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# The Effects of Land Uses on Purplish Soil Erosion in Hilly Area of Sichuan Province, China

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**Abstract**: In order to evaluate the soil erosion rate for different land uses and make recommendations on land-use alternatives for erosion control in hilly and mountain areas on a Purplish soil (Regosols in FAO taxonomy), experimental data were obtained from three continuously monitored sites located at Yanting, Nanbu and Pengxi of Sichuan province. The data showed that the rank of erosion rate is farmland > unfenced grassland > fenced grassland > forestland. The erosion rate of farmland was more than 3 times higher than that of forestland and fenced grassland, indicating that restricting human activity is crucial for over-erosion. The erodibility was higher at the initial period of rainy season for all the three types of land use. The erosion rates of fenced grassland and mature afforestation land were not proportional to rainfall intensity because these land uses changed impact energy of the rainfall. This research showed that restricting human activity, intensifying the management of initial period of rainy season, and increasing the cover rate of land surface are the three major measures for soil erosion prevention. It is recommended that farmers should cease cultivation on farmland at the top of hills and steep slope land return those lands back to grassland or forestland.

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**Key words:** Soil erosion; land use; hilly area; purplish soil

## 1 Introduction

Food grain productivity of dry land per capita has declined significantly during the past few decades (Parr *et al.* 1990). Bowman *et al.* (1990) and Blaikie (1985) indicated that the greatest loss in productivity comes from soil loss, with secondary effects from loss of nutrients due to reduced organic matter and increased soil bulk density. Soil erosion has major ecological and economic consequences in densely populated China, particularly, in a large agriculture province, Sichuan. Chinese food production is the fourth highest in the world, but pressure to feed its population of 1.3 billion people makes topsoil loss a serious threat to food security (Brown and Wolf, 1984). Topsoil loss in China has been documented, although it is often estimated from suspended sediment load in rivers. Water erosion is thought to be a problem in central and southern China, but this was difficult to confirm (Dregne 1992).

Land use is the most important factors affecting soil erosion, and land use could be estimated and used for assessment on its effects on soil erosion. Many evidences showed unreasonable land use accelerated soil erosion (HUANG 2000, JoseÂ *et al.* 2000, Vannie`rea 2003, Lynn Carpenter *et al.* 2001, Dunjó *et al.* 2004). Land use intimately affects the soil erosion rate. Generally, cultivated lands experience the highest erosion yield (CHENG 2002, Hill 1999, Pardini *et al.* 2003, Erskine *et al.* 2002, Collins *et al.* 2001, Garcia-Ruiz *et al.* 1995, WANG *et al.* 2003). And the effect of land use on soil erosion is quantitatively determined by ULSE or LISEM equations (Jürgens 1993).

More than 90,000,000 people rely on the purplish soil (Regosols in FAO soil taxonomy, Entisols in USA soil taxonomy) for their food. Namely, 90% of the population depends on the 30% of the total land area in Sichuan. Consequently, the land of Purplish soil has been over-exploited for many years due to the heavy population and great demand for food. The main evidence is that 47% of farmland is less than 20 cm soil depth due to topsoil removed by soil erosion (ZHANG *et al.* 1990). However, there was little information on field observation to quantify the effects of land uses on soil erosion.

The specific objectives of the current research were (i) to evaluate soil erosion in field plots for different land uses, and (ii) to recommend land use alternatives for soil erosion control.

## 2 Materials and Methods

### 2.1 Sites description

The study was conducted at three sites: Yangting (YT), Nanbu (NB) and Pengxi (PX) located in the central hilly area of Sichuan Province, China (Figure 1) where the topography (hilly) and climate (sub-tropical, with annual average temperature of 17~18 ℃ and rainfall of 800~1000 mm, mostly raining during the raining season from May to August) are similar (LI 1991). The crops are also similar: rice (*Oryza sativa* L.), wheat (*Triticum aestivum* L.), corn (*Zea mays* L.), rape (*Brassica napus* L.), and sweet potato (*Ipomoea batatus* Lam.). The soils derived from interbed purple shale were classified as Purplish soil (Regosols in FAO soil taxonomy, Entisols in USA soil taxonomy).

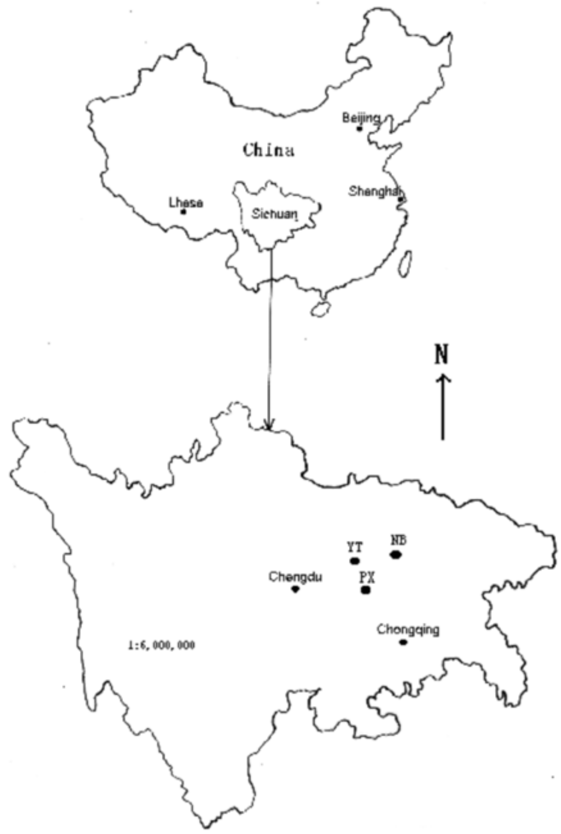


**Figure 1** Map of China showing the location of Sichuan Province and the three experimental sites: Yanting (YT), Nanbu (NB), Pengxi (PX)

### 2.2 Soil erosion rate and runoff measurement

At each site, runoff plots were established for different treatments with no repetition. The details of the treatments for each site were shown in table 1. The farmland treatment wasn't conducted at YT and PX where there is no farmland at the topography because of high slope gradient.

Tanks were installed at the down slope end or outlet of each plot (plot size as showing in table 1) for measurements of sediment and water loss from the plot. Runoff was piped into a sediment collection tank. An aliquot of possible overflow from the sediment collection tank was separated by a multi-slot divisor and collected in a second collection tank (LIU *et al.* 2001). The tanks were designed large enough to store the runoff based on the local maximum rainfall (for a rainfall event of 24 hours) and the parameter of plot size. Sediment and water in the tank were determined for each plot for every rainfall event led to runoff generation. Runoff was determined by measuring the volume of water in the respective tanks. Sediment was determined by manually stirring the runoff in each tank and collecting dip samples (1000 ml) of the mixture. Sediment samples were precipitated with alum, water was decanted, and then oven dried to determine mass (LIU *et al.* 2001). Soil loss (sediment) and runoff were calculated according to the parameters of plot area and tank volume.

Precipitation was measured with a standard siphon rainfall gauge throughout the experiment period. Water-stable aggregate was determined by sifter in water (Institute of Soil Science, Chinese Academy of Sciences, 1978)

In order to eliminate the effect from the obvious diversity of rainfall between years or months and sites on the investigated treatments, soil erosion rate (ER) is expressed in sediment loss of per unit area per 100 mm rainfall for a rainfall event led to runoff generation. In this paper, ER unit is ton $km^{-2}$ $(100\ mm)^{-1}$ (LIU and LIU 1998).

The statistical analysis was made by t-test method.

## 3 Results and Discussions

### 3.1 Characteristics of soil and water losses on yearly basis for different land uses

Generally, for different land uses, the statistical results (Figure 2) showed that the erosion rates were in the order of forestland < fenced grassland < unfenced grassland < farmland. The difference among unfenced grassland, farmland and forestland, fenced grassland reached a significant level ($P<0.08$). Compared with forestland and fenced grassland, the ER of farmland was as high as 400 ton $km^{-2}$ $(100\ mm)^{-1}$, which is significantly higher (300%) than forestland ($P<0.03$), and was 20% higher than the unfenced grassland ($P<0.36$). It suggests that the erosion of arable land is the most serious among the four types of land uses for Purplish soil in hilly

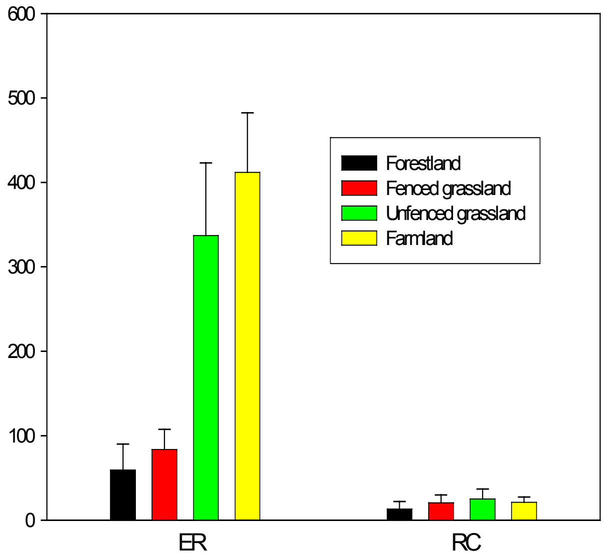


**Figure 2** The erosion rate (ER) and runoff coefficient (RC) of averaged yearly basis for different land uses

area of Sichuan Basin, which is in agreement with the previous reports (CHENG 2002, Hill 1999, Pardini *et al.* 2003, Erskine *et al.* 2002, Collins *et al.* 2001, Garcia-Ruiz *et al.* 1995, WANG *et al.* 2003). Meanwhile, the ER of unfenced grassland was distinctly higher (over 200%) than the fenced grassland（$P=0.0803$）, indicating that human activity greatly accelerate soil erosion , and the region where human activity is intensive is the major sources of soil erosion. Accelerated erosion was attributed to soil tillage that loosen soil to decrease the anti-erodibility for farmland, and livestock grazing or mowing which decrease vegetation coverage on grassland. Therefore, for controlling soil erosion in the researched region, the most important measure to reduce erosion is to restrict the human activities in addition to afforestation and grass planting. Moreover, the difference between unfenced grassland and forestland relied on the coverage of grass: under high coverage rate of grassland (at YT site), the ER of grassland, with a reduction of nearly 20% (Figure 3), was substantially lower than that of forestland（$P=0.0943$）.To our knowledge, the raindrop is bigger because of the higher tree intercepting, the higher is erosivity. On the other hand, the water-stable aggregate of a soil is less, the higher is erodibility. In fact, forestland at YT experienced higher erosion rate than grassland as result of higher trees (Table 1) and less water-stable

**Table 1** The basic features of runoff grounds at initial observational year

| Sites | Treatments | Physiognomy | Experiment period | Plot size ($m^2$) and shape | Soil texture and depth | Bulk density ($g/cm^3$) | Vegetation conditions |
|---|---|---|---|---|---|---|---|
| YT | Forestland | Dividing, south-east slope with gradient of 28.6% | 1990~1993 | 2600, polygon | Sandy-loam, 20~30cm | 1.32~1.35 | Afforestation mixed with Longpeduncled Alder and cypress planted in 1970, with coverage rate of 70%, tree high of over 20m, and with sparse ground cover. |
| | Fenced grassland | | | 3700, polygon | | 1.28~1.33 | The Lalang grass (Imperal Cylindrica Var. Major C.E.) is dominated for the land with nepal coriaria (Coriaria Nepalensis Wall), negundo Chastetree (Vitex Negundo Linn), etc., and the coverage rate of 80~90% |
| NB | Unfenced grassland | Upper south slope with gradient of 21.2% | 1993~1996 | 20*10, rectangle | Gravel loam, 15~25 cm | 1.24~1.31 | The major vegetation is Lalang grass, the other is nepal coriaria, negundo Chastetree, etc., and the coverage lower than 20%. |
| | Fenced grassland | | | | | | The major vegetation is Lalang grass, the other is nepal coriaria, negundo Chastetree, etc., and the coverage more than 60%. |
| | Farmland | | | | | | The annual planting crop is wheat (*Triticum aestivum* L.)——maize (*Zea mays* L.)——sweet potato (*Ipomoea batatus* Lam.), the annual coverage up to 30%, with conventional tillage: a ran up and downslope strip cropping sequence of wheat (0.8 m) and rape (0.7 m) was established after plowing to a depth of 20 cm for the winter and spring crop. A ridge and furrow design was then established after moldboard plowing for the summer and autumn crops with sweet potato planted on the ridge (0.8 m) and maize in the furrows (0.7 m). |
| PX | Forestland | Upper east slope with gradient of 24.9% | 1995~2000 | 20*10, rectangle | Sandy loam, 20~30 cm | 1.32~1.42 | Afforestation mixed with Longpeduncled Alder and cypress in 1982, with coverage rate of 20%, tree high of about 10 m, and with sparse ground cover. |
| | Unfenced grassland | | | | | | The major vegetation is Lalang grass, the other is nepal coriaria, negundo Chastetree, etc., the coverage rate maintaining near 20%. |

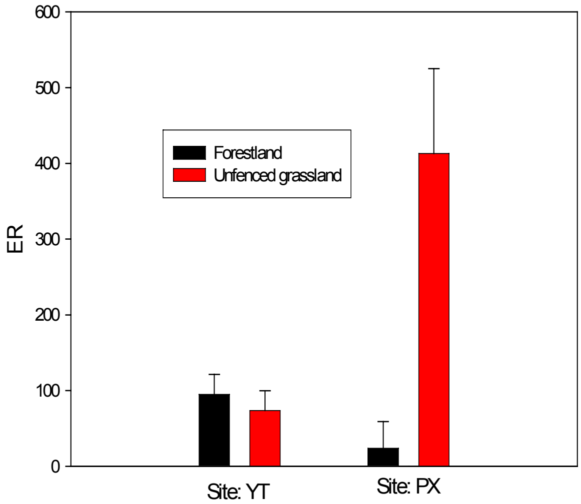


**Figure 3** The comparison of erosion rate (ER) and unoff coefficient (RC) of averaged yearly basis between YT and PX sites for different land uses

aggregate of 5 $mm^{-1}$ size fraction (LIU *et al.* 2001). While under low coverage rate of grassland (at PX site), the inverse result（P=0.0548）was found that the ER of grassland was higher than that of forestland.

The runoff coefficient (RC) of grassland was significantly ($P<0.05$) higher than that of forestland. This result was attributed to that grassland has less intercept capacity of rainfall than forestland; on the other hand, grassland has less microspores because of the shallow and thin root of grass, whereas the forestland have more microspores because of the deep and thick root of tree. The result is less infiltration rate of grassland than forestland. Comparing with farmland, grassland has slightly higher RC because of similar causes.

### 3.2 Characteristics of soil and water losses on monthly basis for different land uses

Figure 4 delineated the characteristics of soil and water loss of monthly basis for different land uses of Purplish soil, which revealing that the magnitudes of soil and water losses were consistent with that of yearly basis. The result showed that the ER is higher at initial period (May) of rainy season, while RC is generally related to the rainfall rather than the period of rainy season. This result was attributed to that, at the beginning of rainy period, there was more erodible matter derived from natural processes and human activities through September to next April than at other rainy period. As time passes during the rainy season, the erodible matter decreases. Therefore, more attention should be focused on development of soil conservation techniques at the initial period of the rainy season, no matter what type of land use is.

### 3.3 Characteristics of soil and water losses under different rainfall intensity for different land uses

At PX (Figure 5 A) site, four rainfall events (two events with about rainfall of 40 mm in 1996, and the other two with about 80 mm rainfall in 1999) were selected to compare the effects of rainfall intensities on erosion of different land uses. The ER difference between forestland and unfenced grassland was greater under higher rainfall intensity than under lower rainfall intensity, especially for rainfall with higher intensity occurring at the initial period of rainy season (May 8, 1996 in the Figure 5 A). The ER of unfenced grassland was nearly 10 times that of forestland. In addition, the ER of forestland did not vary distinctly with rainfall intensity, particularly in 1999, showing that the trees of forestland grow higher, the greater change in features of rainfall is. At NB (Figure 5 B), no significant differences were found between the ERs of three treatments under lower rainfall intensity of 4.4 mm $h^{-1}$ (rainfall is 127 mm), but significant difference was found under higher rainfall intensity of 26.1 mm $h^{-1}$ (rainfall is 58.1 mm). The ER of farmland at this rainfall intensity reached >1000. The ER of fenced grassland (with coverage rate of more than 60%), by and large, didn't vary with rainfall intensity, suggesting the grass (ground-cover in broad sense) with high coverage can reduce the erosivity of rainfall. Therefore, increasing the ground coverage is one of the basic approaches for controlling soil erosion under different land uses.

## 4 Conclusion and Recommended Practical Solutions of Soil Erosion

Forestland and fenced grassland significant reduced erosion rate. Subsequently, soil erosion

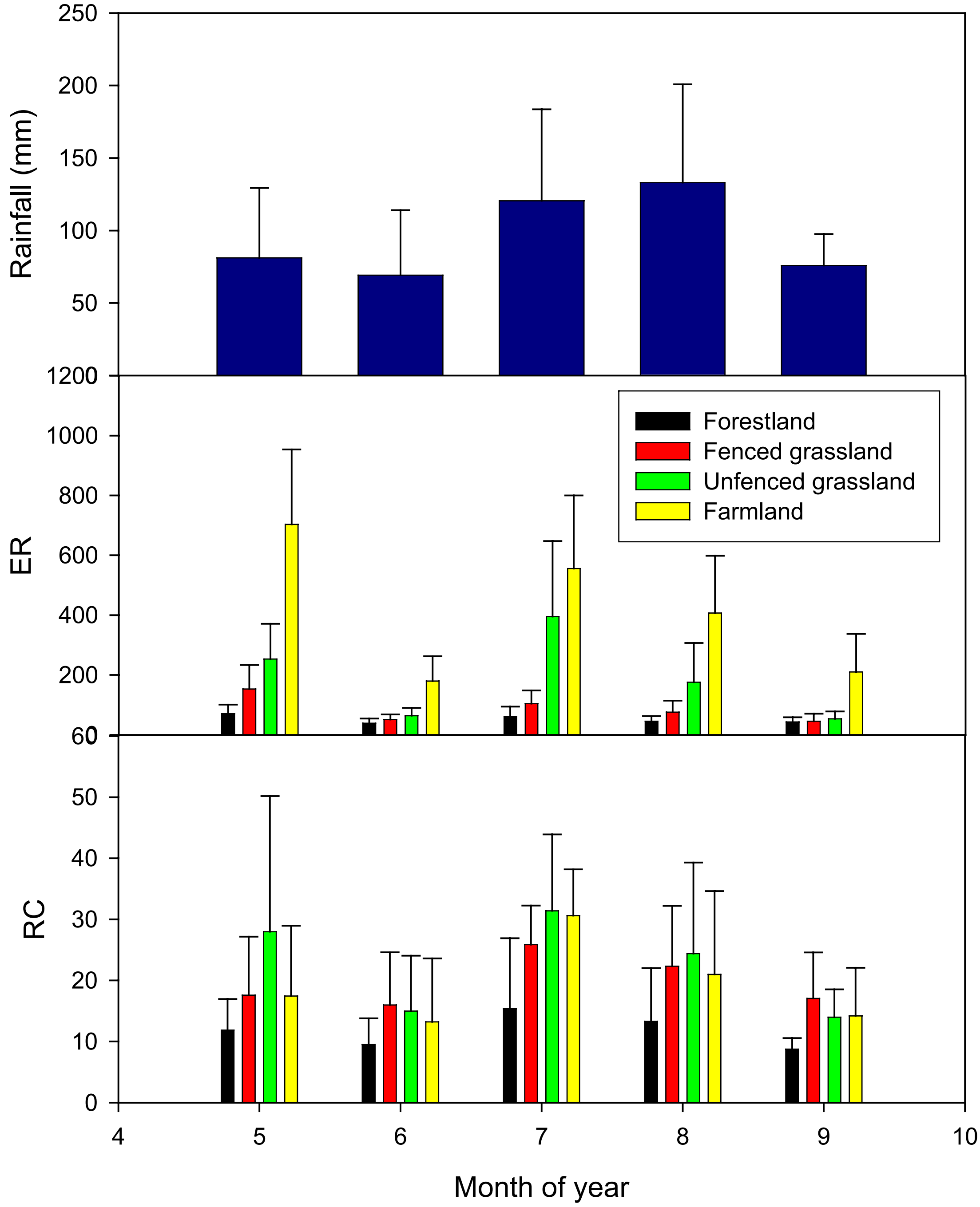


**Figure 4** The rainfall, erosion rate (ER) and runoff coefficient (RC) of averaged monthly basis for different land uses

could be controlled by changing land use and increasing the ground coverage, which was shown as one of the basic approaches for controlling soil erosion under all land uses. Specific approaches are as follows:

Afforestation**:** Hilltop must be covered with forest. This measure has been taken for many years in the Purplish soil areas, especially during the period of the implement of the project of forest shielding belt of the upper reaches of Yantze River. This practice should be continued until all the hilltop and wasteland were afforested.

Giving up farmland for forestland or grassland**:** High slope dry cropland should be given up for grassland or forestland in hilly area of Sichuan Basin.

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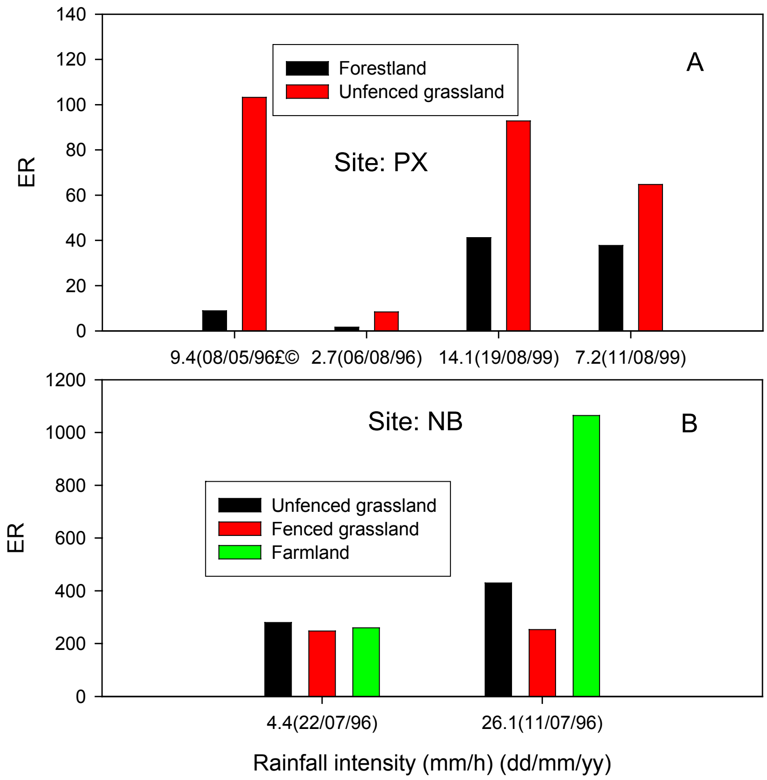


**Figure 5** The erosion rate under different rainfall intensity at PX (A) a nd NB (B) sites for different land uses

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