CATTLE GRAZING IN SUB-TROPICAL GRASSLAND ECOSYSTEM: EVIDENCE FROM MANIPUR, NE INDIA : NEED FOR SUSTAINABLE GRAZING MANAGEMENT AND GOVERNANCE.

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Abstract

The present study has been undertaken to assess the effect of grazing on the soil microbial biomass C, N and P in the soils under the sub-tropical grassland sites in Manipur, N.E. India. The paper argues that Grazing by cattle at low intensities can create a favorable environment for sustaining biodiversity due to moderate grazing. The findings reveal that the maximum value of soil microbial biomass C, N and P increased in moderately grazed site followed by protected site and heavily grazed sites. Thus it indicates that moderate grazing improved the physiochemical characteristics and the soil microbial biomass in the present grassland. Soil microbial biomass is influenced by organic C, total N and P in the grassland soil as evident by significant relation with organic C, total N and P**.** The paper concludes that one of the most compelling, long-term strategies for dealing with the structural causes of our many ecological crises is to create and recognize legitimately, alternative systems of management and governance. Grazing management and governance is also one of the ground upon which theory meets practice and where, in turn, practice is informed by, and evolves, theory. Inevitably, if we are to develop sustainability, we must re-imagine, and re-invent, these measures. Is there a choice? Grazing governance is an imperative for the 21st century.

Introduction

Grazing is one of the most important factors that could change the soil carbon stock in grassland ecosystems (Cui et al. 2005) which influences organic matter input and associated soil properties (Steffens et al. 2009; Winsmeies et al. 2009). Soil microbial biomass which is a potential source of plant nutrient and an indicator of soil fertility varied with different grazing intensity so management of grassland which is about 40% of the global terrestrial area excluding Greenland and Antartica (Suttie et al., 2003), is required with proper grazing intensity. There is limited information on the impact of grazing intensity on the dynamics of soil microbial biomass in the grassland ecosystem of India (Singh et al., 1989; Srivastava 1992; Singh and Yadava, 2006; Singh et al., 2009). Though there are number of studies report from different part of the world (Tracy and Frank, 1998; Bardgett et al., 2001; Li et al., 2005; Wang et al., 2006; Qi et al., 2010). However information is lacking on the impact of grazing intensity on the dynamics of soil microbial biomass in grassland ecosystem from North east India.

The paper examines the changes in microbial biomass C, N and P due to grazing intensity, relationship between microbial biomass and a biotic factors and distribution of microbial biomass in different soil depths.

Materials and Methods

Using a soil corer soil samples were collected at monthly intervals January to December. At each site five replicate samples were collected from 0-10 and 10-20cm soil depth and brought to the laboratory in polythene bags. The soil was sieved through a 2 mm sieve to remove stone, coarse roots and other plant debris and was stored at room temperature for 24 hours. Microbial biomass (C, N and P) was determined by fumigation extraction method (Anderson and Ingram, 1993). Microbial biomass C was determined by modified Walkley Black method and calculated by using (Vance et al. 1987).

$$\text{Microbial C} = K_{EC} \times 2.64.$$

Microbial biomass N was determined by micro-kjeldahl method (Bremner and Mulvaney, 1982) and calculated by Brookes et al. (1985).

$$\text{Microbial N} = K_{EN} \times 1.46.$$

Microbial biomass P was determined by ammonium molybdate stannous chloride method (Sparling et al., 1985) and calculated by Brookes et al. (1982).

$$\text{Microbial P} = K_{EP} \times 2.5$$

Where K_{EC}, K_{EN} and K_{EP} are the difference between C, N and P extracted from fumigated and unfumigated soils.

Student's t-test, linear regression and ANOVA are used to statistically analyze the data.

Result

Microbial biomass C

In the protected grassland site, the soil microbial biomass C ranged from 214±3.7 µg g^{-1} soil (September) to 437.94±9µg g^{-1} soil (May) in the 0-10 cm soil depth and 60.0± 9.23µg g^{-1} soil (September) to 163.3±8.45µg g^{-1} soil (May) in 10-20cm soil depth in different months throughout the year. In the moderately grazed site, the microbial biomass C ranged from 253.0±14.5 µg g^{-1} soil (October) to 506.3±5.3 µg g^{-1} soil (May) at 0-10cm soil depth and 116.0±4.6 µg g^{-1} soil (October) to 177.6±9.83 µg g^{-1} soil (May) in 10-20cm soil depth in different moths throughout the year. In heavily grazed grassland site it ranged from 178.0±3.7µg g^{-1} soil (September) to 375.0±9.8 µg g^{-1} soil (May) at 0-10cm soil depth and 56.66±6.5µg g^{-1} soil (September) to 116.0±0 4.7 µg g^{-1} soil (May) in 10-20cm soil depth . The rate of microbial biomass was in the order of moderately>protected>heavily grazed site.

Seasonally, in protected site soil microbial biomass C was recorded to be maximum during the summer season followed by winter and rainy season at 0-10 cm soil depth . In 10-20 cm soil depth the microbial biomass C were recorded to be maximum during winter followed by summer and rainy season.

In moderately grazed grassland site, seasonally soil microbial biomass C was recorded to be maximum during the summer season followed by winter and rainy in both the soil depths . In heavily grazed grassland, seasonally the microbial biomass C at both the soil depth were recorded to be maximum during summer followed by winter and rainy season.

In protected grassland the analysis of variance indicated a significant difference in microbial biomass C between the different sampling months of rainy ($p< 0.01$) winter ($p <0.01$) and annually ($p <0.01$) at 0-10 cm and 10-20cm soil depth .

In moderately grazed grassland the analysis of variance indicated a significant differences in microbial biomass C between the different sampling months of rainy ($p <0.01$), winter ($p <0.01$) and annually ($p <0.01$) at 0-10 cm soil depth . At 10-20cm soil depth the analysis of variance indicated a significant difference in microbial biomass C between the sampling months of rainy ($p<0.01$), winter ($p <0.05$) and annually ($p <0.01$) .

In heavily grazed grassland the analysis of variance indicated a significant difference in microbial biomass C between the different sampling months of rainy ($p<0.01$), winter ($p <0.01$) and annually ($p<0.01$) at the two soil depth . In protected grasslands the microbial biomass C have significant positive co-relation with soil pH ($r=8.85$, $p<0.01$), soil organic C ($r=0.79$, $p<0.01$), soil total N ($r=0.92$, $p<0.01$) and soil available P ($r=0.88$, $p<0.01$) which explains 71, 61, 84 and 76% variability in microbial biomass C due to variability in these soil nutrients.

In moderately grazed grassland a highly significant positive co-relation was found with soil pH ($r=0.75$, $p<0.01$), soil organic C ($r=0.79$, $p<0.01$), soil total N ($r=0.93p<0.01$) and soil available P ($r=0.84$, $p<0.01$) which explains 59, 62, 86 and 71% of variability in microbial biomass C due to variability in these soil nutrients.

In heavily grazed grassland a highly significant positive correlation was recorded with soil PH ($r=0.73$, $p<0.01$) soil organic C ($r=0.68$, $p<0.05$), soil total N ($r=0.85$, $p<0.01$), and soil available P ($r=0.95$, $p<0.01$) which explains 52, 46, 71 and 90% variability in MBN due to variability in these soil nutrients.

Microbial biomass nitrogen

In protected site the microbial biomass N across the months ranged from 26.28± 0.84µg g^{-1} soil (September) to 67.64± 1. 28µg g^{-1} soil (May) at 0-10cm soil depths. In 10-20cm soil depth microbial biomass N across the months ranged from 11.68± 0.48µg g^{-1} soil (October) to17.52± 1.28µg g^{-1} soil (May) throughout the year.

In moderately grazed site the microbial biomass N across the months' ranged from 29.68±4.3µg g^{-1} soil (September) to70.08±1.68µg g^{-1} soil (May) at 0-10 cm soil depth. In 10-20 cm soil depth microbial biomass N across the months ranged from 9.63±1.38 µg g^{-1} soil (September) to 21.9± 2.23µg g^{-1} soil (May) throughout the year.

In heavily grazed grassland the microbial biomass N across the months ranged from 23.36±2.23µg g^{-1} soil (September) to 62.78±2.28µg g^{-1} soil (May) at 0-10 cm soil depth. In 10-20 cm soil depth microbial biomass N across the month ranged 5.35±0.97µg g^{-1} soil (September) to 16.06±2.29µg g^{-1} soil (May) throughout the year.

Seasonally in protected site, soil microbial biomass N at 0-10 cm soil layer were recorded to be maximum during summer (53.04±7.38μg g^{-1} soil) followed by winter (44.65±1.95μg g^{-1} soil) and rainy (35.14±3.58μg g^{-1} soil) season and contributed 38, 32 and 28% to the annual microbial biomass N respectively.

In 10-20 soil depth seasonally the microbial biomass N were recorded to be maximum during winter (14.70±1.73μg g^{-1} soil) followed by summer season (14.53±1.68μg g^{-1} soil) and rainy season (12.94±0.39μg g^{-1} soil) and contributed 34, 34 and 30% to the total annual microbial biomass N respectively.

In moderately grazed grassland site, seasonally soil microbial biomass N was recorded to be maximum during summer season (56.37±7.04μg g^{-1}) followed by winter season (47.98 ±1.8μg g^{-1} soil)and rainy season (37.37±98.09μg g^{-1} soil) contributed 39,33 and 26% to the annual microbial biomass N respectively at 0-10 cm soil depth.

In 10-20 cm soil depth seasonally the microbial biomass N were recorded to be maximum during summer season (17.19±2.35μg g^{-1} soil) followed by winter season (17.02±1.5μg g^{-1} soil) and rainy season (14.86±1.61μg g^{-1} soil) and contributed 35, 34 and 30% to the annual microbial biomass N respectively.

In heavily grazed grassland, seasonally the microbial biomass N at 0-10 cm soil depth were recorded to be maximum during summer (49.64μg g^{-1} soil) followed by winter season (38.67μg g^{-1} soil) and rainy season (31.14μg g^{-1} soil) and contributed 38, 33 and 27% to the annual microbial biomass N respectively.

In 10-20cm soil depth seasonally the microbial biomass N were recorded to be maximum during summer (13.13μgg^{-1} soil) followed by winter (12.64μg g^{-1} soil) and rainy season (10.12μg g^{-1} soil) and contributed 38, 33 and 27% to the total annual microbial biomass N respectively.

In protected grassland site the analysis of variance indicated a significant difference in microbial biomass N between the different sampling month of summer ($p<0.05$), rainy ($p<0.01$) and annually ($p<0.01$) at 0-10 cm soil depth . At 10-20 cm soil depth the analysis of variance indicated a significant difference in microbial biomass N between the different sampling months of summer ($p<0.01$), winter ($p<0.01$) and annually ($p<0.01$).

In moderately grazed grassland the analysis of variance indicated a significant difference in microbial biomass N between the different sampling months of summer ($p<0.05$), rainy ($p<0.01$) and annually ($p<0.01$) at 0-10cm soil depth .At 10-20 cm soil depth the analysis of variance indicated a significant difference in microbial biomass N between the different sampling months of rainy ($p<0.01$) winter ($p<0.01$) and annually ($p<0.01$).

In heavily grazed grassland the analysis of variance indicated a significant difference in microbial biomass N between the different months of summer ($p<0.01$), rainy ($p<0.01$), winter ($p<0.01$) and annually ($p<0.01$) at 0-10cm soil depth .At 10-20cm soil depth the analysis of variance indicated a significant difference in microbial biomass N between the different sampling months of rainy ($p<0.05$) and annually ($p<0.01$).

In protected grassland site the microbial biomass N have highly significant positive co-relation with soil pH ($r=0.80$ $p<0.01$), soil organic C ($r=0.81$, $p<0.01$), soil total N ($r=0.92$, $p<0.01$), soil available P ($r=0.95$, $p<0.01$) which explains 71, 66, 85 and 88% variability in MBN due to variability in these soil nutrients

In moderately grazed grassland a highly significant positive co-relation was found with soil pH ($r=0.68$, $p<0.05$), SOC ($r=0.82$, $p<0.01$), STN ($r=0.89$, $p<0.01$), SAP ($r=0.84$, $p<0.01$) which explains 47, 68, 80 and 89% variability in MBN due to variability in these soil nutrients.

In heavily grazed grassland a highly significant co-relation was found with soil P^H ($r=0.73$, $p<0.01$), soil organic C ($r=0.68$, $p<0.05$), soil total N ($r=0.85$, $p<0.01$) and soil available P ($r=0.95$, $p<0.01$) which explains 52, 46, 71 and 90% variability in MBN due to variability in these soil nutrients.

Microbial Biomass Phosphorous

In protected grassland site the microbial biomass P across the month range from 11.5 ± 0.36µg g^{-1} (September) to 31.25 ± 2.18µg g^{-1} (May) at 0-10cm soil depth . In 10-20 cm soil depth microbial biomass P across the months ranged from 3.91 ± 0.61µg g^{-1} soil (September) to 10.86 ± 1.11µg g^{-1} soil (May) throughout the year.

In moderately grazed site the microbial biomass P across the month range from 17.37 ±1.00 μg g^{-1} soil (September) to 33.58 ± 1.43μg g^{-1} soil (may) at 0.10cm soil depth. In 10-20 cm soil depth (4.3b) microbial biomass P across the month ranged from 5.00 ± 00 μg g^{-1} soil (September) to 12.33 ± 0.74 μg g^{-1} soil (May) throughout the year.

The microbial biomass P across the months ranged from 8.79±0.7 μg g^{-1} soil (September) to 26.0±0.97μg g^{-1} soil at 0-10cm soil depth. In10-20cm soil depth microbial biomass P across the months ranged from 2.5±0.0 μg g^{-1} soil September to 10.0±0.72μg g^{-1} soil (May) throughout the year in heavily grazed grassland site.

In protected grassland seasonally the microbial biomass P at 0-10cm soil layer were recorded to be maximum during summer (23.81μg g^{-1} soil) followed by the winter (21.08±2.1μg g^{-1} soil) and rainy (17.13±1.72μg g^{-1} soil) soil contribution 44, 33 and 24% to the total annual microbial biomass P respectively.

In 10-20 cm soil depth seasonally the microbial biomass P were recorded to be maximum during summer (8.55±17μg g^{-1} soil) followed by winter (7.28 ± 1.26μg g^{-1} soil) and rainy (5.82±8.39μg g^{-1} soil) season and contributed, 39, 33 and 26% to the total annual microbial P respectively.

Seasonally in moderately grazed grassland the microbial biomass P at 0-10cm soil layer were recorded to be maximum during summer(25.79±3μg g^{-1} soil) followed by winter (23.77±2.66μg g^{-1} soil) and rainy (19.82±1.41μg g^{-1} soil) and contributed 37, 34 and 28% to the total annual microbial biomass P respectively.

In 10-20cm soil depth seasonally the soil microbial biomass P were recorded to be maximum during (10.37±1.03μg g^{-1} soil) followed by winter (8.09± 1. 03μg g^{-1} soil) and rainy (6.98±0.82μg g^{-1}) soil and contributed 40, 31 and 27% to the total annual microbial biomass respectively. In heavily grazed grassland, seasonally the microbial biomass P at 0-10cm soil depth were recorded to be maximum during summer (19.81±3.11μg g^{-1} soil) followed by winter season (18.19±0.27μg g^{-1} soil) and rainy season (14.85±2.25μg g^{-1} soil) and contributed 37, 33 and 28% to the total annual microbial biomass P respectively.

In 10-20 cm soil depth seasonally the microbial biomass P were recorded to be maximum during summer (7.17±1.46μg g^{-1} soil), winter (6.12±1.26μg g^{-1} soil) and rainy (4.59± 0.84μg g^{-1} soil) and contributed 40, 34 and 25% to the total annual microbial biomass P respectively.

In protected grassland the analysis of variance indicated a significant difference in microbial biomass P between the different sampling months of summer ($p<0.01$), rainy ($p<0.01$) and annually ($p<0.01$) at 0-10cm soil depth . At 10-20cm soil depth the analysis of variance indicated a significant difference in microbial biomass P between the different sampling months of rainy ($p<0.01$), winter ($p<0.01$).

In moderately grazed grassland the analysis of variance indicated a significant difference in microbial biomass P between the different sampling months of summer ($p<0.01$), rainy ($p<0.01$), winter ($p<0.01$) and annually ($p<0.01$) at 0-10cm soil depth . At 10-20cm soil depth the analysis of variance indicated a significant difference in microbial biomass P between the different sampling months of summer ($p<0.05$), rainy ($p<0.01$), winter ($p<0.05$) and annually ($p<0.01$).

In heavily grazed grassland the analysis of variance indicated a significant difference in microbial biomass P between the different sampling months of summer ($p<0.05$), rainy ($p<0.01$) winter ($p<0.05$) and annually ($p<0.01$) at 0-10cm soil depth . At 10-20cm soil depth (Table 4.18) the analysis of variance indicated a significant difference in microbial biomass P between the different sampling months of summer ($p<0.01$), rainy ($p<0.01$), winter ($p<0.01$) and annually ($p<0.01$).

In protected grassland a highly significant co-relation was found with soil pH ($r=0.79$, $p<0.01$), soil organic C ($r=0.79$, $p<0.01$), soil total N ($r=0.91$, $p<0.01$) and soil available P ($r=0.90$, $p<0.01$) which explains 61, 61, 82 and 81% variability in microbial biomass P due to variability in these soil nutrients.

In moderately grazed grassland a highly significant co-relation was found with soil pH ($r=0.69$, $p< 0.05$), soil organic C ($r=0.81$, $p<0.01$), soil total N ($r=0. 87$, $p<0.01$) and soil availability P ($p<0.01$) which explains 52, 46, 71 and 90% variability in microbial P due to variability in these soil nutrients .

In heavily grazed grassland a highly significant co-relation was found with soil pH ($r=0.60$, $p<0.05$), soil organic C ($r=0.57$, $p<0.05$), soil total N ($r=0.92$, $p<0.01$) and soil available P ($r=0.85$, $p<0.01$) which explains 37, 33, 85 and 73% variability in microbial biomass P due to variability in these soil nutrients.

Microbial biomass C, N and P as proportion to soil organic C, Total N and available P in protected, moderately and heavily grazed sites.

The soil microbial biomass C represents 1.76 to 2.01% as total soil organic carbon across the season at 0-10cm soil depth, from 1.34 to 1.51% at 10-20cm soil depth. The soil microbial biomass N represent 2.8 to 2.78 as total soil nitrogen across the season at 0-10cm soil depth, from 1.71 to 1.39% at 10-20cm soil depth whereas percent of soil microbial P to soil available P across the season represent 10.25% to 13.1% at 0-10 cm soil depth, from 6.23% to 8.11% at 10-20cm soil depth . The proportion of microbial C, N and P to total soil organic carbon, nitrogen and phosphorous decreased appreciably with the increase of the soil depth across the seasons . The proportion of microbial C,N and P to soil organic Carbon, nitrogen and phosphorous exhibited maximum in summer season followed by winter and rainy.

In protected site the proportion of microbial C to organic C ranges from 1.76 to 2.01% at 0-10 cm soil depth and from 1.34 to 1.51% at 10-20 cm soil depth across the season. The proportion of soil microbial N to total n ranges from 2.8 to 2.78% at 0-10 cm soil depth, from 1.71 to 1.39% at 10-20 cm soil depth whereas percent of soil microbial P to soil available P across the season ranges 10.25% to 13.1% at 0-10 cm soil depth from 6.23% to 8.11% at 10-20 cm soil depth. The proportion of microbial C, N and P to soil organic carbon, nitrogen and phosphorous exhibited minimum in summer season followed by winter and rainy season.

In moderately grazed grassland the soil microbial biomass C contributed 1.8 to 1.9% of total soil organic C across the season at 0-10 cm soil depth, from 1.41 to 1.86% at 10-20 cm soil depth. The soil microbial biomass N contributed 2.58 to 2.86% of total soil nitrogen across the season at 0-10 cm soil depth and from 1.39 to 1.92% at 10-20 cm soil depth whereas percent of soil microbial P to soil available P across the season ranges from 11.65 to 13.55% at 0-10 cm soil depth and from 6.28 to 8.67% at 10-20 cm soil depth. The proportion of microbial n and p to soil total n and available P exhibited maximum in summer season followed by winter and rainy whereas the proportion of microbial C to organic C exhibited maximum in summer followed by rainy and winter.

In heavily grazed grassland the proportion of microbial C to organic C ranges from 1.85 to 2.1% at 0-10 cm soil depth, from 1.18 to 1.31% of 101-20 cm soil depth. The soil microbial N to total N ranges from 2.85 to 3.14% at 0-10 cm soil depth and from 1.5 to 2.2% at 10-20 cm soil depth whereas the proportion of soil microbial P to available P ranges from 9.39 to 11.09% at 0-10 cm soil depth and from 5.45 to 8.38% of 10-20 cm soil depth. The proportion of microbial C and N to soil organic C and soil total N exhibited maximum in summer season followed by winter and rainy whereas the proportion of microbial P to available P exhibited maximum in winter followed by summer and rainy.

The proportion of microbial C, N and P to total soil organic C, N and P decreased appreciably with the increase of the soil depth across the season.

Ratio of soil microbial biomass C, N P in different study sites.

The nutrient ratio of microbial biomass C, N and P of different seasons and soil strata moderately grazed site are set in . The mean C:N, C:P and N:P ratio of microbial biomass across the soil depth were recorded maximum in rainy, winter and winter respectively. The mean C:N, C:P and N:P ratio of microbial biomass across the soil depth were recorded minimum in summer, rainy and summer respectively.

The nutrient ratio of microbial biomass C,N and P at different seasons and soil strata of heavily grazed site are set in.The mean C:N, C:P and N:P ratio of microbial biomass across the soil depth were recorded maximum in rainy season and recorded minimum in summer, summer and rainy season respectively.

Discussion

Soil microbial biomass C, N, P was found to be maximum in moderately grazed grassland followed by protected and heavily grazed study site. Low value of microbial biomass in heavily grazed site may be due to lower rate of supply of organic matter and other nutrients due to grazing. Patches of bare soil due to heavy grazing resulted loss of soil organic matter through wind erosion (Hoffman et al., 2008, Schneidera, et al., 2008) and this changed the plant community (Tong et al., 2011), which decreases the microbial biomass (Holt, 1997).

CONCLUSION

Grazing by cattle at low intensities can create a favorable environment for sustaining biodiversity due to moderate grazing. The findings reveal that the maximum value of soil microbial biomass C, N and P increased in moderately grazed site followed by protected site and heavily grazed sites. Thus it indicates that moderate grazing improved the physiochemical characteristics and the soil microbial biomass in the present grassland. Soil microbial biomass is influenced by organic C, total N and P in the grassland soil as evident by significant relation with organic C, total N and P. The paper thus concluded that one of the most compelling, long-term strategies for dealing with the structural causes of our many ecological crises is to create and recognize legitimately, alternative systems of management and governance. Grazing management and governance is also one of the ground upon which theory meets practice and where, in turn, practice is informed by, and evolves, theory. Inevitably, if we are to develop sustainability, we must re-imagine, and re-invent, these measures. Is there a choice? Grazing governance is an imperative for the 21st century.

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