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Original article

Soil and water conservation on steep slopes by mulching using rice straw and vetiver grass clippings

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ABSTRACT

This research investigated the performance of mulching using rice straw mulch (RC) and vetiver grass clippings as mulch (VGM) in reducing soil loss and runoff during the early stages of cultivation on an agricultural area. The effects of the rainfall intensity and mulch rate in conserving runoff and trapping sediment were determined by field experiments on land with a steep 30% slope. Three rainfall intensities of 35 mm/h, 65 mm/h and 95 mm/h were applied using an artificial rainfall simulator. The effects of five mulch rates (1.0, 1.5, 2.5, 5.0 and 7.5 t/ha) with conventional tillage were compared with un-mulched treatment. Both VGM and RC showed good potential for reducing runoff and soil loss. For a given rainfall intensity of 65 mm/h and a mulch rate of 1.5 t/ha, RC reduced runoff and soil loss less than VGM. For higher mulch rates, RC performed better than VGM. For example, at the 5.0 t/ha mulch rate, RC reduced runoff and soil loss by about 47.5% and 62.9%, respectively, compared to VGM with a corresponding reduction of 42.4% and 53.7%, respectively. It is recommended that application of 5.0 t/ha of RC or 7.5 t/ha of VGM is the most suitable for soil and water conservation.

Introduction

Soil erosion caused by heavy rainfall and surface runoff is a serious problem in agricultural areas especially on inclined slopes where the soil loss can reduce soil productivity and increase sediment and other pollution loads in receiving waters (Coppin and Richards, 1990). Soil erosion often occurs on steep slopes due to improper land use, monoculture and the use of tillage tools that leave the soil bare and pulverize it excessively (Morgan, 1995). After such treatments, the soil can be carried away by heavy rains. This problem affects crop productivity and the incomes of farmers. Soil erosion by runoff is often accepted as an unavoidable phenomenon associated with agriculture on sloping land. However, erosion removes the topsoil which is the part of the soil profile highest in nutrients and organic matter (Zheng et al., 2005; Polyakov and Lal, 2008). Organic matter forms complexes with soil particles so that the erosion of soil particles will also eliminate nutrients (Pardini et al., 2003), thereby reducing the capability of plants to thrive. This has effects on potential productive capacity (Barton et al., 2004; Ge et al., 2007). Erosion control can be achieved in two ways: 1) by reducing the forces applied to the soil (reducing erosivity) and 2) by reducing the susceptibility of the soil to erosion and increasing the capability of soil to resist the forces applied by erosive agents (reducing erodibility). Several concepts are used to control soil erosion under various land uses. These concepts include maintaining vegetative cover, maintaining ground cover, incorporating biomass into wctthe soil, minimizing soil disturbance, adding soil amendments to reduce erodibility, adding supporting practices, preventing excessive rill erosion, avoiding long field length and using barriers (Morgan, 1995).

Using structural practices to control soil erosion has been successful in developed countries, but is not practiced due to its high cost in developing countries (Grimshaw and Helfer, 1995). Using mulching cover on the soil surface to protect soil and water losses has been widely applied and recognized as an alternative technology in many developing countries (Sidhu and Beri, 1989; Bhatt and Khera, 2006; Ramakrishna et al., 2006). Nevertheless, it will be more effective when locally available species are used (Spaan et al., 2005; Marques et al., 2007). The major effects of mulching in protecting soil erosion are: the interception of rainfall by absorbing the energy of raindrops and thus reducing surface

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sealing and runoff, the retardation of erosion by decreased surface flow velocity and the physical restraint of soil movement (Coppin and Richards, 1990; Jepsen et al., 1997). However, the effectiveness of a mulching barrier depends on its characteristics and quantities. Nevertheless, it will be more effective when locally available species are used for soil surface cover (Spaan et al., 2005).

The use of rice straw mulch (RC) as ground cover for seedling nursing, shading and insect damage prevention is popular in Southeast Asia. However, RC is not easily found in the field especially in the highlands as most rice field are located in lowland. Farmers have to spend a lot of money to buy RC when they need it for agricultural practices. Nowadays, a vetiver grass hedge is a bioengineering method to control soil erosion and conserve runoff, which in recent years has proven to be successful in conserving natural resources in over 120 countries because vetiver has many characteristics that can perform this task much better and more cheaply than others (Truong, 2002). In Thailand, vetiver grass hedging has been promoted and used for protecting soil erosion especially in the highlands. In order to manage a hedgerow, the vetiver grass hedge must be systematically cut which produces a large quantity of mulch material from vetiver grass clippings which can be used as vetiver grass mulch (VGM) to conserve runoff and soil loss.

Most previous researchers have studied the conditions for the use of a vetiver grass hedgerow to protect against soil erosion. Furthermore, only a few studies have been carried out using VGM for soil erosion control (Babalola et al., 2007; Donjadee and Chinnarasri, 2012). They found that the VGM has a great potential for reducing soil loss compared with similar plots with and without VGM. However, these studies were on a gentle slope. Therefore, this study quantified the effect of the mulch rate of RC and VGM on runoff and soil loss on a steep slope.

Materials and methods

Experimental plots

The experiment was carried out on plots with bare soil, with RC cover and with VGM cover. The plots were 2 m × 10 m in size and located on a slope of 30%. The plots were demarcated except at the downstream end by concrete bunds of about 30 cm. All plots were laid out in an identical fashion with one control plot (bare soil without mulch) and five mulched plots (bare soil with mulch).

Mulched characteristics

Rice straw mulch (RC) is the vegetative part of the rice plant after the grain and chaff have been removed. The shape of RC is 40–60 cm long and 0.4–0.8 cm wide. The vetiver grass mulch (VGM) is composed of the leaves of vetiver grass which are 40–60 cm long and 0.6–1.2 cm wide. Both RC and VGM were dried in the sunlight for 1 wk before being used in this study.

Soil characteristics

The soil texture of this experiment was characterized as a sandy loam type based on United States Department of Agriculture (Soil Survey Staff, 1998). The particle characteristics of the soil consisted of sand 57.1%, silt 33.6% and clay 9.3%. The organic matter contents at 0–20 cm depth ranged from 1.1% to 1.2% of soil weight. The soil bulk density ranged from 1.12 g/cm^3 to 1.24 g/cm^3 when plowed. The initial soil moisture content varied from 19.0% to 25.2%.

Rainfall simulator

A rainfall simulator similar to that described by Donjadee et al. (2010) was used. The rainfall simulator was set up beside the experimental plot. The simulator consisted of an array of spraying nozzles that can produce raindrops with median drop size diameters of 0.5–4.3 mm. The flow to each nozzle was controlled by a compression stop valve and a pressure regulator. The rainfall intensity was adjusted by the pressure and nozzle spacing. The calibration tests indicated that the Christiansen uniformity (Christiansen, 1941) of the rainfall intensities over the test plot was 81–89%. The nozzles were installed at a height of 7.0 m along the centerline of the tested plot (Fig. 1). The drops could reach a vertical distance of at least 0.5 m above the nozzle before starting to fall as rain, so that the raindrops fell on the soil surface from a vertical distance of at least 7.5 m. They had kinetic energy of at least 95% of natural rainfall (Morgan, 1995). In this study, three rainfall intensities of 35 mm/h, 65 mm/h and 95 mm/h were selected with a duration of 1 h for a 2–200 yr return period in Northern Thailand.

Plot preparation and test procedure

Simulated rainfall erosion tests were performed with three rainfall intensities (35, 65 and 95 mm/h), and five mulch rates (1.0, 2.0, 2.5, 5.0, and 7.5 t/ha) plus one control plot (bare soil plot) on land with a 30% slope. Each test had three replications, resulting in 99 combinations (3 rainfall intensities × 1 land slope × (5 RCs + 5 VGMs + 1 control plot) × 3 replications) of erosion tests being carried out.

The experimental plots were prepared by conventional tillage; therefore, the soil was plowed to a depth of 25 cm. The soil surface was smoothed by rake to produce a similar surface for all testing due to different soil surfaces having different dynamics of soil loss (Helming et al., 1998). Cylindrical sampling cores of 5 cm diameter and 5 cm height with sharp cutting edges were used to collect undisturbed soil samples from 0 to 15 cm depth at 2 m intervals down the slope. These core samples were then oven-dried for 24 h at 105 °C in the laboratory. Soil moisture was gravimetrically determined at the same time. In the VGM plots, a design quantity of vetiver grass clipping was applied as mulch over the plot.

Uniform rainfall at a constant intensity was applied for 1 h to the experimental plots. Runoff samples were collected at 2.5 min intervals until the rainfall was stopped and then was continuously recorded at 3.0 min intervals up to 90 min. Thereafter, the clear water was removed from the collected runoff by pipette, and the remaining sediment was oven-dried at 105 °C for 24 h. Next, the tested soil in the plot was left for at least 2 d before the next test. The tested soil was raked to loosen material from the previous testing. Before each testing, about 5–10 cm of surface soil was removed and replaced by fresh soil.

Results and discussion

Runoff

This study compared the runoff from conventional tillage on a bare soil plot, with runoff from plots covered with different mulches. The two runoff parameters assessed in the mulched plots and bare soil plot in this study were the runoff rate and runoff volume (runoff depth). The runoff rate increased with time and reached a steady state within the first few minutes. This period increased with an increasing mulch rate. The runoff rate of the bare soil plot increased more rapidly than that of the mulched plots in the initial stage of runoff. This behavior was also found by Pan and Shangguan (2006) who studied the runoff hydraulic characteristics