Geomorphology 216 (2014) 114–124

Contents lists available at ScienceDirect

Geomorphology

journal homepage: www.elsevier.com/locate/geomorph

Effect of terrace forms on water and tillage erosion on a hilly landscape in the Yangtze River Basin, China

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ARTICLE INFO

Article history:
Received 6 November 2013
Received in revised form 12 March 2014
Accepted 23 March 2014
Available online 31 March 2014

Keywords:
Terrace form
Soil particle redistribution
Tillage erosion
Water erosion
Yangtze River Basin
China

ABSTRACT

In long-term agricultural practices, cultivated land on long slopes in hilly areas is sometimes terraced to diminish soil loss caused by water and facilitate farming operations. In the Upper Yangtze River Basin, the forms of the terraces vary with the landform, soil resources and traditional techniques used in different areas. This study assessed the pattern of soil redistribution and soil particle size redistribution for two major types of terraces: with and without embankments. Samples of ^{137}Cs and soil texture were collected at the upper and lower parts of terraces, and at an interval of 5 m along the transect of the toposequence of individual terraces. The non-embankment terrace (NET) landscape showed increasing ^{137}Cs downslope, whereas the embankment terrace (ET) landscape exhibited an abrupt change in ^{137}Cs at the embankment. Tillage erosion dominated the soil redistribution, with smaller contributions made by water erosion in the ET landscape. In addition to tillage erosion, water erosion played an important role in the soil redistribution in the NET landscape, resulting in a net soil loss at both the upper and lower parts of the terrace. Soil fine particle fractions exhibited a trend of gradual increase along the transect of the toposequence in the NET landscape, and a similar fraction of fine particles was found at the upper and lower parts of the terrace. The establishment of embankments at the lower end of the terrace obstructed the formation and development of overland water flow, thereby creating a line of null downslope soil transport leading to tillage-induced soil accumulation on the upslope side of the embankment with little granulometric sorting. In the NET landscape, soil loss seemed to increase as a result of tillage erosion (an important delivery mechanism for water erosion), accelerating the on-site soil loss. The embankments at the lower end of the sloping terrace played a crucial role in the soil redistribution patterns of the toposequence, resulting in a shift from a water-dominated erosion process to a tillage-dominated process and a distinct pattern of soil particle size distribution.

1. Introduction

Soil particle redistribution generally arises from soil erosion and deposition on hillslope landscapes. Water and wind cause soil particle movement on slopes, resulting in variation in soil features and especially surface soil properties. The assessment of soil particle redistribution on agricultural landscapes is meaningful for developing and correcting erosion models, establishing sediment budgets and implementing precise agricultural practices (Ampontuah et al., 2006). The maintenance of soil productivity is also associated with soil particle size distribution, as fine particle fractions play an important role in adsorbing and transporting SOC and nutrients (Walling et al., 2002; Zhang et al., 2006; Ge et al., 2007). Soil particles move along slopes with granulometric sorting during the water-induced erosion and deposition processes (Rhoton et al., 1979; Stone and Walling, 1996; Ni and Zhang, 2007). Numerous studies of soil redistribution have been conducted on long hillslopes, such as those in North America and Europe, and have documented that soil redistribution is controlled not only by water and wind erosion, but also by tillage erosion (Lindstrom et al., 1992; Govers et al., 1994; Lobb et al., 1995; Van Muysen et al., 1999; De Alba, 2001). The magnitude of soil redistribution due to tillage on hummocky land in temperate climates may often exceed that of water erosion (e.g., Govers et al., 1996). In terms of shoulder slope landscape positions, it has been estimated that tillage erosion accounts for at least 70% of the total soil erosion in southwestern Ontario, Canada (Lobb et al., 1995). Based on radionuclide (^{137}Cs) tracer studies that have analysed soil redistribution over approximately 40 years, tillage erosion and deposition rate estimates frequently exceed 10 Mg ha^{-1} yr^{-1} at the eroding and aggrading sites of intensively cultivated land (Govers et al., 1996; Van Oost et al., 2003).

In terms of long-term agricultural practice, farmers are aware that terracing can efficiently prevent soil and water losses in fields, and have developed a variety of terraces by dissecting long slopes into

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http://dx.doi.org/10.1016/j.geomorph.2014.03.030
0169-555X/

several short segments, such as level, sloping and reverse sloping terraces. In the hilly areas of the Upper Yangtze River Basin, sloping terraces are dominant, and there are two forms of terrace construction, one with an embankment and one without. Despite the embankment, embanked terraces save on labour and are cost-efficient, as the original geomorphological shape is only slightly transformed with a small amount of construction engineering required. Terracing is effective at decreasing soil erosion by water, but may cause more intensive soil redistribution by tillage unless a levelled surface is created. A few studies have documented the severity of tillage translocation and erosion at the upper slope positions of linearly terraced hillslopes through the use of ^{137}Cs or physical tracers (Quine et al., 1999; Zhang et al., 2004a,b). Radiocaesium data have shown that soil translocation on short terraced slopes is more intense than that on long slopes (Zhang et al., 2006). Hoeing is used extensively to till fields, and unilateral downslope tillage is normally performed by overturning and pulling soil in the downslope direction to save time and energy. This has a positive effect on downslope soil translocation.

Water erosion was once commonly assumed to be a unique soil redistribution process in the hilly areas of the Upper Yangtze River Basin. Recent studies there have demonstrated that tillage erosion is also an important soil redistribution process (Zhang et al., 2006, 2009), and that tillage erosion is a non-negligible process of soil redistribution in agricultural fields in other parts of the world (Lindstrom et al., 1990, 1992; Lobb et al., 1995; Govers et al., 1996; Poesen et al., 1997; Quine et al., 1999; Quine and Zhang, 2002; Heckrath et al., 2005). However, few studies have examined soil particle size distribution by water and tillage erosion in different types of terraces. Studying the features of soil redistribution along the transect of a toposequence comprising a series of terraces rather than individual terraces would increase our understanding of soil redistribution mechanism.

The objectives of this study are (1) to examine the soil redistribution rates and features of the two contrasting types of terraces, i.e., with and without embankments; (2) to determine patterns of water and tillage erosion along the toposequence with different types of terraces; and (3) to establish mechanisms for the horizontal and vertical distributions of soil particles for the two types of terraces.

2. Materials and methods

2.1. Study sites

The study area was situated in the Upper Yangtze River Basin in China, an area that presents a variety of geomorphological settings consisting mainly of hills and mountains. Two hilly areas were selected for comparison. One was located in Jianyang County in the Sichuan Basin (30° 26′ N and 104° 28′ E) and the other in Zhongxian County (30° 25′ N and 108° 11′ E) in Chongqing Municipality (Fig. 1). The annual temperatures averaged 17.4 °C at the Jianyang site and 19.2 °C at the Zhongxian site, and the mean annual precipitation amounts were 872 and 1150 mm, respectively. Given the differences in landforms, soil resources, traditional techniques and other attributes, different forms of terraces were established in the two areas. Due to a serious shortage of land resources at the Zhongxian site, embankments were not established at the lower end of the sloping fields. Instead, the slope length changed through the dissection of long slopes into short slope segments, forming non-embankment terraces (NETs). At the Jianyang site, terraces were constructed on the contour and separated by mound embankments

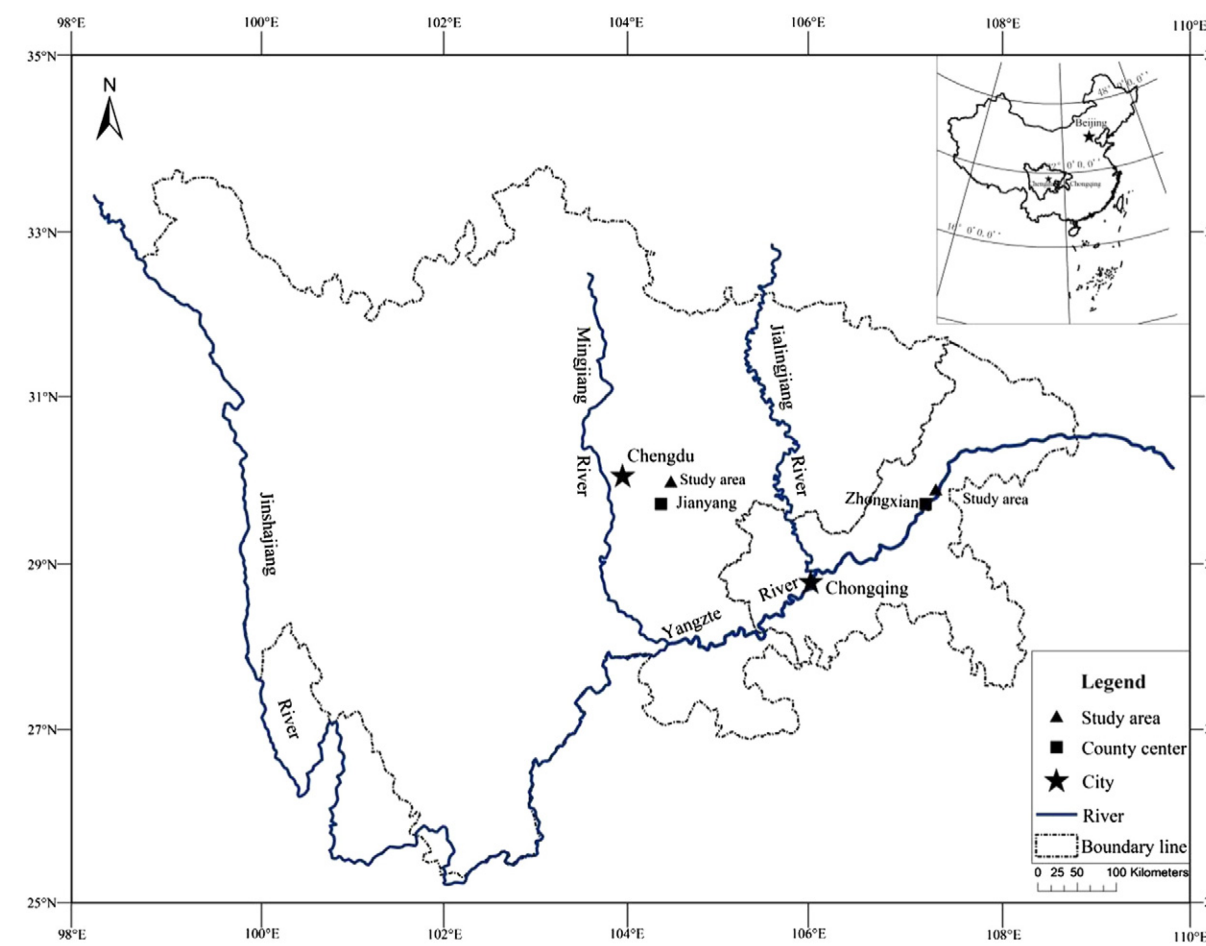

Fig. 1. Map showing the study site locations.