°, especially concentrated in slope between 15° and 25°. Therefore, studying the erosion of hilly area is important for soil and water conservation in Zhejiang Province.

The experiment was conducted in the runoff plots located at Shifei village, Zhuji County, Zhejiang Province, which belongs to the Cao'ejiang River watershed in southeast China, around 29 °44′N, 120 °23′E (Fig. 1(a)). The topography of this region is mainly hilly area, and the soil is dominated by red soil, classified as oxisols according to USDA (Staff., 1999). The climate of this area belongs to subtropical monsoon climate. The average precipitation is 1373.6 mm per year, and the average annual temperature is 16.3 °C.

### 2.2. Runoff plot establishment

Runoff plot observation is a classical method in studying soil erosion. The method was invented in the 1960s by USDA for monitoring the erosion amounts all over USA, and it soon prevailed all over the world as a standard method for soil erosion research.

Our experiment was started in October 2008. Lin, C. et al., 2009 pointed out that in some situation, it is better to use grass species than wood species in contour hedgerow system for soil and water conservation (Lin et al., 2009). In this experiment, we selected two species to establish the grass hedgerows. The selecting principles are as follows: (1) the species can grow fast enough under the local condition to establish the hedgerows in a short time; (2) the species should not spread on the slope, or severely compete with crops on nutrients and water potentially. Finally, we chose Hemerocallis citrine and Ophiopogon japonicas, both of which were commonly used in building grass hedgerows in China (Chen et al., 2006; Li et al., 2003; Shen, 1998).

This experiment included 4 runoff plots. Each plot was equally divided into 6 small plots (1.5 m × 10 m) by concrete plates as treatments (Fig. 1(b)). In total, there were 6 treatments and each treatment had 4 repetitions. The 6 treatments including the control with no hedgerows (Control), single strip with Hemerocallis citrine (SC), and single strip with Ophiopogon japonicas (SJ), double strips with Hemerocallis citrine (DC), double strips with Ophiopogon japonicas (DJ), and two strips consisted of one strip Hemerocalliscitrina and one strip Ophiopogon japonicas (CJ). There were 3 grass strips in each treatment (Fig. 1(b)).

### 2.3. Simulating rainfall

Simulated rainfall was a supplement to natural precipitation. Simulated rainfall was implemented by sprinkler at one side of the plot. The sprinkler at 0.1 kPa water pressure can cover 4 treatments (6 m long) at one time. To ensure the uniformity of rainfall, the data of the middle 2 treatments were measured each time. Each rainfall was at 0.1 kPa, lasting for 30 min. The rainfall intensity was maintained in the range from 40 mm/h to 45 mm/h.

### 2.4. Measurement of erosion and runoff

After each precipitation event, either natural precipitation event or simulated precipitation event, soil erosion and runoff samples were collected by tanks at the bottom of plots. Befor the sample was collected from each tank, we stirred the liquid in the tank for 10–15 min and made sure the eroded sediment distributed evenly in the liquid. Then the erosion and runoff samples were taken from each tank's outlet. Each sample had 500 mL suspension liquid of sediment. The amount of runoff in each tank was measured in the depth, and multiplied by the area of each tank to get the volume. The formula is as follows:

$$V=(D-P)A \tag{1}$$

where $V$ is the volume of runoff (mm$^3$), $D$ is the depth in the tank (mm), $P$ is the rainfall depth (mm), and $A$ is the area of the tank (mm$^2$). Because the tanks were not sealed above, the precipitation fell into it. To get the absolute value of the runoff volume, we subtracted the rainfall depth from the measured depth in the tank.

The amount of erosion was measured by weighing the soil in the samples and calculating the soil concentration, where the soil was filtered from the suspension liquid and dried in oven. The soil amount in each sample was then multiplied by the total volume of runoff to get the total erosion amount of each plot. The formula is as follows:

$$E=(m/500)V \tag{2}$$

where $E$ stands for the erosion amount from each plot (g), $m$ for the soil weight in each sample (g/500 mL), and $V$ for the volume of runoff (mL).

### 2.5. Rare earth element tracing method

Rare earth elements (REEs) were laid downstream every hedgerow strip to trace the erosion source from three different parts of the slope (Fig. 1(b)). The background REEs' concentrations were measured before the experiment to decide the applied concentration. Eu, Er and Dy were chosen as tracers because of the low background concentrations and the high sensitivity in