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The effect of plant hedgerows on the spatial distribution of soil erosion and soil fertility on sloping farmland in the purple-soil area of China

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ABSTRACT

Recently the effect of plant hedgerows on controlling soil and water loss has been well recognized, and this technology has been widely applied in the world. However, there are few studies on hedgerows' effect on soil fertility of sloping lands. With an 8-year fixed field experiment, we investigated the effect of two different hedgerows on soil fertility through comparing with the control. Our results showed that along contour lines across the field, clay particles tended to accumulate above plant hedgerows but to be eroded downward below hedgerows. Except for potassium (K), all plant nutrients and soil organic matter showed the same distribution pattern as clay particles. K, however, was evenly distributed in the field without any noticeable influence from hedgerows. Since the beginning of our field experiment, soil phosphorus (P) kept accumulating, while soil organic matter and K were in depletion. Taken together, our results suggest that better nutrient management for the sloping lands should reduce P but increase farm manure and K. As far as the whole sloping field is concerned, special attention in nutrient management should be paid to the soil stripes below hedgerows, the portions suffering from more serious soil erosion.

1. Introduction

Purple soil prevails in the upper reaches of the Yangtze River, which is one of the most important soils for agricultural production in subtropical areas of China. Due to abundant rainfall and erosive topographic conditions, tremendous soil loss occurs during summer storms. Moreover, intensive cultivation and socioeconomic pressure have accelerated soil erosion on sloping lands (Guo et al., 2008). As a result, soil erosion becomes a serious challenge for agricultural development in these areas. Alley-cropping is introduced to sloping farmlands as a soil-conservation method in hilly areas, which plays a significant role in reducing soil erosion, controlling non-point source pollution, increasing system output and debasing the input of sloping land (Tu et al., 2005). Thus, this method has been widely used in mountain areas of both torrid and temperate zones. With the efforts of Chen et al. (2002), 11 economical hedgerow patterns and their combinations have been developed to fit the slopes, soil types and weather conditions in the upper reaches of the Yangtze River, which has extended to more than 130,000 ha in southwestern China. Several studies have reported the effect of hedgerows on controlling soil erosion (Salvador-Blanes et al., 2006; Cullum et al., 2007; Raffaelle et al., 1997; Xu et al., 1999) and non-point source pollution (Chaubey et al., 1995) in the last two decades, and particularly some studies have focused on its influence on micro-topographic features (Dabney et al., 1997) and the shape change of slope (Zheng, 2006; Tian et al., 2003). However, so far there has been no study about hedgerows' effect on the spatial variation of soil fertility and the productivity of lands. In the late 1990s, Zhu et al. (2003) studied the redistribution process of soil particles on sloping lands with alley cropping, but failed to estimate the effect of hedgerows with different ages on the redistribution of soil particles for a larger area due to the small size of trial area (10 m × 2 m) and the limited period (5 years). In this study, we aimed to investigate the spatial redistribution of soil fertility in the plot after hedgerows were planted, thereby providing important sights into the hedgerow-management optimization.

2. Study site and methodology

2.1. Background of the study site

Our field experiment was carried out in the upper reaches of the Tuo River system of the Yangtze River, 104°34′12″ to 104°35′19″E and 30°05′12″ to 30°06′44″N with an altitude of 395 m. This region is in a subtropical monsoon climate zone with an average annual

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Table 1
Some nutrition properties of the soil in this study.

pH	8.0
OM	0.94
Total N (%)	0.056
Total P (%)	0.068
Total K (%)	1.59
Avail. N (mg kg^{-1})	44
Avail. P (mg kg^{-1})	3.05
Avail. K (mg kg^{-1})	91.3

Table 2
Fertilizer rates used for different crops (kg/ha).

Crops	N	P_2O_5	K_2O
Corn (*I. mays L.*)	186.3	99	99
Sweet potato (*Dioscorea esculenta*)	58.5	58.5	58.5
Wheat (*Triticum L.*)	135	67.5	37.5

precipitation of 966 mm (ranging from 725.2 to 1290.7 mm), of which 70% falls from June to September. The average annual temperature is 16.8 °C, with an average summer high of 27.4 °C in July and an average winter low of 7.4 °C in January. The area is dominated by purple soil, classified as Entisol according to the soil taxonomy of the U.S.D.A. (Soil Survey Staff, 1999), which is usually 50–80 cm in depth with relatively light texture and poor soil fertility (Table 1).

2.2. Materials and methods

The trials started in November 1997, including three runoff plots (7 m × 20 m each) separated by concrete plates. The experiment was designed with three treatments: the control (without hedgerows), three strips with vetiver (*Vetiveria zizaniodes*) planted in contour, and three strips with false indigo (*Amorpha fruticosa*) planted in contour. The hedgerow belt was 0.5 m wide, and the distance between two hedgerows was 6.16 m. The hedge crops were planted in rows with a spacing distance of 0.2 m, and the distance between tow plants in a row was 0.2 m (Fig. 1). Both hedgerows were controlled to be about 0.5 m high. One year after the hedgerows were planted, the canopy of vetiver fully covered the soil surface of the hedgerow belt; and the distance between false indigo plants was 0.1 m.

The crop rotation was wheat, corn and sweet potato, accounting for 40% of the use of arable land in this area (Yang et al., 1997). For each year, Xushu 18, a variation of sweet potato, was used and transplanted around June 16th with a population of 45,000 plants per ha; Chengdan 18, a corn race, was sown around April 12th with a population of 42,000 plants per ha and harvested around August 20th; Chuanmai 22, a wheat variation, was used in the trial and sown around November 7th. Alley cropping was combined with winter crop (wheat) and summer crops (corn and sweet potato) intercropping. The wheat was seeded by 13.3 cm between seeding holes and 23.3 cm between rows and harvested in middle May. Table 2 lists the fertilizer rates used for different crops. It has been 8 years since the hedgerows were first established in 1997, and the terraces were gradually formed due to the growth of the hedgerows.

After wheat was harvested in 2006, soil samples were taken at five points at 1.5, 3.5 and 5.5 m from the hedgerows in each plot, and these samples were mixed to represent the upper, middle and lower parts of the plot, respectively (from the bottom to the top of the slope, the sample-location distances were 2, 4, 6, 8.5, 10.5, 12.5, 15, 17 and 19 m). The total nitrogen (N), phosphorus (P), potassium (K), organic matter (OM) and soil texture were analyzed. The total N was measured with Kjeldahl method (Lu, 2000a); the total P was fused by Na_2CO_3 and analyzed by the colormetric method (Lu, 2000b); the total K was fused by NaOH and analyzed by the flame photometry (Lu, 2000c); OM was analyzed by the $K_2Cr_2O_7$ volumetric method (Lu, 2000d); and soil texture was analyzed by the specific-gravity method (Lu, 2000e).

The amounts of runoff and sediment from each plot were collected by tanks at the plot bottom after each rain, measured by V-notch, and recorded daily with a SW40 water level gauge. The runoff flux was calculated according to the following formula:

$$Q = \frac{8}{15} m(2g)^{1/2} H^{5/2} \operatorname{tg}\left(\frac{\theta}{2}\right),$$

where Q stands for runoff flux (ml/s), m for runoff coefficient which can be obtained by calibration experiment, H for the water level of V-notch (cm), θ for the angle of V-notch in degree (30°), g for the acceleration of gravity. The runoff amount was calculated according to the following formula:

$$M = \sum_{i=1}^{n} Q_i \frac{t_i}{1000},$$

where M stands for runoff amount (l), Q_i for runoff flux (ml/s), t_i for the time of runoff overflowing the V-notch keeping in the runoff flux of Q_i (s).

After every rain, five runoff samples were taken in the tank with a beaker, and the sediment content was measured by filter paper. The amount of sediment was equal to the runoff volume multiplied by the sediment concentration measured.

The plots, 20° in slope, were divided by the concrete plates of 50 cm in height with one half buried into the soil and the other half projected above the surface. The slope change of the plots with

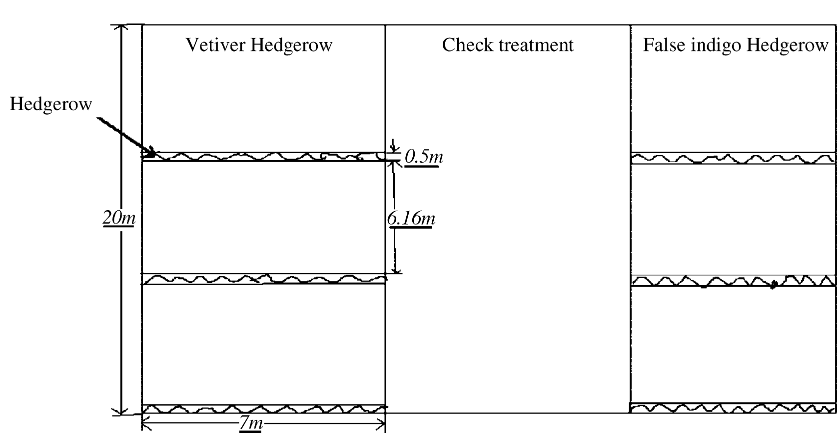

Fig. 1. Treatment layout of this field experiment.