Carbon-Nitrogen Ratios in Rangeland Soils in Various Agriculture Response Units in Three Watersheds in the Central Himalayas, India

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Abstract. CN ratios of rangeland soils in selected agriculture response units (ARUs) prevailing in three watersheds, Kosi, Alaknanda, and Pindar, in the Indian Central Himalayan mountains were analyzed. The ratios varied significantly ($P<0.05$) with ARUs and seasons. Interaction between ARUs and season was also found significant ($P<0.05$). In Alaknanda Watershed soil CN ratios ranged from 6.62 to 20.58. Soil CN ratio values differed significantly ($P<0.05$) with seasons and ARUs. Soil CN ratios in the rangelands of Pindar Watershed were recorded between 6.54 and 11.29. The ratios varied significantly ($P<0.05$) in seasons and ARUs. Interaction between ARUs and season was also found significant ($P<0.05$). Rangeland soil CN ratio values of all ARUs were further statistically analyzed in all three watersheds. Minimum soil CN ratios were seen at Pindar and maximum at Alaknanda watershed. The ratios variation was seen in all the rangelands and it was found significant at a significance level of 5%. Interaction between Kosi and Alaknanda was found non-significant while between Kosi and Pindar and Alaknanda and Pindar it was significant ($P<0.05$) throughout the study. Variation in soil CN ratios in both agricultural and rangeland soils was seen in each watershed. In the Kosi watershed, soil CN ratios ranged from 6.74 to 15.06; in Alaknanda from 6.36 to 20.58 and in Pindar from 5.75 to 14.38. CN ratios have an absolute relationship with temperature and are higher when higher rainfall occurs and moisture prevails. The ratios also impact soil acidity and other soil quality parameters.

Introduction

Carbon-nitrogen (CN) ratios of soil organic matter are related to the patterns of nitrogen immobilization and mineralization during organic matter decomposition by microorganisms. The CN ratio values decrease as decomposition proceeds (Kumar et al. 2020, Parmar et al. 2021) and are negatively correlated with the rate of nitrogen mineralization in decomposition experiments by soil incubation, and can indicate the decomposition rate in terrestrial ecosystems.

CN ratios serve as a useful indicator of site quality because it is related to the speed of decomposition and the rate at which organic nutrients are mineralized and become available for re-absorption into the vegetation (Singh 2020). This study attempts to measure the vital soil CN ratios in mountain agroecosystems in the Indian Central Himalayas.

Methods and Study Sites

Indian Central Himalaya covers the Uttarakhand State in India. The state has a total area of 53,566 km², of which 93% is mountainous of which 64% is covered by forests and rangelands. The climate and vegetation vary greatly with altitude and slope orientation, from glaciers at the highest altitudes to subtropical forests at the lower elevations. The region being hilly with deep valleys, the temperature varies considerably from place to place depending on elevation.

Agriculture in the Himalayan mountains, such as the Indian Central Himalaya, is the farming system or agroecosystem based with rangelands, cultivated land, livestock, and households as the main integral components. Ecosystem response to agricultural performance varies according to many factors, such as mountain altitude, slope orientation (north/ south aspect), climate (season), etc. All the responding factors are prevailing in all the villages. Thus a village was chosen as an ARU. In total, 30 ARUs were selected randomly in the three purposely selected watersheds, Kosi, Alaknanda, and Pindar. Soil samples from agricultural (cultivated) lands and rangelands in each ARU in each watershed were collected in different seasons from multiple sites and their carbon and nitrogen contents were determined using standard chemical analysis methods. All ARUs were further statistically analyzed to get overall status for soil CN ratios in watersheds.

Results and Discussion

CN Ratios in agricultural soils

The CN ratios were found in the range of 9.12 to 15.06, 6.36 to 19.68, and 5.75 to 14.38 in Kosi, Alaknanda, and Pindar watersheds, respectively. The soil CN ratios differed significantly (P<0.05) with seasons and ARU in all the ARUs. Interaction between ARUs and seasons was also found significant at 5% level (Figs. 1, 2, 3).

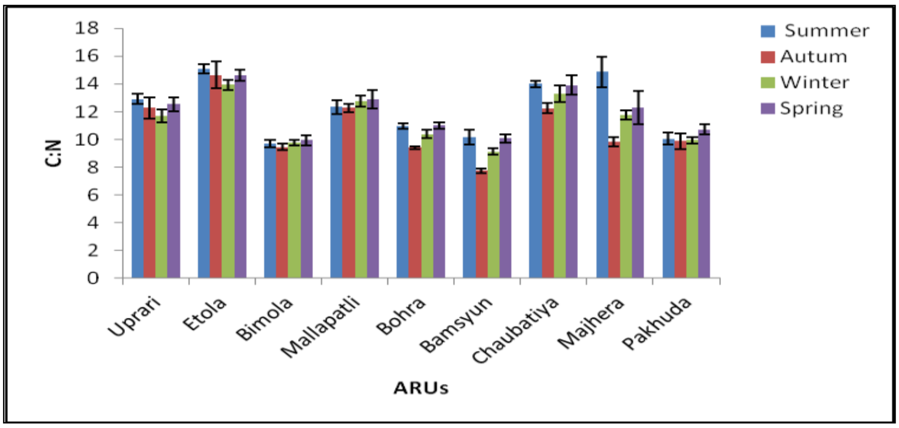

Figure 1: Seasonal variation in CN ratios of agricultural soils of studied ARUs in Kosi watershed

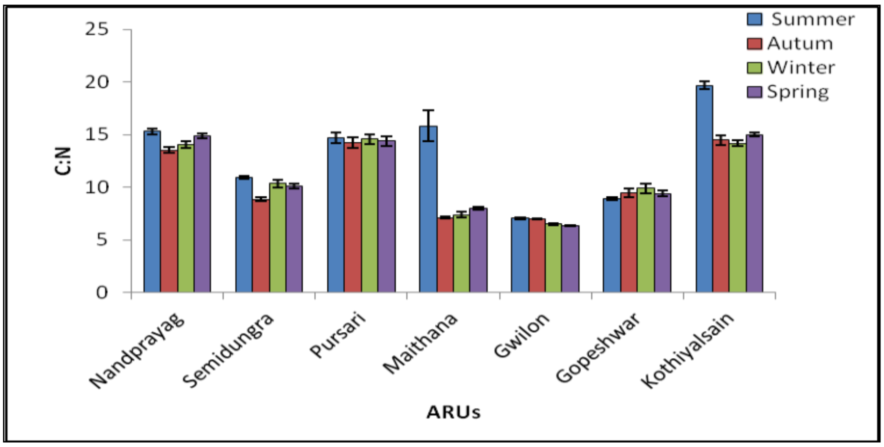

Fig. 2: Seasonal variation in CN ratios in Agricultural soils of studied ARUs in Alaknanda watershed

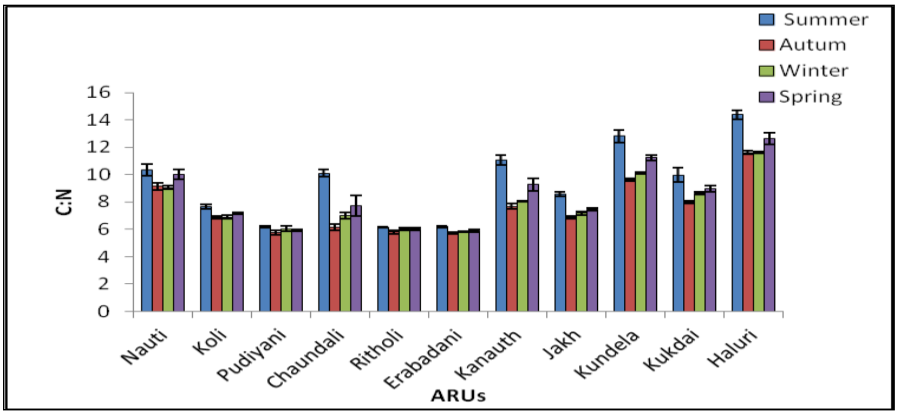

Figure 3: Seasonal variation in CN ratios in agricultural soils of studied ARUs in Pindar watershed

Variation in CN ratios in agricultural soils

Soil CN ratio variation was seen in all agricultural lands and it was found significant (P<0.05). Interaction between Kosi and Alaknanda was found non-significant while interaction between Kosi and Pindar, and Alaknanda and Pindar was found significant (P<0.05).

CN ratios in rangeland soils

CN ratios of rangeland soils were in the range of 6.74 to 14.15, 6.62 to 20.58, and 6.54 and 11.29 in the Kosi, Alaknanda, and Pindar watersheds. The values varied significantly (P<0.05) with ARUs and seasons. Interaction between ARUs and season was also found significant (P<0.05) (Figs. 4, 5, 6).

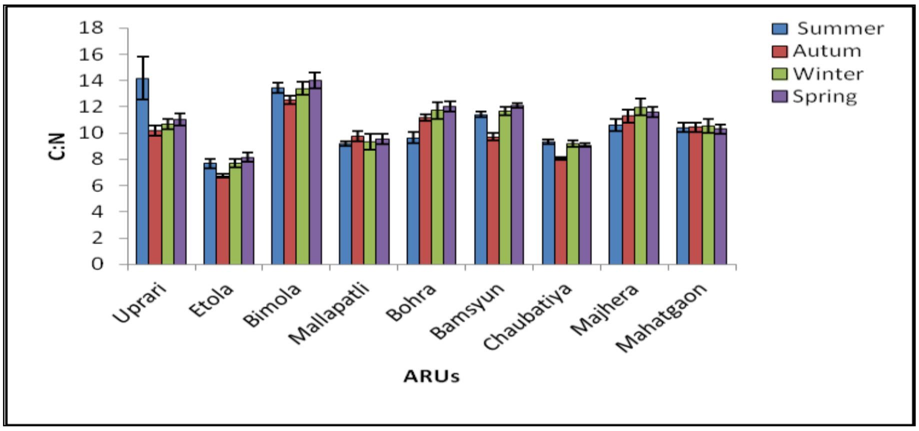

Figure 4: Seasonal variation in CN ratio in rangeland soils of studied ARUs in Kosi watershed

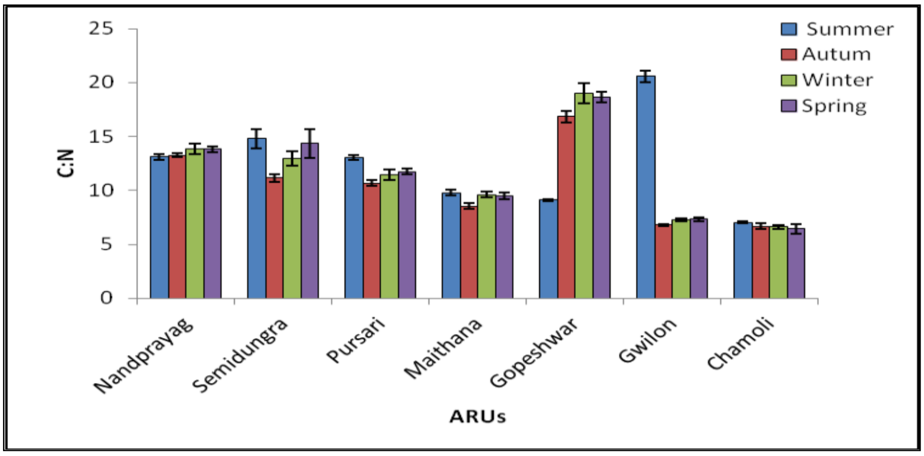

Figure 5: Seasonal variation in CN ratios rangeland soils of studied ARUs in Alaknanda watershed

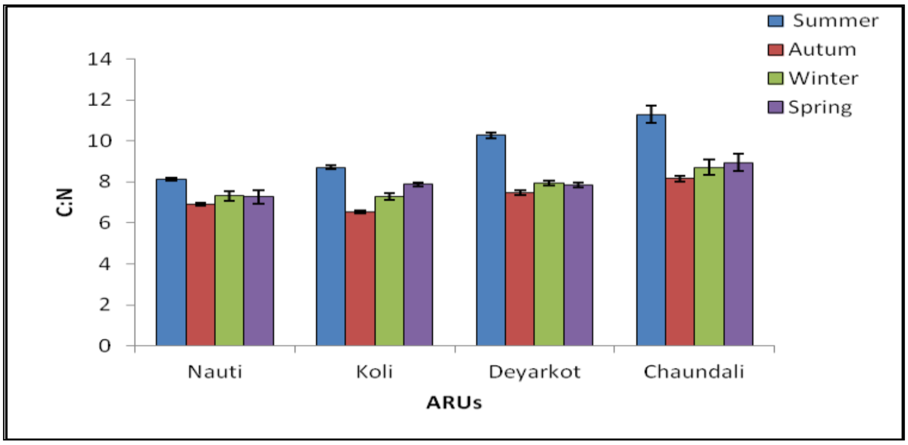

Figure 6: Seasonal variation in CN ratios in rangeland soils of studied ARUs in Pindar watershed

Variation in CN ratios in rangeland soils

Soil CN ratio variation was seen in all the rangelands and it was found significant at a significance level of 5%. Interaction between Kosi and Alaknanda was found non-significant while between Kosi and Pindar, and Alaknanda and Pindar it was significant ($P<0.05$).

Variation in soil CN ratios for uncultivated and cultivated land uses in the watersheds

Variation in soil CN ratio in both agricultural and rangeland soils was seen in each watershed. In the Kosi watershed, the soil CN ratios ranged from 6.74 to 15.06, in Alaknanda from 6.36 to 20.58, and in Pindar, it ranged from 5.75 to 14.38. In statistical analysis, in all three watersheds, the soil CN ratios varied significantly ($P<0.05$) in the land uses, seasons, and ARUs, and interaction between the following was found significant (<0.05): i) land use and seasons, ii) land use and ARUs, iii) seasons and ARUs, and iv) seasons, ARUs and land use.

Seasonal changes in soil CN ratios reveal that these values have an absolute relationship with temperature. The ratios are wider when higher rainfall occurs and moisture prevails. Higher acidity also increases the value of CN ratios. The studies of soil carbon and nitrogen in tropical forest ecosystems have suggested an increase in the soil CN ratios with a decrease in temperature and an increase in moisture (Nautiyal and Singh 2013). Temperatures in mountain agroecosystems are also influenced by slope orientation: a south-oriented slope is generally warmer than a north-oriented slope.

Conclusion

This study is of significance from the viewpoint of the significance of soil health of which carbon and nitrogen contents in general and CN ratios in particular are crucial indicators of soil health vital for the productive performance of soil ecosystems. The soil CN ratios also determine the potential role of the soil ecosystems in carbon sequestration and, thus, in climate change mitigation.

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