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Impact of fodder grasses and organic amendments on productivity and soil and crop quality in a subtropical region of eastern Himalayas, India

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ABSTRACT

Agriculture in the Eastern Indian Himalayas is characterized by fragility and marginality with about 77% of the geographical area under hills and degraded plateau. Thus, field experiments were conducted for three consecutive years during 2008–2011 to assess the impact of perennial fodder grasses and sources of nutrient supply on productivity and quality of soil and fodder under terrace conditions in a subtropical degraded hill soil of Meghalaya, India (980 m above sea level). The treatment consisted of four fodder crops and three sources of nutrients. Fodder crops were broom grass (*Thysanolaena maxima*), congosignal grass (*Brachieria rosenesis*), hybrid napier (*Pennisetum typhoides* x *P. purpureum*) and guinea grass (*Panicum maximum*). Three sources of nutrient supply were organic, inorganic and control (inherent soil fertility conditions). Farmyard manure (FYM) was used as organic source of nutrient supply on N equivalent basis and P nutrition was supplemented through rock-phosphate. Fertilizer urea, single super phosphate and muriate of potash were used as inorganic source of nutrients. The dry fodder yield increased in each successive year and three year average dry fodder yield was significantly higher with hybrid napier (28.1 Mg ha^{-1}) than other grasses. Among nutrient sources, the average dry fodder yield under organic amendment (22.9 Mg ha^{-1}) was 27.5 and 64.4% higher than that under inorganic fertilizer (17.9 Mg ha^{-1}) and control (13.9 Mg ha^{-1}), respectively. Crude fibre (35.9%) and lignin (7.02%) concentrations were the maximum in hybrid napier whereas, cellulose (39.1%) was the highest in congosignal grass. On the contrary, crude protein concentration was the maximum in broom grass (8.27%), and it was at par with that in hybrid napier. The available N, P, K and soil organic carbon (SOC) contents were significantly higher ($P = 0.05$) under organic compared to those under other nutrient sources. The SOC concentration (17.2 g kg^{-1}) and stock (32.2 Mg ha^{-1}) after three years under organic treatment was 5.3 and 2.1% and 13.3 and 8.1% higher than that recorded under inorganic and control, respectively. The study indicated suitability of fodder grasses and organic amendments in improving quality of marginal degraded hill soils.

1. Introduction

In the eastern Indian Himalayas, 'slash and burn' agriculture (widely known as *jhuming* or shifting cultivation) is practiced on ~0.88 million hectare (M ha) area (Choudhury et al., 2013). Deforestation by 'slash and burn' exacerbates soil erosion and ecosystem degradation (Saha et al., 2007). *Bun* cultivation; involving raised beds of 0.15–0.30 m height, 0.75–1 m width with almost equal width under sunken area made along the slopes; is a modified form of shifting cultivation. In this system, biomass is

Abbreviation: a.s.l, above sea level; CO_2, carbon dioxide; CEC, cation exchange capacity; DHA, dehydrogenase activity; DTPA, diethylene tetramine penta acetic acid; Fe, iron; FYM, farmyard manure; ICAR, Indian Council of Agricultural Research; Cu, copper; CD, critical difference; NS, not significant; Mn, manganese; M ha, million hectare; Mg, mega gram; $NaHCO_3$, sodium bicarbonate; NH_4OAC, ammonium acetate; NEH, Northeastern Hill; OM, organic matter; ρb, bulk density; SEm, standard error of mean; SMBC, soil microbial biomass carbon; SOC, soil organic carbon; TEA, tri ethanol amine; Zn, zinc.

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burnt under the *bun* (raised beds) and area is abandoned after two or three years. The system is widely used in the Meghalaya plateau and it aggravates soil erosion and degradation (Saha et al., 2012a). Adverse effects of shifting cultivation, *bun* cultivation and deforestation on plant and animal genetic resources, desertification, soil erosion inducing nutrient loss, and siltation of water bodies have been widely reported (Ramakrishnan, 1993; Marafa and Chau, 1999). Soil loss on steep slopes (44–53%) by shifting cultivation in North Eastern Hill (NEH) region of India has been reported as 40.9 Mg ha^{-1} yr^{-1} and the corresponding losses of soil organic carbon (SOC) and plant nutrients (kg ha^{-1}) are 702.9 of SOC, 63.5 of P and 5.9 of K (Singh and Singh, 1981). Soil erosion under first and second years, and on abandoned shifting cultivation area have been estimated at 147, 170 and 30 Mg ha^{-1} yr^{-1}, respectively (Singh and Singh, 1981). Soil erosion, due to inappropriate cultural practices and burning of biomass, results in significant loss of SOC and carbon dioxide (CO_2) emission (Brown, 1997). Steep slopes, cultivation along the slope, low input, minimal nutrient replacement and high rainfall are among major causes of soil degradation in the NEH region of India (Ghosh et al., 2009).

Maintaining and enhancing soil quality are crucial to sustaining agricultural productivity and environmental quality (Lal, 2004). Continuous cropping, without use of conservation-effective measures, has negative effects on the soil and environment (e.g., loss of SOC, soil erosion, water pollution). Thus, soil management methods are needed that enhance use efficiency of inputs, reduce losses and minimize adverse impacts on the environment. Biological methods of soil and water conservation, especially grass/vegetation covers are suitable for hilly ecosystems, and are also cost-effective. Soil quality management in the fragile hill ecosystems under humid conditions should include permanent pastoral grasses (Saha et al., 2012a). Perennial grasses provide year-round ground cover, which reduces run-off and soil erosion from sloping land (Ghosh et al., 2009). Perennial grass cover improves physico-chemical properties of the soil by adding organic matter (OM) (Bonnin and Lal, 2012). The contribution of soil organic matter (SOM) from grasses can increase water stable aggregates (WSA), mean weight diameter (MWD), and soil moisture retention (Ekwue, 1990). Larger root mass, root exudates, and the presence of fungal hyphae in soils under grasses improve the stability of macro-aggregates (Tisdall and Oades, 1982).

Forages are integral component of any farming system suitable for the hill ecosystem to supply green fodders for livestock (Ghosh et al., 2009), reduce runoff (Saha et al., 2012b) and improve soil quality (Choudhury et al., 2013). Lack of good quality fodder reduces milk yield and increases cost of dairying. Diverse range of perennial forages {broom grass (*Thysanolaena maxima*), congosignal grass (*Brachieria rosenesis*), napier grass (*Pennisetum typhoides* x *P. purpureum*), guinea grass (*Panicum maximum*), setaria (*Setaria sphacelata*), etc.} are suitable for cultivation on degraded soils of the NEH region (Gupta, 2004) and have better fodder quality compared to native grasses.

Cultivation of forages in degraded and sloping lands not only supplies green palatable fodders to livestocks but also rehabilitates the degraded soils by improving physico-chemical properties (Ghosh et al., 2009). Forages have strong root systems compared to field crops (such as rice, maize etc.), protect soil and improve aggregation. A geospatial study in NEH region of India covering about 10.1 M ha, reported high SOC concentration from grassland and second only to forest land use. The SOC stock under perennial grassland was 47 Mg ha^{-1} vs. 23 Mg ha^{-1} under degraded and abandoned *jhum* (shifting cultivation) land (Choudhury et al., 2013).

Mechanically disturbed soil is a source of CO_2 through mineralization of OM by microbes, while undisturbed soils can be a sink for C (Al-Kaisi et al., 2005). Most degraded and depleted soils contain a lower SOC pool than in those under natural ecosystems (Bonin and Lal, 2014). Decline in SOC creates an array of negative effects on land productivity (Saha et al., 2012b). Thus, restoring SOC pool is essential for improving soil quality, crop productivity, and enhancing numerous ecosystem services (Sundaram et al., 2012). Soils under perennial grasses and those which are undisturbed for a long time are potential C sinks because the grasses add OM to soils through root growth, and decline in OM mineralization because of lack of tillage (Conant et al., 2001; Gentile et al., 2005). Further, conversion of degraded cropland soils to forage and perennial grasses lead to C sequestration (Grandy and Robertson, 2007). Grasslands have high inherent SOM concentration that supplies plant nutrients; increases soil aggregation, limits soil erosion, and also increases cation exchange capacity (CEC) and water storage. Thus, establishing perennial grasses and forages is a good measure for improving soil quality in degraded lands (Bonin and Lal, 2012).

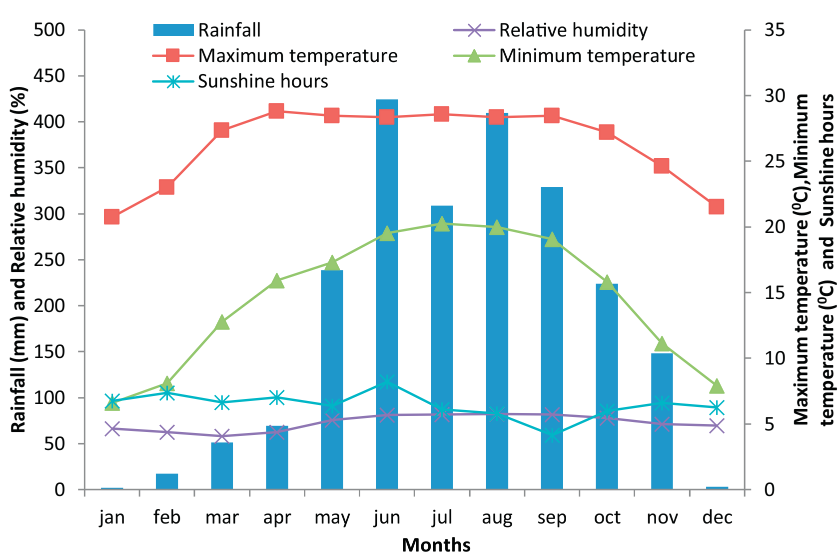

Fig. 1. Mean monthly weather parameters during 2008–11.