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An investigation of soil translocation and erosion by conservation hoeing tillage on steep lands using a magnetic tracer

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ABSTRACT

The mechanism of tillage erosion has been increasingly recognized for nearly two decades, irrespective of mechanized or non-mechanized agriculture areas. Yet, control measures on tillage erosion were relatively less studied. A type of conservation tillage approach, referred to as "non-overturning hoeing tillage" was studied in comparison with conventional tillage in hilly areas of Chongqing, near the Yangtse Gorges reservoir areas, southwestern China. The magnetic tracer was used to label experimental plots of soil to measure soil translocation in the tillage direction. A comparison experiment between conventional and conservation tillage was conducted on a series of hillslopes with slope gradients ranging from 0.08 to 0.65 m m^{-1}, with paired plots at neighboring sites on the same hillslope. Mean soil displacement in the downslope direction by conservation tillage, being 0.11 m was much shorter than that by conventional tillage with 0.33 m. Tillage transport coefficients were 17 and 35 kg m^{-1} tillage pass^{-1} when conservation tillage was conducted, and 37 and 118 kg m^{-1} tillage pass^{-1} under conventional tillage, respectively, for k_3 and k_4. Tillage erosion rates by conservation tillage, estimated at 28 Mg ha^{-1} year^{-1} significantly decreased with a reduction of 63%, when compared to those by conventional tillage estimated at 78 Mg ha^{-1} year^{-1}. The magnetic tracer method is an efficient and effective one for measuring tillage translocation, and therefore, estimating tillage erosion rate. It is suggested that non-overturning hoeing tillage largely diminishes soil downslope translocation and results in a significant reduction in tillage erosion.

1. Introduction

Many studies demonstrated that tillage results in soil loss on convex upper slope positions and soil accumulation on concave lower slope positions in a topographically complex landscape (Lindstrom et al., 1992; Govers et al., 1994; Lobb et al., 1995; Van Muysen et al., 2000; De Alba, 2001; Van Oost et al., 2003; Papiernik et al., 2007), while a number of studies reported that tillage produces the progressive downslope movement of soil in linear steep slope landscapes (Zhang et al., 2004a,b, 2008; Turkelboom et al., 1997, 1999). Tillage translocation, defined as the transport and resultant displacement of soil by tillage (Govers et al., 1999), is normally measured with a tracer method, i.e. a volume of soil is labeled and tilled, and then changes in tracer concentrations before and after tillage are used to calculate soil translocation. The tracer method for measuring soil translocation includes physical and chemical ones. Physical tracer used in measuring tillage translocation has so far involved metal cubes (Govers et al., 1994; Thapa et al., 1999a), rock fragments (Thapa et al., 1999b; Nyssen et al., 2000) and gravels (Zhang et al., 2004a,b), and chemical tracer radiocaesium (Lobb et al., 1995; Quine et al., 1999a) and chloride (Lobb et al., 1999). Although these methods can be well used to evaluate tillage erosion in different regions, they are either high cost or time consuming in the course of tracer collection or sample determination. In the case of radiocaesium application, it is necessary to control radiocaesium dose, otherwise there would be radioactive hazards both to operators and land-users, and it represents a significant outlay in terms of fieldwork and gamma detector time (Quine et al., 1999b). For other chemical methods, sample analyses also need much time. For physical methods, there is a large amount of work on tracer (gravel) collection in the field. For downslope displacement measurement, for instance, in order to obtain a maximum rate of tracer recovery all the soil that maybe contain tracers has to be collected in thin slices, from the baseline position of the plot in the direction of tillage to the farthest distance of tracer distribution. Furthermore, the process of

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separating tracers from soil is also markedly time consuming due to a large volume of soil samples. In this study, therefore, we propose a magnetic tracer method to quickly measure soil translocation.

Comparison studies on tillage erosion by different tillage implements have been conducted in a few parts of the world (Van Oost et al., 2006). Van Muysen and Govers (2002) have documented that tillage transport coefficient k (123 kg m^{-1} tillage tillage $pass^{-1}$) from a secondary tillage operation by combined rotary harrow and seeder is comparable with k-values of mouldboard and chisel implements. Conservation tillage implements (the chisel plough is generally promoted to reduce water erosion in Atlantic Canada) and secondary tillage implements (offset disc and vibrashank) can move as much soil as conventional tillage implements such as the mouldboard plough within potato fields in Atlantic Canada (Tiessen et al., 2007). The mean displacement distance and mean annual tillage-induced soil loss were reduced by approximately 70% using contour ridge tillage compared to contour moldboard plowing and moldboard plowing up and downslope on steep lands in Claveria, Philippines (Thapa et al., 1999a).

In hilly areas of southwest China, hoeing tillage is predominant due to small patches of fields and steep hillslopes. Soil erosion by tillage is evident at the hilltop and upper slope positions (Turkelboom et al., 1997, 1999; Zhang et al., 2004b). Although contour tillage is considered as a conservation tillage measure to reduce tillage erosion (Quine et al., 1999a,c), it has not been generally practiced due to the requirements of energy saving during the farmer's tillage operation. In this study, "non-overturning hoeing tillage", a conservation tillage method is used to keep energy saving and reduce soil erosion. Specific objectives of this study were (1) to examine the influence of slope gradient on soil translocation under different tillage methods and (2) to compare non-overturning hoeing tillage with conventional tillage regarding the effects of soil conservation.

2. Materials and methods

2.1. The study area

The study area was located in Zhongxian County (30°03′–30°35′N and 107°32′–108°14′E), Chongqing City, belonging to the Yangtze Gorges reservoir areas of the Upper Yangtze River Basin (Fig. 1). Original geomorphologic feature showed steep hillslopes and deep valleys. The altitude in this county varies between 117 and 1680 msal, with 70% of the area present below 600 msal. The elevation ranges from 179.8 to 245.0 msal in the catchment of this study area. Landscape topography is presently characterized by tiered sloping terraces with short slopes (generally 5–15 m in length) and large slope gradients. The study area has a subtropical climate with a mean annual temperature of 19.2 °C and mean annual precipitation of 1150 mm. Frost-free period averages 320 days per year. A variety of crops are grown, mainly including wheat, maize, sweet potato, peanut, sorghum, and legumina. In this area, there is a large density of population and small land area, with an area of approximate 0.03 ha per capita (i.e. 33 persons per ha). In the 1960s–1990s, almost all the land was cultivated with a slope gradient up to 35°. Up to approximately the year 2000, under the Central Government's policy, steep cultivated land with >25° slope gradient was converted into forestland and grassland to conserve soil and water in agricultural landscapes. Despite this, cultivation still occurs in between the rows of young trees on the very steep slope because of serious shortage of land resources.

2.2. Experimental procedure and data calculation

Tillage experiments were conducted on nine sloping terraces with slope gradients of 0.08–0.65 m m^{-1}. One paired plots on each sloping terrace were established to perform the two contrast tillage. Two types of tillage measures were performed: conventional tillage and conservation tillage which is known as

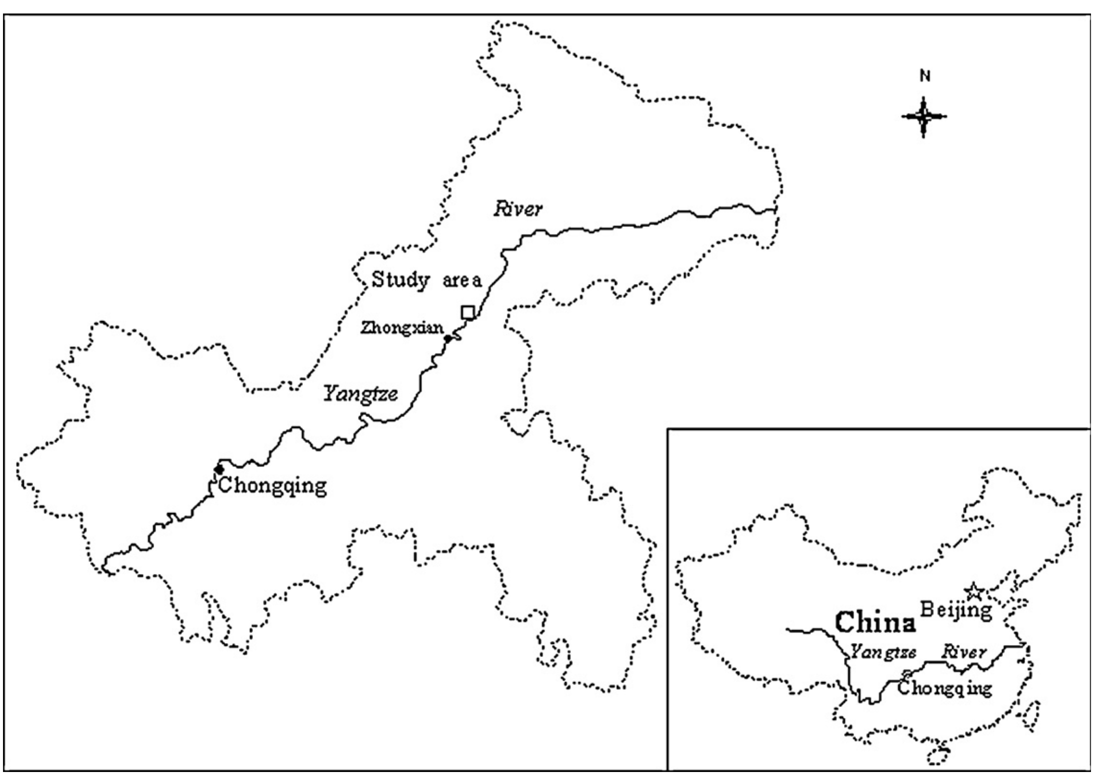

Fig. 1. Location map of the study area.