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Soil organic Carbon and total Nitrogen in Himalayan rangeland

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ABSTRACT

The objective of this study is to identify and quantify the present status of carbon and nitrogen pool in Himalayan rangeland and to make recommendations for enhancing carbon and nitrogen storage for rangeland management. To meet the aforementioned objectives, the field study was conducted in 2011 -2013. The study showed that soil organic carbon was highest in legume seeding sub-plot in topsoil (28.53 ± 2.6) t/ha of heavily grazed area. Similarly, total nitrogen was highest in bottom soil (2.81 ± 0.16) t/ha in legume seeding sub-plot of the enclosed un-grazed area. Usually, heavily grazed and legume seeding sub-plots had more soil organic carbon and soil organic nitrogen concentration compared to others. The value of above ground biomass was an increasing trend with decreasing grazing intensity but for below-ground biomass, it was just the reverse. On the basis of the results of this study, the grazing intensity is positively correlated with above ground and below ground biomass and soil organic carbon but no any response with soil total nitrogen and soil bulk density.

Keywords— *Biomass, Carbon, Climate change, Himalayan, Soil, Rangeland*

1. INTRODUCTION

Rangelands occupy approximately 40-70% globally [1], [2] & [3] of the terrestrial land surface. In Nepal, the rangeland occupies 23% of total land [4]. Rangeland contains about 36% of the world's total carbon in above- and below-ground biomass [5]. It is estimated that rangelands globally sequester carbon (C) in soil at a rate of 0.5 Pg C/yr [6] & [7]. Some studies indicate that rangeland management practices could provide a substantial global sink for atmospheric carbon in grasslands. Grazing can increase, decrease, or maintain unaltered the size of both pools [8], [9] & [10]. High altitude and cold rangeland have a high capacity to sink carbon on the soil. The soil organic carbon pool is important and at risk especially in the Himalayan region [11]. Despite having high carbon stocking capacity rangelands have poor carbon stock. The rangeland productivity and carbon pool are declining day by day due to high degradation and overexploitation. Various management practices on rangelands have not been observed and recommended for carbon stocking in nature yet. Thus it is essential to find the actual carbon stocking rate of the rangeland. The objective of the present study was to estimate total carbon on various management practices in Himalayan rangeland. Grazing experiment was conducted in a temperate grassland of Eastern Nepal to (1) evaluate the influence of different grazing intensities on soil C and N storage, (2) explore the influence of legume treatment on the distribution of C and N in soil profiles and (3) relate the soil bulk density and nitrogen on C distribution (4) test the hypothesis that grazing intensity and legume treatment alter the C and N stock in Himalayan rangeland.

2. RESEARCH METHODOLOGY

2.1 Study Area

The study was conducted in the Tinjure-Milke-Jaljale (TMJ) Mountain ridge-political border of three districts, i.e., Taplejung, Tehrathum, and Sankhuwasabha of Eastern Nepal. Geographically the area lies between 27º 6' 57" to 27º 30' 28" north latitude and 87º19' 46" to 87º 38' 14" east longitude.

The study area was established in 2011 in a randomized block design. Three experimental plots were fixed viz. (a) rangeland with heavily grazed (heavily season-long grazing) HG (b) rangeland with occasional grazed, SG (c) ungrazed enclosures rangeland, UG. Continuous heavily season-long grazing means the rangeland is grazed as usual way as it runs since its practices without disturbing. Each plot was further divided into legume overseeded sub-plot and non-legume sub-plot. At the end of the 3 years grazing experiment (late September 2013), ten sampling points were established in two parallel transect lines. One quadrat (30 cm × 30 cm) was established at each sampling point. Within each quadrat, three soil cores were collected at depths of 0–5 cm (soil profile), 5-10 cm (second soil profile) and 10–15 cm (third soil profile). Similarly, soil bulk density was determined for three different strata by using the core method [12].

2.2 Soil Sampling

Soil samples were collected from each subplot with the help of soil core having 4 cm diameter and 15 cm length. The soil sample was dried in an oven at 100°C till constant weight. It was crumbled with thumbs and sieved through 2 mm sieve. Meanwhile, the bulk density of the soil sample was taken. The remaining particles were weighed, sieved and stored for further analyses.

2.3 Sample Analysis

2.3.1 Determination of soil bulk density: The bulk density of sampled soil was determined by a standard method [12]. Equation (1) was used for the calculation of soil bulk density.

$$\text{Bulk Dencity (g/cm}^3) = \frac{\text{Oven Dry Mass (g)}}{\text{Core Volume (cm}^3) - \left[\frac{\text{Mass of coarse fragments (g)}}{\text{Density of Rock fragments (g/cm}^3)}\right]} \quad (1)$$

2.3.2 Determination of total organic carbon: Soil organic carbon was analyzed from the stored sample by the [13] Chromic Acid Wet Oxidation Method. The organic carbon (%) and total organic carbon were calculated using the equations (2) and (3) respectively.

$$Organic\ Carbon = \frac{0.003 \times N \times 10\ ml \times (1 - T/s) \times 100}{ODW} - \frac{3(1 - T/S)}{W} \quad (2)$$

Where,

N = normality of $K_2Cr_2O_7$

T = volume of $FeSO_4$ used in the sample titration (ml)

S = volume of $FeSO_4$ used in the blank titration (ml)

ODW = oven-dry weight (g) of soil sample

$$\text{Soil Organic carbon (SOC)} = \text{Organic Carbon Content (\%)of soil} \times \text{Soil bulk density (g/cm}^3) \times \text{Thicknessof horizon (cm)} \quad (3)$$

2.3.3 Determination of total nitrogen: The nitrogen content in the soil sample was determined by the Kjeldahl method [14]. The nitrogen % and total nitrogen were determined using the relation (4) and (5) respectively:

$$Nitrogen\ (\%, wet\ basis) = \frac{(Sample\ titer - Blank\ titer) \times N\ of\ HCl \times 14 \times 100 \times 100}{Aliquot(ml) \times Wt.of\ sample\ (g) \times 1000} \quad (4)$$

$$\text{Total Nitrogen (TN)} = \text{Organic Nitrogen Content (\%) of soil} \times \text{Soil bulk density (g/cm}^3) \times \text{Thicknessof horizon (cm)} \quad (5)$$

2.4 Statistical Analysis

All of the data analyses were carried out by using IBM-SPSS statistics version 20 [15] software. Three-way ANOVAs were used to analyze the main and interactive effects of grazing intensities, legume treatment, and soil profiles on total nitrogen, soil organic carbon, and the ratio of carbon and nitrogen (C: N). Significance levels were set at $\alpha = 0.05$ for all tests. Residuals were examined and data were transformed when necessary to improve homoscedasticity. Fisher's Least Significant Difference (LSD) was used to test the significance of means that were considered significantly different at $\alpha = 0.05$ probability level.

3. RESULTS AND DISCUSSION

3.1 Soil Organic Carbon (SOC) and Total Nitrogen (TN)

This study revealed that soil organic carbon was highest in legume over-seeded plot in 0 - 5 cm depth (28.53 ± 2.6) t/ha of the heavily grazed area and lowest in the non-legume plot in 10 - 15 cm depth (13.96 ± 1.26) t/ha of occasionally grazed the area. Usually, there were generally decreasing trends for soil organic carbon concentration with increasing soil depth in both legume and non-legume heavily grazed areas as well as occasionally grazed area but differences were not significant (Figure 1: A and C). Conversely, SOC was more or less equal in all depth in the enclosed un-grazed area (Figure 1 A). Regardless of the legume treatment in the study area, SOC concentration was not statistically significant among the grazing intensities plots. The main effect of grazing intensity on soil organic carbon was not significant but soil core depth and legume over-seeded (F = 9.02, p= 0.000) (F = 6.03, p= 0.01) were significant. Similarly, the interaction effect of the independent variables of the research showed the following results. Heavily grazed and occasionally grazed area had significantly high SOC concentration in legume over-seeded plot than non-legume plot (F = 9.91, p = 0.002 and F = 9.28, p = 0.003, respectively) but un-grazed plot had marginal significantly less SOC (F = 3.75, p = 0.05). Similarly, in heavily grazing area, 10 – 15 cm depth had significantly less SOC than 0 – 5 cm depth (p = 0.001) and 5 – 10 cm depth (p = 0.003). In occasionally grazed area, 0 – 5 cm depth had significantly high SOC than 5 – 10 cm (p = 0.01) and 10 – 15 cm depth (p = 0.001). On the contrary, soil depth had no effect in the un-grazed plot. The interaction effect on soil organic carbon of legume treatment was significantly high in 0 – 5 cm than 10 – 15 depth (p = 0.01) and other depth comparisons were not significant. Similarly, non-legume plot, 10 – 15 cm depth had significantly less SOC than 0 – 5 cm depth and 5 – 10 cm depth (p = 0.001 and p = 0.01, respectively).

Total nitrogen was highest in 10 - 15 cm depth (2.81 ± 0.16) t/ha in legume over-seeded plot and lowest in 5 - 10 cm depth (0.89 ± 0.04) t/ha in non-legume plot of enclosed un-grazed.

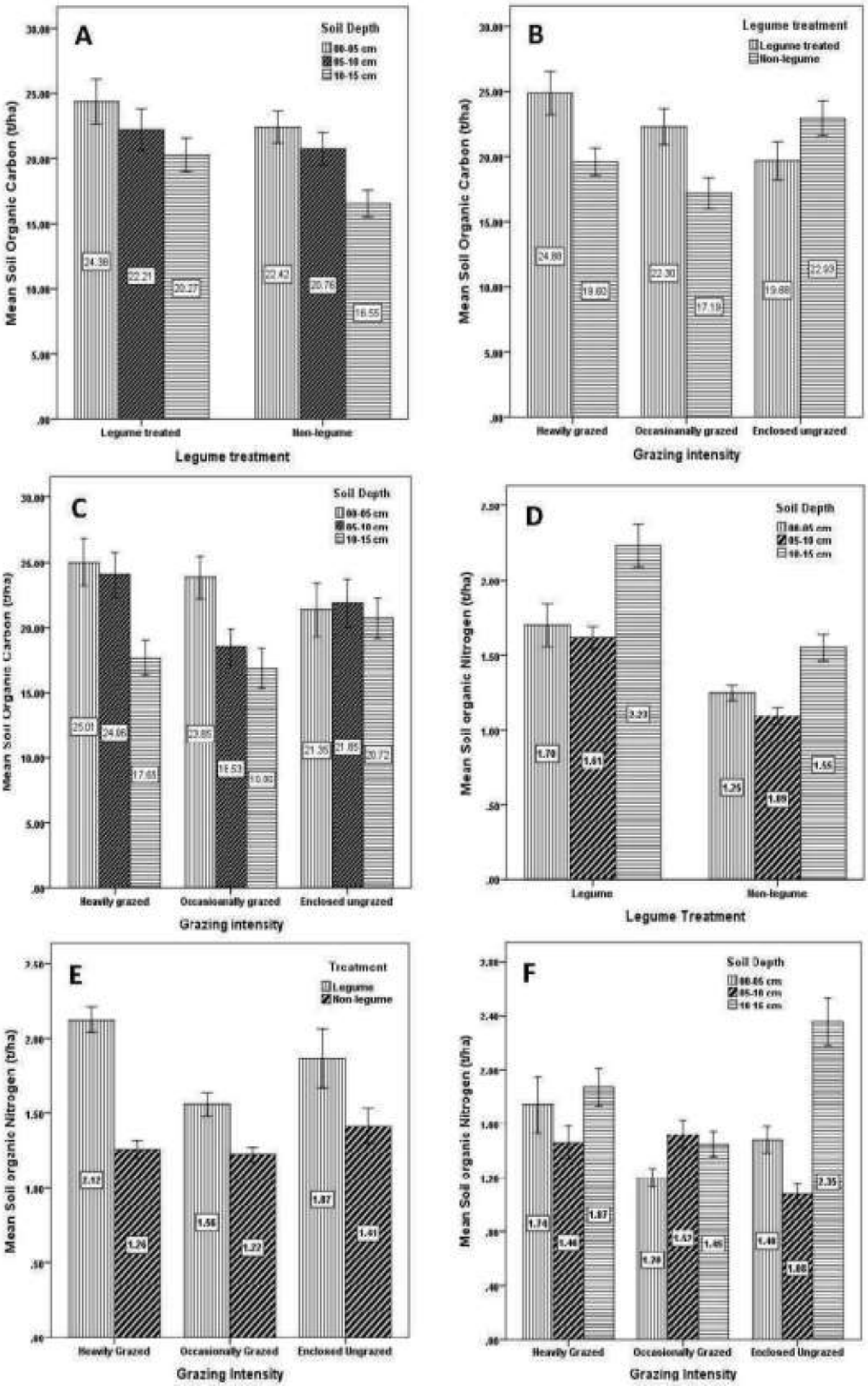

Fig. 1: SOC and TN changes on high altitude Himalayan rangeland under various management (A, D) Interaction effects of soil depth and legume treatment on SOC and TN (B, E) Interaction effects of grazing intensity and legume treatment on SOC and TN (C, F) Interaction effects of grazing intensity and soil depth on SOC and TN

The study revealed that total nitrogen concentration was higher in legume over-seeded plot than in non-legume plot in all grazing types (Figure 1: E and F). The difference was significant. On the other hand, there was inconsistent TN concentration in a soil depth of various grazing intensity. However, their differences were significant (Figure 1 D).

There was a significant main effect for grazing intensity ($F = 14.76$, $p = 0.000$), legume treatment ($F = 129.87$, $p = 0.000$) and soil depth ($F = 45.29$, $p = 0.000$) on total nitrogen concentration. Grazing intensity and legume treatment had highly significant effect towards total nitrogen concentration. As can be seen interaction effect in Figure 1, in the all grazing types had significantly high total nitrogen on legume over-seeded plot than non-legume plot (F = 106.656, p = 0.000, F = 16.14, p = 0.0001 and F = 29.08, p = 0.000, respectively). Similarly, the enclosed non-grazed plot had significantly high TN on 10-15 cm soil depth (F = 80.44, p = 0.0000) than upper layers, 0-5 cm depth and 5-10 cm depth. The interaction of the legume treatment and soil depth on total nitrogen showed that all depth of soil viz. 0-5 cm, 5-10 cm and 10-15 cm had significantly high TN in legume over-seeded plot than non-legume pots (F = 29.32, p = 0.000, (F = 38.67, p = 0.000 and (F = 65.68, p = 0.000).

3.2 Grazing and legume treatment on Soil C and N storage

The results confirm that grazing impact is inconsistent on C and N storage while legume treatment shows positive correlation on carbon and nitrogen storage in high altitude rangeland. In the case of soil depth, N storage shows increasing trend along with soil depth but C storage shows decreasing order with soil depth in the Himalayan rangeland. In the result, soil C and N storage were slightly lesser in occasionally grazed area compared to heavily grazed and enclosed un-grazed area (Figure 1). In the finding, SOC concentration was not statistically significant among the various grazing intensities. Possible explanations for soil C storage enhancement with un-grazed exclosure include increases in production, elevated nutrient availabilities, and facilitation of vegetation regeneration [16], [17] & [18]. Some scholars suggested that grazing accelerates the rate of nutrient cycling by stimulating primary production and net nutrient flux, thereby increasing the percentage of the system's nutrients that are available and which cycle rapidly near the soil surface [19]. On the other hand, it is reported from temperate grassland of Northeast, India, maximum values of soil organic C and total N in the light grazing site may be due to the presence of a large standing pool of organic matter and a higher rate of decomposition of plant litter through trampling by cattle [20]. The low total soil organic C and N in the heavily grazing sites may be due to a reduction in aboveground biomass owing to excessive grazing by the cattle. Similar findings were also reported in a sub-montane ecosystem [21] and in Inner Mongolian grassland [22]. However, the legume treatment showed a marginally significant difference for SOC on legume treated sub-plot and non-legume sub-plot of the study area (Figure 1: C). Some rangeland scholars reported that Carbon (C) and Nitrogen (N) storage declined in the heavily grazed grasslands, and soil acted as a C source. Declines in soil C and N storage under long-term heavy grazing have been reported [23], [24], [18] & [25]. Repeated and frequent grazing results in decreased root elongation and biomass [26] & [27], and hence lower C inputs into the soil from the roots [28]. Accumulation and storage of carbon and nitrogen on soil depend on the various conditions e. g. climate and biota [29], time [30], topography, and parent material (specifically soil texture; [31] & [32]). Thus, the magnitude of the carbon storage on rangeland depends not only grazing intensity but also other various conditions.

Research findings reveal those lower soil profiles (10-15 cm) of legume over-seeded plot, as well as all grazing intensities, have high TN concentration than surface soil profile. Soil depth is positively correlated to TN but negatively correlated to SOC concentration in Himalayan rangeland. The possible explanations are that the crude form of biomass contains more carbon at the surface layer because it is not buried while getting decomposed. Once buried, the biomass releases more nitrogen at depth. The higher levels of soil organic C and N in the surface soil of the grazed rangeland may be due in part to the effects of grazing on litter and standing dead components of the above-ground biomass. Although grassroots are the primary source of organic matter in rangeland soils, above-ground litter provides a secondary source [33]. In contrary, reported that nitrogen storage was not significantly different in either the 0–10 cm or 10–30 cm soil layers among various grazing intensities [34]. Grazing increases SOC in deep soils but reduces it in shallow soils [10].

On the other hand, legumes are often preferentially grazed compared to grasses [35],[36],[37]& [38]. The less organic material may be returned to the soil for grazed legume mixed grassland as they are often used more efficiently than grasses for animal tissue gain [39] & [37]. Thus, C and N from legume mixed pastures were likely recycled through vegetation, cattle, and soil to a greater extent than C and N from without legume grassland.

In this regard, the conclusion could be made that a short-term (3 years) grazing treatment does not significantly alter the carbon and nitrogen concentration of the soil in a rangeland’s ecosystem.

4. CONCLUSION

The soil organic carbon and total nitrogen concentration were high in legume treated plot but did not significantly alter with grazing intensity. Soil organic carbon showed a decreasing trend with increasing soil depth in legume and non-legume of heavily grazed areas as well as occasionally grazed the area. This study concluded that short-term grazing does not significantly alter the carbon and nitrogen but legume treatment increases both carbon and nitrogen because the source of nitrogen, legume, accelerates the growth of herbs and add biomass and nutrients.

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