Soil & Tillage Research 170 (2017) 104–113

Contents lists available at ScienceDirect

Soil & Tillage Research

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

Weed strip management for minimizing soil erosion and enhancing productivity in the sloping lands of north-eastern India

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ARTICLE INFO

Keywords:
Sloping land technology
Soil conservation
Soil cover management

ABSTRACT

Soil erosion and shifting cultivation are the major constraints to agriculture in the north-eastern region of India. Low acceptance of cost-intensive soil conservation technologies (e.g., terracing) calls for developing low-cost erosion control measures. Thus, a field experiment was conducted during the monsoon period of 2008 and 2009, in runoff plots on a land slope of 40% to test the hypothesis that weed cover, if properly managed, minimizes soil erosion and improves soil productivity. The treatments implemented in duplicates were: maize (*Zea mays*) under shifting cultivation (T_1), maize on contour lines (T_2), groundnut (*Arachis hypogea*) on upper and maize on lower half of treatment plot, with both on contour lines (T_3), groundnut on contour lines (T_4) and maize on contour lines with natural vegetation as buffer strips (T_5). The average sediment concentration of runoff water varied from 5.20 g L^{-1} (T_1) to 1.07 g L^{-1} (T_5) in 2008 and from 3.84 (T_1) to 0.89 g L^{-1} (T_5) in 2009. The soil loss ranged from 20.8 (T_1) to 4.7 Mg ha^{-1} (T_5), with corresponding loss of 670–147 kg ha^{-1} of SOC, 6.85–1.48 kg ha^{-1} of available N, and 2.14–0.87 kg ha^{-1} of available P. Weed strips and weed mulch on the upstream side of maize rows in T_5 led to formation of stable mini-terraces promoting better plant and root growth. This study indicates cover management involving selective weed retention can reduce soil erosion, favourably modify land slope and promotes soil productivity.

1. Introduction

Soils, apart from being a medium for plant growth, provide numerous ecosystem services (Keesstra et al., 2016), contribute to mitigating climate change effects and ensuring a healthy environment. Healthy soils with optimum soil functions are vital for sustaining food production and ensuring food and nutrition security to mankind. Soils, being the largest terrestrial carbon pool, play a critical role in sequestering atmospheric carbon and contribute to mitigating greenhouse gas emissions. However, soil erosion leading to a decline in land quality is a major global issue adversely affecting sustainable agricultural productivity (Lal, 2001; Keesstra et al., 2016; Biddoccu et al., 2016). The role of soil erosion is increasingly becoming important due to the intricate relationship between land degradation and global food security (Gessesse et al., 2015; Keesstra et al., 2016). In India, about 45% of the land area is under various forms of land degradation (Lenka et al., 2012a), with severe water erosion in the high rainfall hilly regions. As per the 2011 Indian census, the north-eastern region of India with a geographical area of 26.2 million ha, has a population of 44 million. The region accounts for 3.65% of the total population of the country as against a land share of 7.9%. About 72% of the land area in the region is hilly (Das et al., 2009). Out of the total land area, 28% has an altitude higher than 1200 m and 18% between 600 and 1200 m above mean sea level (Das et al., 2009). Being one of the most ecologically-sensitive and challenging regions of the country, it is prone to severe soil erosion, loss of fertile top soil and environmental degradation due to hilly terrain and prevailing shifting cultivation (slash and burn agriculture) practices (Singh et al., 2012; Das et al., 2014; Nath et al., 2016).

Shifting cultivation, locally known as *Jhum* cultivation, is the major form of agriculture in this region. It is an ecologically viable system of agriculture provided that the fallow cycles (replenishment phase) are long enough to maintain soil fertility and expectations of productivity are not high. However, increasing population pressure has reduced the duration of the fallow phase from 15 to 20 years to 3 to 4 years, causing significant decline in crop yield and soil fertility. Repeated use of land

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http://dx.doi.org/10.1016/j.still.2017.03.012
Received 5 October 2016; Received in revised form 13 February 2017; Accepted 19 March 2017
Available online 05 April 2017

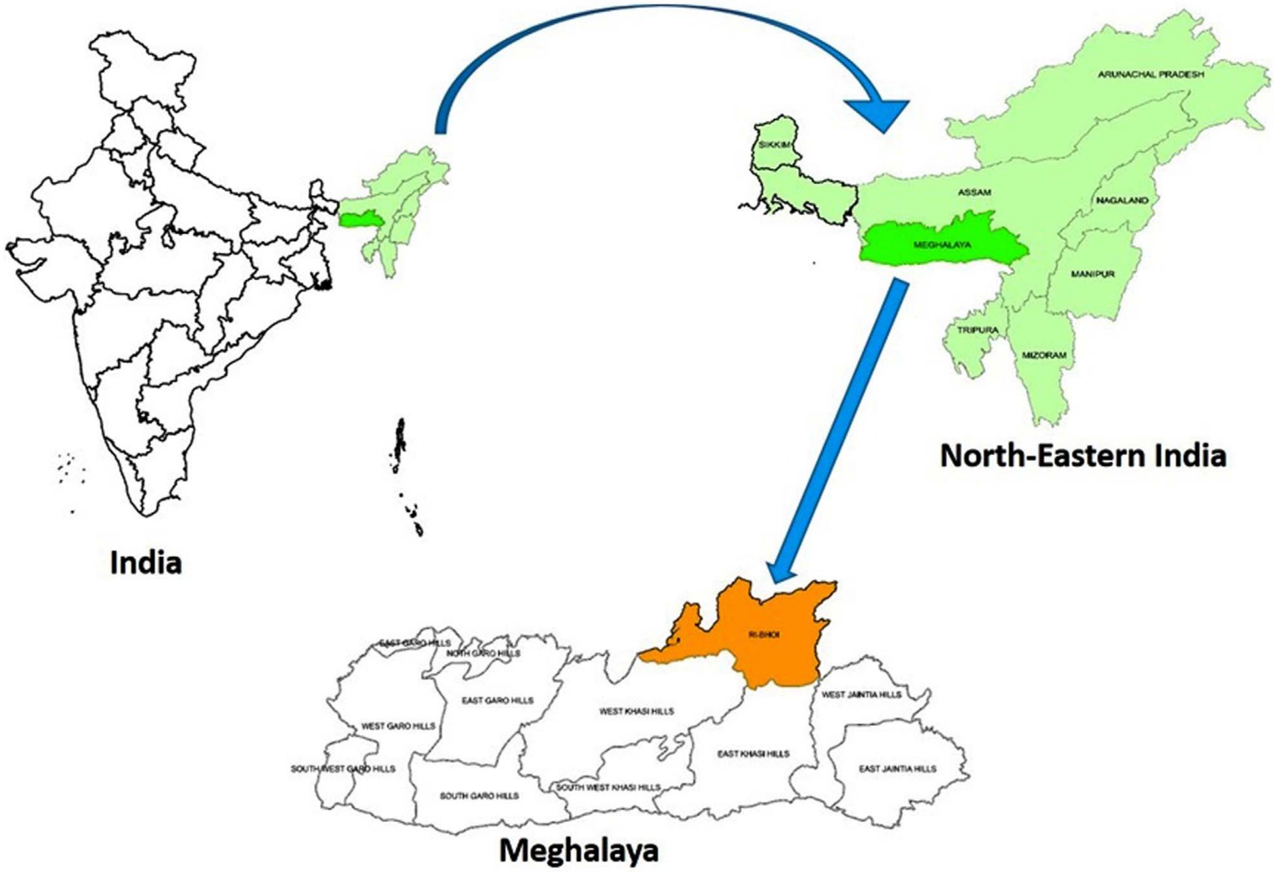

Fig. 1. Location of the study site.

with a short replenishment phase converts the shifting cultivation fallows into degraded wastelands (Lenka et al., 2012a). This requires the farmers to clear new forest areas, aggravating the loss of forest and biodiversity and creating a vicious cycle of deforestation- environmental degradation-low crop yield-poverty-more deforestation. About 80% of the area of the region is affected by moderate to severe erosion (Velayutham, 1999; Singh et al., 2012). About 59 Mg ha^{-1} yr^{-1} of soil erosion has been reported from land with a slope gradient of 45% (Sharma and Prasad, 1995; Sharma et al., 2014; Sharma and Sharma, 2005) and 170 Mg ha^{-1} from a slope of 70% (Singh and Singh, 1978). About 88.3 million tonnes of soil and about 0.5 million tonnes of plant nutrients are lost every year from the region through erosion (Sharma and Prasad, 1995).

Because of the predominantly hilly terrain, a small proportion of the cultivated lands is flat or has a low elevation gradient. These lands are situated near the valleys and are owned by richer members of the community. Thus, most of the agriculture activities are done on sloping lands. Cultivation in the hills and lands situated in the hill slopes is beset with two key problems. First, accelerated soil erosion is severe in the entire north-eastern region. Rainfall received in the region is > 2000 mm per annum, and is accompanied with torrential storms during the monsoon season (Das et al., 2014). The combined action of torrential rains during the monsoon months and the steep slope gradient results in washing away of the fertile soil and applied inputs including seeds. Secondly, walking up the slope for routine agricultural practices becomes difficult particularly during wet months.

Predominant crops in the shifting cultivation region of north-eastern India are rice (*Oryza sativa* L.), maize (*Zea mays*), potato (*Solanum tuberosum*) and ginger (*Zingiber officinales*). A modified method of shifting cultivation, known as *Bun* cultivation, is practised particularly in the Shillong plateau region, where crops are grown ‘along the slope’ on raised beds. These beds are formed by excavating the soil from both sides and the subsoil layers and leaving narrow channels between two beds for safe disposal of water. Because of the higher level of soil manipulation, this method is more devastating than the traditional shifting cultivation method in terms of soil erosion (Singh et al., 2012). About 0.39 million ha of the 2.28 million ha area of the Shillong plateau region is managed by shifting cultivation, and as much as 76.6 Mg ha^{-1} yr^{-1} of soil is lost under this system of farming (Satapathy, 1996).

Depending upon slope gradient, erosion control on arable lands is attempted through biological measures such as live barriers of grasses and hedges (Dass et al., 2011; Lenka et al., 2012b), surface cover of standing crops or crop residues (Lenka et al., 2012a; Das et al., 2014; Biddoccu et al., 2016; Cerdà et al., 2016) and through modification of land configuration and conservation tillage practices (Kuotsu et al., 2014; Ghosh et al., 2015). In a long-term runoff monitoring study in Italy, grass cover reduced runoff by at least 37% and soil loss was 10 times lower as compared to reduced tillage (Biddoccu et al., 2016). For highway embankment erosion control, Bakr et al. (2015) demonstrated the efficacy of surface mulch through a rainfall simulation experiment. In their experiment, the cumulative runoff loss as a percentage of the applied rainfall reduced from 90% for the tilled plot to 28% in treatments having 10 cm compost/mulch. In any case, the principle is to reduce the runoff velocity and in the long run to alter the land configuration suitably so as to reduce the slope gradient. Terracing, recommended as the best land management system for agriculture on sloping lands, is often not accepted by farmers due to high initial investment. Further, most of the sloping lands are either community lands or owned by small and marginal farmers. Thus, terracing is economically unfeasible.

Alternatively, judiciously managed natural vegetation in accord with specific crop growth stages, serves both as cover and buffer strip.