CHAPTER VII

NUTRIENT CYCLING AND INFLUENCE BY GRAZING

7.1 INTRODUCTION

Life on the earth is dependent upon the cycle of elements in the biosphere (Bormann & Likens 1967). All the tissues of the plants are made up of complex organic compounds, which are synthesized by the uptake of minerals from soil. These organic compounds return to soil after the death of the plant and form the humus; further breakdown of humus mineralises them into ionic and molecular forms. It becomes available for next plants coming up (Rodin & Bezilevich 1967).

Nutrient requirement is generally viewed as the nutrient quantity annually incorporated into biomass production (Switzer & Nelson 1972; Grier & Ballard 1981; Cole & Rapp 1982). These nutrients recycle again and again endlessly shuttling from organic to inorganic compounds from trophic level to trophic level and plant to animal to soil to water. The pattern of biological circulation of nutrient differs from biome to biome through polar to tropical latitudes (Rodin & Bezilevich 1967). Life requires a constant cycling of nitrogen, oxygen and water. These cycles include a gaseous phase and have self regulating feedback mechanism that make them relatively perfect (Odum 1971), whereas the elements with sedimentary cycles (i.e. phosphorus, potassium, calcium, magnesium) show a continuous loss from biological system in response to erosion with ultimate deposition in sea. Therefore, these sedimentary cycles are less perfect and more easily disrupted by man than carbon and nitrogen cycle (Odum 1971). However, these elements are not less important to life (Bormann & Liken 1967).

Odum (1971) considered the circulation of mineral material and unidirectional flow of energy as two great and equally important laws of ecology. In an ecosystem the mineral cycling through various components can be considered as good indicator of continuity and stability of the living system and thus is believed to be a useful strategy for ecosystem analysis (Pomeroy 1970). Uptake of nutrients might be one way of calculating the photosynthetic rate and hence primary productivity. Nutrient uptake is a quantity of a given nutrient obtained from soil during the year (Ovington 1962; Cole *et al.* 1970; Duviyneard & Denaeyer–De Smet 1970).

Research on grazing lands has historically focused on the effects of various management practices on forage production and animal response; little attention has been given to the impact of grazing on the nutrient dynamics of soil (Manley *et al.* 1995). Soil health has become a major research target for rangeland management strategies in the recent years. Milchunas and Lauenroth (1993) considered the impact of grazing on rangeland as; species composition a fast, annual net primary productivity an intermediate, and soil nutrient pool a slow response variable. Soil nutrient dynamics will largely depend on the intensity, grazing history and types of grazing livestock, temporal cycle and edaphic factors. Ruess and McNaughton (1987) suggested that grazing accelerates the rate of nutrient cycling by stimulating primary production and net nutrient flux, thereby increasing the percentage of system's nutrients that are available and which are rapidly near the soil surface. Nutrient present in the soil will be available for the plants to utilise in response to its requirement and influence by surrounding biotic and abiotic factors that forms an interdependent linkage called as nutrient cycling. The nutrient pool in the soil and vice versa will influence the plant health. Livestock can be a major vector of nutrient removal from rangelands through volatilisation of nitrogen, export of milk and urine to other land types (Powel *et al.* 1995). Thus, cycling of biomass through livestock and the use of manure and urine to fertilise the soil will be important linkage between livestock and soil productivity. As grasslands form an important source of forage for animals, it is very essential to study soil and plant nutrient status as influenced by grazing. This chapter reports on nutrient cycling through plant-herbivore-soil interactions.

7.2 METHODS

Biomass samples of plant species were collected from the field and milled into powder for analysis. The details of procedure have been given in chapter VI.

Procedure of element estimation

The detail procedure for the estimation of nitrogen and phosphorus for plant samples has been given in chapter IV.

Standing state of nutrient in plant and soil

The standing state for vegetation refers to the quantity of individual nutrient (i.e. Nitrogen and Phosphorus) in annual biomass of plant compartments (shoot, root and litter). The value is achieved by multiplying standing state of biomass with corresponding nutrient value.

Nutrient budget

The standing state of nutrient is not as informative as the annual transfer rates between compartments because they are only approximate measure of the storage capacity of the compartments. The method used by Billore and Mall (1976) was followed to estimate net input and output for nutrients. Net uptake for each element was calculated by summing the positive increase in aboveground biomass of positive increment in belowground biomass during temporal cycle. Output of net uptake to standing dead was calculated by summing positive increment in aboveground biomass. The input in litter compartment from standing dead was computed by summing initial standing dead crop biomass + (increment in standing dead – final standing dead).

Output of net uptake to standing belowground was calculated by difference i.e. net uptake – (net uptake to standing dead + net uptake to litter). The decomposition of litter was computed by summing of initial standing crop of litter + (increment in litter compartment – final standing crop of litter), whereas the loss from underground compartment was calculated by multiplying the particular nutrient equivalent with dry matter loss from the underground. The total loss was computed by adding loss from litter + loss from underground. It was considered as release. The difference between uptake and release was taken as retention.

Chemical analysis of soil samples and livestock faecal matters

The soil samples were collected from the study sites for two different depths (0-15 cm and 15-30 cm) and packed inside polythene bags and brought to laboratory. These samples were air-dried and sieved to pass through 2-mm sieve before digestion for nitrogen, phosphorus and organic carbon estimation.

Analysis of total nitrogen in soil was done through modified Kjeldahl method as given by Anderson & Ingram (1993). It was obtained by digesting the samples in the presence of sulphuric acid and catalyst (copper sulfate, mercuric oxide, selenium powder and potassium sulfate). The nitrogen is converted into ammonium sulfate and can be determined after distillation in alkaline condition. The amount of total nitrogen was calculated by the following formula:

$$N(\%) = \frac{A \times \text{solution volume (ml)}}{10 \times \text{aliquot volume (ml)} \times w}$$

Where, A = ml of HCl used for titration, w = sample weight (g)

Total phosphorus of soil samples was extracted using acidified ammonium fluoride after oxidation employing 30% H_2O_2 and then estimated by chlorostannous reduced molybdophosphoric blue colour method in the HCl system (Jackson 1967). Per cent phosphorus was calculated using the following formula:

$$P(\%) = \frac{C \times \text{solution volume (ml)}}{10 \times \text{aliquot volume (ml)} \times w}$$

Where, C = concentration (mg), w = sample weight (g)

Organic carbon of the soil sample was estimated after partial oxidation with an acidified dichromate solution, which is modified

Walkey-Black Method (Anderson & Ingram 1993). The amount of organic carbon was computed in per cent by the formula;

$$C\,(\%) = \frac{(k \times 0.1)}{w \times 74}$$

Where, k = concentration (mg), w = sample weight (g)

7.3 RESULTS

7.3.1 Plant Nutrient Concentration

Aboveground plant parts

The nutrient concentration for some important species in temperate and alpine/subalpine grasslands are presented in Table 7.1. Generally, aboveground biomass of temperate plants recorded higher concentration of nitrogen than the alpine and subalpine species. Plants in exclosure plots have higher concentration of nitrogen than grazed plots in all the study sites. Nitrogen concentration ranged from 1.48 to 3.41% among temperate species whereas it ranged from 1.01 to 1.87% among alpine and subalpine species. Analysis of variance showed significant (P<0.0001) difference of nitrogen concentration among the different species. Grazing significantly (P<0.01) reduced nitrogen concentration of plants (Table 7.1). Composite plant sample analysis showed that nitrogen concentration of aboveground biomass increased with the advancement of growing season and peaked during August and then declined towards the end of season in all the study sites except at Deorali where it peaked during June (P<0.01). Grazing significantly reduced nitrogen concentration of plants (P<0.05). Nitrogen concentration ranged from

1.71 to 2.71% at Yuksam, 1.62 to 2.95% at Sachen, 0.91 to 1.22% at Deorali and from 0.92 to 1.42% at Dzongri. Analysis of variance showed significant (P<0.0001) difference in nitrogen concentration across the study sites (Table 7.2).

Similarly, phosphorus concentration was also higher in plants from exclosure plots as compared to grazed plots. Phosphorus concentration of plants ranged from 0.171 to 0.339% among temperate species while it ranged from 0.163 to 0.377% among alpine and subalpine species. Analysis of variance showed that phosphorus concentration among the species differed significantly (P<0.0001). Grazing showed no significant difference in phosphorus concentration of plants and their interaction was also not significant (Table 7.1).

Composite sample analysis showed that phosphorus content of shoot biomass was not significant across the study sites. It increased with the advancement of growing season and peaked during June-August and then declined by the end of growing season (P<0.01). Grazing showed no significant difference in phosphorus concentration of plants. Phosphorus concentration ranged from 0.163 to 0.247% at Yuksam, 0.168 to 0.233% at Sachen, 0.117 to 0.216% at Deorali and from 0.113 to 0.222% at Dzongri (Table 7.2).

Belowground plant parts

Nitrogen concentration of belowground parts of plants differed significantly (P<0.01) across the study sites. Nitrogen concentration increased with the advancement of growing season and peaked during July-August and then declined towards the end of growing season

($P<0.0001$). Grazing has increased nitrogen concentration of belowground plant parts significantly ($P<0.01$). Analysis of variance showed that site and grazing treatment interactions were significant ($P<0.05$) with least standard deviation value of 0.138. The value of nitrogen concentration ranged from 0.71 to 0.87% at Yuksam, 0.63 to 1.16% at Sachen, 0.74 to 1.38% at Deorali and from 0.63 to 1.50% at alpine Dzongri (Table 7.3).

Phosphorus concentration of belowground plant parts differed significantly across the study sites ($P<0.0001$). It increased with the advancement of growing season and peaked during July-August and then declined towards the end of the season ($P<0.01$). Grazing showed no significant change in phosphorus concentration in belowground parts of plants. Phosphorus concentration ranged from 0.122 to 0.152% at Yuksam, 0.103 to 0.168% at Sachen, 0.108 to 0.160% at Deorali and from 0.117 to 0.238% at Dzongri (Table 7.3).

Litter mass

Nitrogen concentration of litter mass differed significantly across the study sites ($P<0.01$). It increased with the advancement of growing season and peaked during August and then declined towards the end of the growing season ($P<0.0001$). Grazing showed no significant difference in nitrogen concentration in litter mass. Nitrogen concentration ranged from 0.78 to 1.32% at Yuksam, 0.88 to 1.24% at Sachen, 0.97 to 1.42% at Deorali and 0.94 to 1.68% at Dzongri (Table 7.4).

Phosphorus concentration of litter mass did not differ significantly among study sites. It increased with the advancement of growing season and peaked during June-August and then declined towards the end of the growing season ($P<0.05$). Grazing showed no significant effect on phosphorus concentration in litter mass. Phosphorus concentration of litter mass samples ranged from 0.216 to 0.338% at Yuksam, 0.213 to 0.317% at Sachen, 0.231 to 0.331% at Deorali and from 0.214 to 0.314% at Dzongri (Table 7.4).

7.3.2 Standing State of Nutrient of Plants

Nitrogen

Standing state of nitrogen of aboveground plant parts increased with growing season and peaked during August and then declined towards the end of season in both grazed and exclosure plots in all the study sites. At Yuksam grazing reduced nitrogen content of pasture (per unit area basis) by around 40%. It's content ranged from 3.69 to 6.81 g m^{-2} in grazed plots and 5.05 to 17.37 g m^{-2} in exclosure plots (Table 7.5). At Sachen, standing nitrogen content in exclosure plots was more than by 30%. Nitrogen content ranged from 3.29 to 11.22 g m^{-2} in grazed and 5.1 to 20.44 g m^{-2} in exclosure plots. At Deorali, nitrogen content was more in exclosure plots than grazed plots by more than 35%. Nitrogen content ranged from 1.44 to 3.73 g m^{-2} in grazed plots and 2.03 to 6.81 g m^{-2} in exclosure plots. At Dzongri, it was more by 30% in exclosure plots than grazed plots. It ranged from 1.48 to 3.72 g m^{-2} in grazed plots and 2.43 to 7.65 g m^{-2} in exclosure plots (Table 7.5).

Standing state of nitrogen of belowground parts increased with growing season, peaked during August and then declined towards the end of the growing season in both grazed and exclosure plots at all the study sites (Table 7.5). At Yuksam, grazing reduced nitrogen content of belowground plant parts by more than 30%. It ranged from 2.55 to 4.18 g m^{-2} in grazed plots and 3.38 to 4.29 g m^{-2} in exclosure plots. At Sachen, grazing reduced nitrogen content of belowground plant parts by more than 10%. Nitrogen content ranged from 1.96 to 5.40 g m^{-2} in grazed plots and 3.38 to 5.48 g m^{-2} in exclosure plots. At Deorali, grazing increased nitrogen content of belowground parts by more than 25% except during October. Nitrogen content ranged from 10.32 to 12.07 g m^{-2} in grazed plots and 8.49 to 10.48 g m^{-2} in exclosure plots. At Dzongri, grazing increased nitrogen content of belowground parts by more than 30%. Nitrogen content ranged from 10.16 to 13.91 g m^{-2} in grazed plots and 5.25 to 7.35 g m^{-2} in exclosure plots (Table 7.5).

Standing state of nitrogen in litter increased with growing season and peaked during August and then declined towards the end of the growing season in Yuksam but reverse trend was observed at Sachen, Deorali and Dzongri. Grazing reduced nitrogen content of litter by more than 40% at Yuksam and the value ranged from 0.38 to 0.52 g m^{-2} in grazed plots and 0.79 to 1.03 g m^{-2} in excosure plots. At Sachen, grazing reduced nitrogen content by more than 25%. It ranged from 0.52 to 1.00 g m^{-2} in grazed plots and 0.87 to 1.44 g m^{-2} in exclosure plots. At Dzongri, grazing reduced its content by more than 50%. It ranged from 0.12 to 0.33 g m^{-2} in grazed plots and 0.34 to 1.04 g m^{-2} in exclosure plots (Table 7.5).

Phosphorus

Standing state of phosphorus of aboveground parts increased with growing season peaked during August and declined towards the end of season at all the study sites (Table 7.6). At Yuksam grazing reduced phosphorus content (per unit area basis) by around 40%. Phosphorus content of shoot ranged from 0.352 to 0.778 g m^{-2} in grazed plots and 0.512 to 1.012 g m^{-2} in exclosure plots. At Sachen, standing phosphorus content of shoot in exclosure plots was more by 30%. Phosphorus content ranged from 0.341 to 1.039 g m^{-2} in grazed and 0.51 to 1.60 g m^{-2} in exclosure plots. At Deorali, grazing reduced phosphorus content by 25%. Phosphorus content ranged from 0.215 to 0.743 g m^{-2} in grazed plots and 0.350 to 1.197 g m^{-2} in exclosure plots. At Dzongri, grazing reduced phosphorus content by 30%. Phosphorus content ranged from 0.182 to 0.598 g m^{-2} in grazed plots and 0.320 to 1.197 g m^{-2} in exclosure plots.

Standing state of phosphorus in belowground parts increased with growing season, peaked during August and then declined towards the end of the growing season in both grazed and exclosure plots at Yuksam, Sachen and Deorali but at Dzongri it declined starting from April until the end of growing season. At Yuksam, grazing reduced phosphorus content of belowground plant parts by 30%. Phosphorus content of root ranged from 0.419 to 0.702 g m^{-2} in grazed plots and 0.565 to 0.815 g m^{-2} in exclosure plots. At Sachen, grazing reduced phosphorus content of root by 10%. Phosphorus content ranged from 0.393 to 0.878 g m^{-2} in the grazed plots and 0.542 to 0.982 g m^{-2} in the exclosure plots. At Deorali, grazing increased phosphorus content of belowground parts by 25% except during October. It ranged from 1.198 to 1.357 g m^{-2} in grazed plots and 1.089 to 1.225 g m^{-2} in exclosure plots. At Dzongri, grazing increased phosphorus content of belowground parts by 30%. Phosphorus content ranged from 1.162 to 2.762 g m^{-2} in grazed plots and 1.218 to 2.218 g m^{-2} in exclosure plots (Table 7.6).

At Yuksam, grazing reduced standing state of phosphorus in litter by 40% and the values ranged from 0.085 to 0.110 g m^{-2} in grazed plots and 0.207 to 0.300 g m^{-2} in exclosure plots (Table 7.6). At Sachen, grazing reduced phosphorus content of litter by 25%. It ranged from 0.19 to 0.27 g m^{-2} in grazed plots and 0.23 to 0.31 g m^{-2} in exclosure plots. At Deorali, grazing reduced phosphorus content in litter by 75%. It ranged from 0.02 to 0.09 g m^{-2} in grazed plots and 0.05 to 0.22 g m^{-2} in exclosure plots. At Dzongri, grazing reduced phosphorus content by 50%. It ranged from 0.017 to 0.029 g m^{-2} in grazed plots and 0.059 to 0.200 g m^{-2} in exclosure plots (Table 7.6).

7.3.3 Nutrient Status of Soil

Total nitrogen

Grazing significantly increased nitrogen concentration of soil ($P<0.0001$). Nitrogen concentration differed significantly among the different study sites ($P<0.0001$). Upper (0-15 cm) soil depths showed higher nitrogen concentration compared to lower (15-30 cm) depth, and differed significantly between depths ($P<0.0001$). Nitrogen concentration did not differ significantly between 1998 and 1999. It ranged from 0.33 to

0.88% at Yuksam, 0.407-0.547% at Sachen, 0.490-0.551% at Deorali and 0.310-0.477% at Dzongri. It's content ranged from 292 to 432 g m^{-2} at Yuksam, 428-586 g m^{-2} at Sachen, 519-561 g m^{-2} at Deorali and 463-575 g m^{-2} at Dzongri (Table 7.7).

Total phosphorus

Grazing has no significant effect on phosphorus concentration of soil. Phosphorus concentration significantly differed with soil depth but did not vary among the study sites. Analysis of variance showed no significant interaction on phosphorus concentration between site, treatment, soil depth and year. Phosphorus concentration of soil ranged from 0.019-0.031% at Yuksam, 0.013-0.028% at Sachen, 0.018-0.036% at Deorali and 0.007-0.029% at Dzongri. It's contents ranged from 16.46-26.90 g m^{-2} at Yuksam, 13.67-29.95 g m^{-2} at Sachen, 19.10-38.14 g m^{-2} at Deorali and from 10.47-35.87 g m^{-2} at Dzongri (Table 7.9).

Organic carbon

Grazing significantly reduced organic carbon concentration of soil (P<0.0001). It significantly got lowered with soil depth (P<0.0001) and also varied with sites (P<0.0001). There was no significant difference between 1998 and 1999. Analysis of variance showed that interactions between sites, treatment, depth and year were significant (P<0.0001) with least standard deviation value of 0.117. Organic carbon concentration of soil ranged from 3.46-5.61% at Yuksam, 3.73-5.23% at Sachen, 4.24-5.86% at Deorali and from 3.66 to 4.66% at Dzongri. It's content ranged from 3058-4866 g m^{-2} at Yuksam, 3921-5599 g m^{-2} at Sachen, 4494-5990 g m^{-2} at Deorali and 4965-6961 g m^{-2} at Dzongri (Table 7.10).

Carbon:Nitrogen ratio

Carbon:Nitrogen ratio ranged from 11.50-12.69 (grazed) and 9.79-11.48 (exclosure) at Yuksam, 8.98-0.23 (grazed) and 8.29-11.56 (exclosure) at Sachen, and 8.64-10.64 (grazed) and 10.68-10.93 (exclosure) at Deorali, and 9.69 to 15.03 (grazed) and 9.08 to 10.63 (exclosure) at Dzongri.

Nitrogen:Phosphorus ratio

Nitrogen:Phosphorus ratio ranged from 14.86-21.74 (grazed) and 12.69-21.05 (exclosure) at Yuksam, 18.22-29.44 (grazed) and 18.5-35.69 (exclosure) at Sachen, 13.64 to 18.37 (grazed) and 23.43-28.39 (exclosure) and from at Deorali, and 12.92-21.37 (grazed) and 33.17-51.57 (exclosure) at Dzongri (Table 7.10).

7.3.4 Chemical Composition of Faecal Matters

Nitrogen, phosphorus and organic carbon concentration of faecal materials of yak, dzo, cow, horse and sheep has been estimated (Table 7.11).

Nitrogen

Nitrogen concentration was highest in dzo followed by yak, cow, sheep and least in horse. It differed significantly among them ($P<0.0001$) with least standard deviation value of 0.14. Nitrogen concentration among the different livestock faecal matter ranged from 1.41 to 1.89%.

Phosphorus

Phosphorus concentration was highest in cow followed by dzo, yak, sheep and least in horse. It differed significantly ($P<0.0001$) between animal type faecal matter with least standard deviation value of 0.078. The value ranged from 0.20 to 0.50%.

Organic carbon

Organic carbon concentration was highest in horse followed by cow, sheep, yak and least in dzo. It differed significantly ($P<0.05$) between animal type faecal matters with least standard deviation value of 0.668. Organic carbon concentration among livestock ranged from 6.72 to 8.35%.

7.3.5 Nutrient Cycling

Total nitrogen uptake by plants was 4.60 g m^{-2} yr^{-1} in the grazed and 13.47 g m^{-2} yr^{-1} in the exclosure plots at Yuksam, 11.68 g m^{-2} yr^{-1} (grazed) and 17.55 g m^{-2} yr^{-1} (exclosure) at Sachen, 3.73 g m^{-2} yr^{-1} (grazed) and 7.26 g m^{-2} yr^{-1} (exclosure) at Deorali, and 6.20 g m^{-2} yr^{-1} (grazed) and 7.53 g m^{-2} yr^{-1} (exclosure) at Dzongri (Table 7.12). Total nitrogen released from litter and root were 1.22 g m^{-2} yr^{-1} (grazed) and 1.00 g m^{-2} yr^{-1} (grazed) at Yuksam, 2.79 g m^{-2} yr^{-1} (grazed) and 1.96 g m^{-2} yr^{-1} (exclosure) at Sachen, 1.50 g m^{-2} yr^{-1} (grazed) & 1.88 g m^{-2} yr^{-1} (exclosure) at Deorali, and 3.49 g m^{-2} yr^{-1} (grazed) and 2.28 g m^{-2} yr^{-1} (exclosure) at Dzongri. Nitrogen removed by grazing was recorded as

9.42 g m^{-2} yr^{-1} at Yuksam, 7.41 g m^{-2} yr^{-1} at Sachen, 2.81 g m^{-2} yr^{-1} at Deorali and 3.16 g m^{-2} yr^{-1} at Dzongri (Table 7.12).

Phosphorus uptake by plants was 0.684 g m^{-2} yr^{-1} in grazed and 1.405 g m^{-2} yr^{-1} in exclosure plots at Yuksam, 1.243 g m^{-2} yr^{-1} (grazed) and 1.530 g m^{-2} yr^{-1} (exclosure) at Sachen, 0.547 g m^{-2} yr^{-1} (grazed) and 1.103 g m^{-2} yr^{-1} (exclosure) at Deorali, and 0.990 g m^{-2} yr^{-1} (grazed) and 1.255 g m^{-2} yr^{-1} (exclosure) at Dzongri (Table 7.13). Total phosphorus released from litter and root were 0.191 g m^{-2} yr^{-1} (grazed) and 0.240 g m^{-2} yr^{-1} (grazed) at Yuksam, 0.536 g m^{-2} yr^{-1} (grazed) and 0.517 g m^{-2} yr^{-1} (exclosure) at Sachen, 0.089 g m^{-2} yr^{-1} (grazed) and 0.257 g m^{-2} yr^{-1} (exclosure) at Deorali, and 0.552 g m^{-2} yr^{-1} (grazed) and 0.444 g m^{-2} yr^{-1} (exclosure) at Dzongri. Phosphorus removed by grazing was recorded as 0.695 g m^{-2} yr^{-1} at Yuksam, 0.392 g m^{-2} yr^{-1} at Sachen, 0.397 g m^{-2} yr^{-1} at Deorali and 0.454 g m^{-2} yr^{-1} at Dzongri (Table 7.13).

Out of the total uptake of nitrogen, 73.07% was retained while 26.93% released in the grazed condition and 92.44% retained while 7.56% released in the exclosure plot at Yuksam; 75.46% retained while 24.54% released in the grazed and 88.76% retained while 11.24% released in the exclosure plot at Sachen; 59.67% retained while 40.33% released in the grazed and 72.23% retained while 27.77% released in the exclosure plot at Deorali, and 41.74% retained while 58.26% released in the grazed and 67.93% retained while 32.07% released in the exclosure plot at Dzongri (Table 7.14).

Out of the total uptake of phosphorus, 71.17% was retained while 28.83% released in the grazed condition and 81.71% retained while 18.29% released in the exclosure plot at Yuksam; 54.69% retained while 45.31% released in the grazed and 65.30% retained while 34.70% released in the exclosure plot at Sachen; 84.58% retained while 15.42% released in the grazed and 73.86% retained while 26.14% in the exclosure plot at Deorali, and 43.56% retained while 56.44% released in the grazed and 61.09% retained while 38.91% released in the exclosure plot at Dzongri (Table 7.14).

7.4 DISCUSSION

In the present investigation two important elements (nitrogen and phosphorus) for plants and three elements (nitrogen, phosphorus and organic carbon) for soil and livestock faecal matters were analysed under exclosure and grazed treatment plots. Plants uptake these nutrients from soil and are allocated into three main compartments (i.e. aboveground, belowground and litter) for the production of organic compounds with their incorporation into biomass (Kramer & Kozlowaski 1960). These elements were more in aboveground and belowground biomass and decreased as the plant material moved to litter stage; might be due to weathering or leaching of the respective elements by rain interception or by back translocation before moving into dead stage (Billore & Mall 1976). These differences can be contributed to relative requirements of individual elements in the metabolic process and to availability of the nutrients in the ecosystem (Billore & Mall 1976). Maximum percentage values of nitrogen and phosphorus was recorded during peak growing season and then declined towards the end of the growing season; this might be due to the arrest of elements by unfavourable surrounding climate as temperature declined and rainfall reduced in the subsequent months. The annual leaf fall and subsequent conversion to litter mass followed by decomposition brings back the nutrients to the soil. Some amount of nutrients also returned back to soil through urine and faecal matters as showed by the chemical analysis of the present study where nitrogen concentration ranged from 1.41 to 1.89%, phosphorous concentration 0.20 to 0.50% and organic carbon ranged from 6.72 to 8.35% among the livestock.

Grazing modifies nitrogen budgets in grassland (Hobbs *et al.* 1991). Higher concentration of nitrogen and phosphorus in the aboveground biomass in the exclosure plots might be due to healthy growth of plants and active metabolism which accumulates higher nutrients as compared to the plants which are injured due to grazing removal and less photosynthetic areas. The results of the present study are in accordance to Gupta (1985, 1986), Sundriyal (1986) but contrary to Pandey and Simba (1986) who found that nitrogen and phosphorus increased on grazed grassland than protected grasslands.

In the present study, standing states (aboveground + belowground) of nitrogen was more in forested pastures as compared to alpine and subalpine pastures in exclosure plots whereas a reverse trend was observed in grazed plots. Grazing reduced total standing state of nitrogen in forested pastures and subalpine but contrary to it, higher value was recorded in alpine pasture. This can be explained by higher contribution from the belowground parts in alpine pastures. Higher accumulation of nitrogen in the belowground biomass in alpine pasture in mainly attributed to short growing season and storage in belowground part during winter. In the present study, standing nitrogen ranged between 147-259 kg ha^{-1} in exclosure and 110-176 kg ha^{-1} in grazed pastures at different sites which is comparatively higher than the Central Himalayan report of 117 kg ha^{-1} (Billore & Mall 1976) and 116 kg ha^{-1} (Sundriyal 1986). Contrary to nitrogen, phosphorus was more in alpine pastures. Exclosure plots always had higher standing phosphorus compared to grazed plots. Standing state of phosphorus ranged from 24.0-30.4 kg ha^{-1} in exclosure and 14.8-26.9 kg ha^{-1} in grazed pastures. These values are well comparable with the standing state of phosphorus as reported to be 22 kg ha^{-1} in the Central Himalaya (Sundriyal 1986) and 32 kg ha^{-1} in the Central Indian grasslands (Billore & Mall 1976).

Bauer *et al.* (1987) found that grazing reduced soil organic carbon and increased soil nitrogen. Some researchers reported increases in both soil organic carbon and nitrogen (Dormaar *et al.* 1990; Dormar & William 1990; Ruess & McNaughton 1987) while other studies have found no response in soil organic carbon and nitrogen to grazing (Milchunas & Lauenroth 1993; Kieft 1994; Mathews *et al.* 1994). Soil had higher amount of carbon and nitrogen in the surface 30 cm of the grazed pastures as compared to native rangeland where livestock were excluded, however, soil carbon and nitrogen below 30 cm was similar among all the grazing treatments (Manley *et al.* 1995). This might be due to the faecal matters of grazing animals in the open-grazed pastures.

Contrary to it soil organic carbon and nitrogen losses with grazing (Holland *et al.* 1992) because of increase in allocation of carbon and nitrogen to regrowing leaves and a decrease in allocation of carbon to root (Detling *et al.* 1979) resulting in root biomass (Dormaar *et al.* 1990; Johnston 1961) and reduced root exudate contributes to soil organic matter (Manley *et al.* 1995). In the present study open pastures have higher percentage of nitrogen and carbon than the exclosure plots. This might be due to the faecal matters of livestock (faecal matters have 1.4 to 1.88% nitrogen and 7.0-8.3% carbon). In the open-grazed pastures, due to trampling by grazing animals the litter might have mixed to the soil resulting into quicker decomposition, which enriched soil organic carbon. Responsible grazing enhances the overall soil quality (Manley *et al.* 1995).

Nutrient uptake, retention and release in the present study are comparable with the reports from other parts of the Himalaya and tropical grasslands (Table 7.15). In the present study, nitrogen and phosphorus uptake was more efficient at Sachen as compared to other sites where as at Yuksam and Deorali (high grazing intensity) uptake was least. This clearly indicates that grazing intensity influence nutrient uptake. Nutrient retention was higher at Sachen, where most of the plants are ferns having greater root proportions. Nutrient release was highest at Dzongri alpine pasture mainly attributed to short growing period, short life cycle of annuals and death of aboveground parts within six months.

Livestock graze a considerable volume of biomass and in the process nutrients are also removed. However, these nutrients are again returned back to pastures through faecal matters. Nitrogen and phosphorus return to soil through faecal matters by cow, yak and dzo were considerably higher than those of horse and sheep. In most of the rangeland management consideration of nutrient return through livestock faecal matters has been neglected. There is a major impact and contribution to soil fertility from cycling back of nutrients through consumption of biomass and release through faecal matter. More emphasis should be given in considering this aspect in pasture management. The plant community types, species composition and structure, and their response to various climatic conditions are important features that regulate nutrient cycling. Therefore, more comprehensive studies that lead to understanding of nutrient cycling for livestock and pasture management in a gradient of ecological conditions as observed in Khangchendzonga Biosphere Reserve would be helpful and essential ■

Table 7.1 Nutrient concentration of aboveground biomass of some dominant plant species of grazed and exclosure plots at four elevation study sites along the Yuksam-Dzongri trail in Khangchendzonga Biosphere Reserve.

Ecological sites/species	Treatment	Nutrient concentration (%)	
		Nitrogen	Phosphorus
Temperate			
Elatostema sessile	Grazed	2.74	0.193
	Exclosure	2.76	0.221
Viola sp.	Grazed	2.98	0.298
	Exclosure	3.34	0.309
Eupatorium cannabinum	Grazed	2.51	0.227
	Exclosure	2.45	0.211
Impatiens sp.	Grazed	2.74	0.200
	Exclosure	2.93	0.201
Hydrocotyle javanica	Grazed	3.21	0.243
	Exclosure	3.41	0.292
Pilea scripta	Grazed	1.48	0.171
	Exclosure	2.09	0.200
Diplazium umbrosum	Grazed	3.11	0.303
	Exclosure	3.25	0.339
Brachiaria sp.	Grazed	2.91	0.191
	Exclosure	3.01	0.203
Silaginella sp.	Grazed	2.61	0.197
	Exclosure	2.63	0.224
Hedychium ellipticum	Grazed	2.16	0.217
	Exclosure	2.92	0.229
Composite sample	Grazed	2.61	0.222
	Exclosure	2.83	0.239
Alpine/subalpine			
Poa sp. I	Grazed	1.02	0.165

	Exclosure	1.12	0.209
Poa sp. II	Grazed	1.63	0.227
	Exclosure	1.87	0.234
Poa sp. III	Grazed	1.29	0.316
	Exclosure	1.32	0.377
Potentilla peduncularis	Grazed	1.03	0.210
	Exclosure	1.32	0.209
Aletris pauciflora	Grazed	1.03	0.163
	Exclosure	1.06	0.185
Bistorta affinis	Grazed	1.04	0.200
	Exclosure	1.12	0.201
Hemiphragma heterophyllum	Grazed	1.34	0.173
	Exclosure	1.35	0.190
Potentilla microphylla	Grazed	1.01	0.173
	Exclosure	1.21	0.212
Potentilla coriandrifolia	Grazed	1.21	0.187
	Exclosure	1.35	0.213
Juncus thomsonii	Grazed	1.23	0.202
	Exclosure	1.63	0.226
Composite sample	Grazed	1.13	0.202
	Exclosure	1.29	0.213

ANOVA**: Nitrogen-** Species $F_{19,80}$=26.82, P<0.0001; Treatment $F_{1,80}$=7.40, P<0.01; Species × Treatment $F_{19,80}$=0.406, NS. **Phosphorus-** Species $F_{19,80}$=3.50, P<0.0001; Treatment $F_{1,80}$=3.31, NS; Species × Treatment $F_{19,80}$=0.15, NS.

Table 7.2 Nitrogen and phosphorus concentration in aboveground biomass of herbaceous plants from grazed and exclosure plots at four different elevation study sites (Yuksam = warm temperate, Sachen = cool temperate, Deorali = subalpine, and Dzongri = alpine) along the Yuksam-Dzongri trail.

Nutrient/study sites	Treatment	Nutrient concentration (%)			
		April	June	August	October
Nitrogen					
Yuksam	Grazed	1.73	2.14	2.02	1.71
	Exclosure	2.14	2.38	2.71	2.08
Sachen	Grazed	1.62	2.42	2.30	1.84
	Exclosure	1.93	2.37	2.95	2.11
Deorali	Grazed	0.93	1.12	1.06	0.78
	Exclosure	0.91	1.22	1.16	0.93
Dzongri	Grazed	0.93	1.13	1.20	0.92
	Exclosure	1.12	1.27	1.42	1.08
Phosphorus					
Yuksam	Grazed	0.178	0.216	0.231	0.163
	Exclosure	0.203	0.219	0.247	0.211
Sachen	Grazed	0.168	0.211	0.213	0.186
	Exclosure	0.193	0.233	0.231	0.184
Deorali	Grazed	0.155	0.202	0.211	0.117
	Exclosure	0.157	0.216	0.204	0.141
Dzongri	Grazed	0.143	0.173	0.193	0.113
	Exclosure	0.183	0.204	0.222	0.142

ANOVA: **Nitrogen**- Site $F_{3,64}$=47.02, P<0.0001; Month $F_{3,63}$=4.81, P<0.01; Treatment $F_{1,64}$=5.65, P<0.05; Site × Month $F_{9,64}$=0.39, NS; Site × Treatment $F_{3,64}$=1.05, NS; Month × Treatment $F_{3,64}$=0.21, NS; Site × Month × Treatment $F_{9,64}$=0.26, NS. **Phosphorus**- Site $F_{3,64}$=1.94, NS; Month $F_{3,63}$=4.82, P<0.01; Treatment $F_{1,64}$=2.23, NS; Site × Month $F_{9,64}$=0.19, NS; Site × Treatment $F_{3,64}$=0.15, NS; Month × Treatment $F_{3,64}$=0.037, NS; Site × Month × Treatment $F_{9,64}$=0.071, NS.

Table 7.3 Nitrogen and phosphorus concentration of belowground biomass of herbaceous plants in grazed and exclosure plots at four different elevation study sites (Yuksam = warm temperate, Sachen = cool temperate, Deorali = subalpine, and Dzongri = alpine) along the Yuksam-Dzongri trail.

Nutrient/study sites	Treatment	Nutrient concentration (%)			
		April	June	August	October
Nitrogen					
Yuksam	Grazed	0.81	0.85	0.87	0.77
	Exclosure	0.73	0.83	0.80	0.71
Sachen	Grazed	0.64	1.16	0.91	0.73
	Exclosure	0.73	0.88	0.82	0.63
Deorali	Grazed	0.99	1.26	1.38	0.74
	Exclosure	0.92	1.13	1.32	0.81
Dzongri	Grazed	0.92	1.32	1.50	1.07
	Exclosure	0.73	0.81	0.83	0.63
Phosphorus					
Yuksam	Grazed	0.133	0.138	0.146	0.127
	Exclosure	0.122	0.127	0.152	0.131
Sachen	Grazed	0.128	0.168	0.149	0.114
	Exclosure	0.117	0.152	0.147	0.103
Deorali	Grazed	0.112	0.138	0.160	0.108
	Exclosure	0.118	0.142	0.153	0.141
Dzongri	Grazed	0.235	0.238	0.226	0.117
	Exclosure	0.216	0.231	0.218	0.133

ANOVA**: Nitrogen**- Site $F_{3,64}$=4.46, P<0.01; Month $F_{3,63}$=8.59, P<0.0001; Treatment $F_{1,64}$=11.38, P<0.001; Site × Month $F_{9,64}$=1.41, NS; Site × Treatment $F_{3,64}$=2.78, P<0.05; Month × Treatment $F_{3,64}$=1.18, NS; Site × Month × Treatment $F_{9,64}$=0.75, NS; $LSD_{(0.05)}$=0.138. **Phosphorus**- Site $F_{3,64}$=10.86, P<0.0001; Month $F_{3,64}$=4.58, P<0.01; Treatment $F_{1,64}$=0.04, NS; Site × Month $F_{9,64}$=1.37, NS; Site × Treatment $F_{3,64}$=0.15, NS; Month × Treatment $F_{3,64}$=0.19, NS; Site × Month × Treatment $F_{9,64}$=0.06, NS.

Table 7.4 Nitrogen and phosphorus concentration of litter mass in grazed and exclosure plots at four different elevation study sites (Yuksam = warm temperate, Sachen = cool temperate, Deorali = subalpine, and Dzongri = alpine) along the Yuksam-Dzongri trail.

Nutrient/study sites	Treatment	Nutrient concentration (%)			
		April	June	August	October
Nitrogen					
Yuksam	Grazed	0.84	1.26	1.32	0.82
	Exclosure	0.87	1.13	1.26	0.78
Sachen	Grazed	0.96	1.21	1.24	0.94
	Exclosure	1.07	1.16	1.23	0.88
Deorali	Grazed	1.13	1.36	1.42	1.08
	Exclosure	1.08	1.11	1.38	0.97
Dzongri	Grazed	1.18	1.47	1.71	1.12
	Exclosure	1.21	1.22	1.68	0.94
Phosphorus					
Yuksam	Grazed	0.216	0.278	0.309	0.238
	Exclosure	0.228	0.338	0.323	0.216
Sachen	Grazed	0.261	0.286	0.300	0.213
	Exclosure	0.229	0.268	0.317	0.247
Deorali	Grazed	0.281	0.331	0.301	0.256
	Exclosure	0.284	0.316	0.309	0.231
Dzongri	Grazed	0.261	0.304	0.249	0.222
	Exclosure	0.238	0.317	0.297	0.214

ANOVA: **Nitrogen-** Site $F_{3,64}$=5.04, P<0.01; Month $F_{3,64}$=13.4, P<0.0001; Treatment $F_{1,64}$=1.02, NS; Site × Month $F_{9,64}$=0.60, NS; Site × Treatment $F_{3,64}$=0.16, NS; Month × Treatment $F_{3,64}$=0.62, NS; Site × Month × Treatment $F_{9,64}$=0.09, NS. **Phosphorus-** Site $F_{3,64}$=0.85, NS; Month $F_{3,64}$=2.84, P<0.05; Treatment $F_{1,64}$=0.012, NS; Site × Month $F_{9,64}$=0.27, NS; Site × Treatment $F_{3,64}$=0.29, NS; Month × Treatment $F_{3,64}$=0.34, NS; Site × Month × Treatment $F_{9,64}$=0.26, NS.

Table 7.5 Standing state of nitrogen in various plant components of grazed and exclosure plots at four different elevation study sites (Yuksam = warm temperate, Sachen = cool temperate, Deorali = subalpine, and Dzongri = alpine) along the Yuksam-Dzongri trail.

Study sites	Plant components	Treatment	Standing state of nitrogen (g m^{-2})			
			April	June	August	October
Yuksam	Aboveground	Grazed	3.91	6.03	6.81	3.69
		Exclosure	5.05	10.99	17.37	7.03
	Belowground	Grazed	2.55	2.86	4.18	3.10
		Exclosure	3.38	4.01	4.29	3.49
	Litter mass	Grazed	0.45	0.52	0.49	0.38
		Exclosure	0.79	0.99	1.03	0.83
Sachen	Aboveground	Grazed	3.29	7.94	11.22	3.85
		Exclosure	5.10	10.50	20.44	6.03
	Belowground	Grazed	1.96	4.91	5.40	3.09
		Exclosure	3.38	4.46	5.48	3.83
	Litter mass	Grazed	1.00	0.94	0.52	0.83
		Exclosure	1.44	1.18	0.87	0.98
Deorali	Aboveground	Grazed	1.76	3.11	3.73	1.44
		Exclosure	2.03	4.75	6.81	2.61
	Belowground	Grazed	10.32	12.07	11.70	10.83
		Exclosure	8.49	9.75	10.48	9.21
	Litter mass	Grazed	0.36	0.27	0.10	0.11
		Exclosure	0.83	0.62	0.22	0.71
Dzongri	Aboveground	Grazed	1.87	3.18	3.72	1.48
		Exclosure	2.64	5.33	7.65	2.43
	Belowground	Grazed	10.16	13.02	13.91	10.63
		Exclosure	5.25	7.35	7.01	5.77
	Litter mass	Grazed	0.33	0.25	0.12	0.15
		Exclosure	1.04	0.74	0.34	0.76

Table 7.6 Standing state of phosphorus in various plant components in grazed and exclosure plots at four different elevation study sites (Yuksam = warm temperate, Sachen = cool temperate, Deorali = subalpine, and Dzongri = alpine) along the Yuksam-Dzongri trail.

Study sites	Plant components	Treatment	Standing state of phosphorus (g m^{-2})			
			April	June	August	October
Yuksam	Aboveground	Grazed	0.402	0.609	0.778	0.352
		Exclosure	0.512	1.012	1.583	0.713
	Belowground	Grazed	0.419	0.465	0.702	0.511
		Exclosure	0.565	0.613	0.815	0.645
	Litter mass	Grazed	0.085	0.110	0.110	0.110
		Exclosure	0.207	0.300	0.260	0.230
Sachen	Aboveground	Grazed	0.341	0.692	1.039	0.389
		Exclosure	0.510	1.032	1.600	0.526
	Belowground	Grazed	0.393	0.711	0.878	0.482
		Exclosure	0.542	0.771	0.982	0.545
	Litter mass	Grazed	0.270	0.220	0.130	0.190
		Exclosure	0.310	0.270	0.230	0.270
Deorali	Aboveground	Grazed	0.293	0.562	0.743	0.215
		Exclosure	0.350	0.840	1.197	0.396
	Belowground	Grazed	1.230	1.322	1.357	1.198
		Exclosure	1.089	1.225	1.215	1.128
	Litter mass	Grazed	0.090	0.070	0.020	0.040
		Exclosure	0.220	0.180	0.050	0.170
Dzongri	Aboveground	Grazed	0.287	0.451	0.598	0.182
		Exclosure	0.432	0.857	1.197	0.320
	Belowground	Grazed	2.594	2.367	2.095	2.762
		Exclosure	2.145	2.095	1.842	2.218
	Litter mass	Grazed	0.070	0.052	0.017	0.029
		Exclosure	0.200	0.193	0.059	0.173

Table 7.7 Nitrogen concentration and content of soil in grazed and exclosure plots at four different elevation study sites (Yuksam = warm temperate, Sachen = cool temperate, Deorali = subalpine, and Dzongri = alpine) along the Yuksam-Dzongri trail.

Nutrient/study sites	Soil depth (cm)	1998		1999	
		Gr	Ex	Gr	Ex
Concentration (%)					
Yuksam	0-15	0.481	0.400	0.488	0.461
	15-30	0.413	0.330	0.431	0.386
Sachen	0-15	0.530	0.464	0.547	0.417
	15-30	0.443	0.461	0.492	0.407
Deorali	0-15	0.551	0.523	0.511	0.539
	15-30	0.511	0.490	0.491	0.498
Dzongri	0-15	0.406	0.399	0.477	0.398
	15-30	0.310	0.361	0.330	0.403
Content (g m^{-2})					
Yuksam	0-15	417.0	346.9	423.4	399.8
	15-30	396.0	291.7	380.8	341.0
Sachen	0-15	567.3	496.5	585.6	446.5
	15-30	465.4	484.7	482.0	428.1
Deorali	0-15	561.0	531.6	519.6	548.4
	15-30	541.4	519.2	520.3	527.9
Dzongri	0-15	489.6	480.6	575.1	479.1
	15-30	463.4	539.3	492.9	601.8

Gr = grazed, Ex = exclosure. ***ANOVA*:** Site $F_{3,62}$=31, P<0.0001; Soil depth $F_{1,62}$=69, P<0.0001; Treatment $F_{1,62}$=70, P<0.0001; Year $F_{1,62}$=0.021, NS; Site × Soil depth $F_{3,62}$=5.15, P<0.001; Site × Treatment $F_{3,62}$=7.6, P<0.0001; Site × Year $F_{3,62}$=6.19, P<0.0001; Soil depth × Treatment $F_{1,62}$=10.5, P<0.05; Soil depth × Year $F_{1,62}$=5.32, P<0.05; Treatment × Year $F_{1,62}$=1.14, NS; Site × Soil depth × Treatment $F_{3,62}$=2.12, NS; Site × Soil depth × Year $F_{3,62}$=9.8, P<0.0001; Site × Treatment × Year $F_{3,62}$=9.33, P<0.0001; Soil depth × Treatment × Year $F_{1,62}$=0.057, NS; Site × Soil depth × Treatment × Year $F_{3,62}$=6.2, P<0.0001; $LSD_{(0.05)}$=0.152.

Table 7.8 Total phosphorus concentration and content of soil in grazed and exclosure plots at four different elevation study sites (Yuksam = warm temperate, Sachen = cool temperate, Deorali = subalpine, and Dzongri = alpine) along the Yuksam-Dzongri trail.

Nutrient/study sites	Soil depth (cm)	1998		1999	
		Gr	Ex	Gr	Ex
Concentration (%)					
Yuksam	0-15	0.029	0.019	0.031	0.028
	15-30	0.019	0.026	0.029	0.030
Sachen	0-15	0.018	0.013	0.028	0.020
	15-30	0.016	0.013	0.027	0.022
Deorali	0-15	0.030	0.020	0.036	0.023
	15-30	0.028	0.018	0.036	0.021
Dzongri	0-15	0.019	0.009	0.026	0.012
	15-30	0.007	0.024	0.018	0.011
Content (g m^{-2})					
Yuksam	0-15	25.14	16.46	26.90	24.30
	15-30	16.81	22.99	25.63	26.54
Sachen	0-15	19.28	13.91	29.95	21.41
	15-30	16.82	13.67	28.38	23.13
Deorali	0-15	30.54	20.34	36.60	23.40
	15-30	29.67	19.10	38.14	22.25
Dzongri	0-15	22.92	10.86	31.32	14.43
	15-30	35.87	10.47	26.92	16.65

Gr = grazed, Ex = exclosure. ***ANOVA*:** Site $F_{3,62}$=2.29, NS; Soil depth $F_{1,62}$=4.26, P<0.05; Treatment $F_{1,62}$=2.61, NS; Year $F_{1,62}$=2.79, NS; Site × Soil depth $F_{3,62}$=0.69, NS; Site × Treatment $F_{3,62}$=0.201, NS; Site × Year $F_{3,62}$=1.67, NS; Soil depth × Treatment $F_{1,62}$=1.48, NS; Soil depth × Year $F_{1,62}$=0.097, NS; Treatment × Year $F_{1,62}$=0.312, NS; Site × Soil depth × Treatment $F_{3,62}$=0.821, NS; Site × Soil depth × Year $F_{3,62}$=0.72, NS; Site × Treatment × Year $F_{3,62}$=1.42, NS; Soil depth × Treatment × Year $F_{1,62}$=0.05, NS; Site × Soil depth × Treatment × Year $F_{3,62}$=2.17, NS.

Table 7.9 Organic carbon concentration and content of soil in grazed and exclosure plots at four different elevation study sites (Yuksam = warm temperate, Sachen = cool temperate, Deorali = subalpine, and Dzongri = alpine) along the Yuksam-Dzongri trail.

Nutrient/study sites	Soil depth (cm)	1998		1999	
		Grazed	Exclosure	Grazed	Exclosure
Concentration (%)					
Yuksam	0-15	4.59	5.56	5.61	5.02
	15-30	3.46	5.24	5.01	3.78
Sachen	0-15	5.03	4.82	4.99	5.23
	15-30	3.82	4.53	4.42	3.73
Deorali	0-15	5.71	5.86	5.63	5.89
	15-30	5.27	4.81	4.24	5.32
Dzongri	0-15	4.12	4.46	4.62	4.23
	15-30	3.81	4.66	4.13	3.66
Content ($g\ m^{-2}$)					
Yuksam	0-15	4822	3981	4866	4354
	15-30	4631	3058	4427	3341
Sachen	0-15	5160	5385	5342	5599
	15-30	4762	4016	4226	3921
Deorali	0-15	5960	5807	5726	5990
	15-30	5130	5586	4494	5639
Dzongri	0-15	5375	4965	5568	5099
	15-30	6961	5689	6319	5467

ANOVA: Site $F_{3,62}$=87, P<0.0001; Soil depth $F_{1,62}$=231, P<0.0001; Treatment $F_{1,62}$=22.8, P<0.0001; Year $F_{1,62}$=0.183, NS; Site × Soil depth $F_{3,62}$=31, P<0.0001; Site × Treatment $F_{3,62}$=42, P<0.0001; Site × Year $F_{3,62}$=2.09, NS; Soil depth × Treatment $F_{1,62}$=14.6, P<0.0001; Soil depth × Year $F_{1,62}$=25.7, P<0.0001; Treatment × Year $F_{1,62}$=1.71, NS; Site × Soil depth × Treatment $F_{3,62}$=43, P<0.0001; Site × Soil depth × Year $F_{3,62}$=4.87, P<0.001; Site × Treatment × Year $F_{3,62}$=3.9, P<0.05; Soil depth × Treatment × Year $F_{1,62}$=26, P<0.0001; Site × Soil depth × Treatment × Year $F_{3,62}$=7.99, P<0.0001; $LSD_{(0.05)}$=0.152.

Table 7.10 Ratio between organic carbon and nitrogen (C/N) and between nitrogen and phosphorus (N/P) of soils in grazed and exclosure plots at four different elevation study sites (Yuksam = warm temperate, Sachen = cool temperate, Deorali = subalpine, and Dzongri = alpine) along the Yuksam-Dzongri trail.

Ratio/study sites	Soil depth (cm)	1998		1999	
		Grazed	Exclosure	Grazed	Exclosure
C/N					
Yuksam	0-15	11.56	11.48	11.50	10.89
	15-30	12.69	10.48	11.62	9.79
Sachen	0-15	9.09	10.84	9.12	11.56
	15-30	10.23	8.29	8.98	9.16
Deorali	0-15	10.64	10.92	11.02	10.93
	15-30	9.41	10.76	8.64	10.68
Dzongri	0-15	10.99	10.33	9.69	10.63
	15-30	15.03	10.55	12.52	9.08
N/P					
Yuksam	0-15	16.59	21.05	15.74	16.46
	15-30	21.74	12.69	14.86	12.87
Sachen	0-15	29.44	35.69	19.54	20.85
	15-30	27.69	35.46	18.22	18.50
Deorali	0-15	18.37	26.15	14.19	23.43
	15-30	18.25	28.39	13.64	23.71
Dzongri	0-15	21.37	44.33	18.35	33.17
	15-30	12.92	51.57	18.33	36.64

Table 7.11 Chemical concentration of faecal materials for different livestock grazing animals. Analysis has been done on dry weight samples.

Animal types	Concentration (%)		
	Nitrogen	Phosphorus	Organic carbon
Yak	1.87	0.42	7.00
Dzo	1.89	0.49	6.72
Cow	1.63	0.50	7.78
Horse	1.40	0.20	8.35
Sheep	1.41	0.37	7.23

ANOVA: **Nitrogen-** Animal type $F_{4,10}$=17.01, P<0.0001, LDS$_{(0.05)}$=0.140; **Phosphorus-** Animal type $F_{4,10}$=16.74, P<0.0001, LDS$_{(0.05)}$=0.078; **Organic carbon-** Animal type $F_{4,10}$=5.62, P<0.05, LDS$_{(0.05)}$=0.668.

Table 7.12 Annual uptake and loss of nitrogen (g m^{-2} yr^{-1}) at four different elevation study sites (Yuksam = warm temperate, Sachen = cool temperate, Deorali = subalpine, and Dzongri = alpine) along the Yuksam-Dzongri trail.

Study sites	Treatment	Soil (g m^{-2} upto 30 cm)	Net uptake				Shoot to litter	Loss from litter	Loss from root	Total loss	Removed by grazing
			Shoot	Root	Litter	Total					
Yuksam	Grazed	1318	2.90	1.63	0.07	4.60	3.12	0.14	1.08	1.22	9.42
	Exclosure	937	12.32	0.91	0.24	13.47	10.34	0.20	0.80	1.00	
Sachen	Grazed	1229	7.93	3.44	0.31	11.68	7.37	0.48	2.31	2.79	7.41
	Exclosure	926	15.34	2.10	0.11	17.55	14.41	0.31	1.65	1.96	
Deorali	Grazed	978	1.97	1.75	0.01	3.73	2.29	0.26	1.24	1.50	2.81
	Exclosure	833	4.78	1.99	0.49	7.26	4.20	0.61	1.27	1.88	
Dzongri	Grazed	1325	2.24	3.75	0.21	6.20	2.24	0.21	3.28	3.49	3.16
	Exclosure	937	5.01	2.10	0.42	7.53	5.22	0.70	1.58	2.28	

Table 7.13 Annual uptake and loss of phosphorus (g m^{-2} yr^{-1}) at four different elevation study sites (Yuksam = warm temperate, Sachen = cool temperate, Deorali = subalpine, and Dzongri = alpine) along the Yuksam-Dzongri trail.

Study sites	Treatment	Soil (g m^{-2} upto 30 cm)	Net uptake				Shoot to litter	Loss from litter	Loss from root	Total loss	Removed by grazing
			Shoot	Root	Litter	Total					
Yuksam	Grazed	1318	0.376	0.283	0.025	0.684	0.426	-	0.191	0.191	0.695
	Exclosure	937	1.062	0.250	0.093	1.405	0.870	0.070	0.170	0.240	
Sachen	Grazed	1229	0.698	0.485	0.060	1.243	0.650	0.140	0.396	0.536	0.392
	Exclosure	926	1.090	0.400	0.040	1.530	1.074	0.080	0.437	0.517	
Deorali	Grazed	978	0.450	0.127	0.020	0.547	0.597	0.070	0.159	0.089	0.397
	Exclosure	833	0.847	0.136	0.120	1.103	0.801	0.170	0.087	0.257	
Dzongri	Grazed	1325	0.311	0.667	0.012	0.990	0.416	0.053	0.499	0.552	0.454
	Exclosure	937	0.765	0.376	0.114	1.255	0.877	0.141	0.303	0.444	

Table 7.14 Annual balance sheet of nitrogen and phosphorus (g m^{-2} yr^{-1}) from four different elevations study sites (Yuksam = warm temperate, Sachen = cool temperate, Deorali = subalpine, and Dzongri = alpine) along the Yuksam-Dzongri trail.

Study sites	Treatment	Nutrient	Soil (g m^{-2}) upto 30 cm	Uptake	Retention		Release	
				(g m^{-2})	(g m^{-2})	(%)	(g m^{-2})	(%)
Yuksam	Grazed	Nitrogen	1318	4.530	3.310	73.07	1.220	26.93
		Phosphorus	30	0.659	0.469	71.17	0.190	28.83
	Exclosure	Nitrogen	937	13.230	12.230	92.44	1.000	7.56
		Phosphorus	56	1.312	1.072	81.71	0.240	18.29
Sachen	Grazed	Nitrogen	1229	11.370	8.580	75.46	2.790	24.54
		Phosphorus	60	1.183	0.647	54.69	0.530	45.31
	Exclosure	Nitrogen	926	17.440	15.480	88.76	1.960	11.24
		Phosphorus	50	1.490	0.973	65.30	0.517	34.70
Deorali	Grazed	Nitrogen	978	3.720	2.220	59.67	1.500	40.33
		Phosphorus	20	0.577	0.488	84.58	0.089	15.42
	Exclosure	Nitrogen	833	6.770	4.890	72.23	1.880	27.77
		Phosphorus	33	0.983	0.726	73.86	0.257	26.14
Dzongri	Grazed	Nitrogen	1325	5.990	2.500	41.74	3.490	58.26
		Phosphorus	30	0.978	0.426	43.56	0.552	56.44
	Exclosure	Nitrogen	937	7.110	4.830	67.93	2.280	32.07
		Phosphorus	19	1.141	0.697	61.09	0.444	38.91

Table 7.15 Comparison of annual uptake, retention and release of nutrients of the present study and its comparison with different ecosystems of India.

Vegetation types	Nutrient parameters	Nutrients (kg ha^{-1})	
		Nitrogen	Phosphorus
Sehima grassland (Ratlam)[1]	Uptake	58	16
	Retained	29	9
	Release	29	7
Tropical grassland (Jhansi)[2]	Uptake	83	10
	Retained	36	2
	Release	47	8
Alpine grassland (Garhwal Himalaya)[3]	Uptake	41-89	18-42
	Retained	28-71	11-29
	Release	13-18	7-13
Present investigation			
(Yuksam-warm temperate forbs dominated)	Uptake	54-132	7-13
	Retained	33-122	5-11
	Release	12-10	1.9-2.4
(Sachen-cool temperate ferns dominated)	Uptake	114-174	12-15
	Retained	86-155	6-10
	Release	20-28	5.2-5.3
(Deorali-subalpine grassland)	Uptake	37-68	6-10
	Retained	22-49	5-7
	Release	15-19	0.9-2.6
(Dzongri-alpine grassland)	Uptake	60-71	10-11
	Retained	25-48	4-7
	Release	23-35	4.5-5.5

Billore and Mall (1976)[1]; Trivedi and Misra (1983)[2]; Sundriyal (1986)[3]

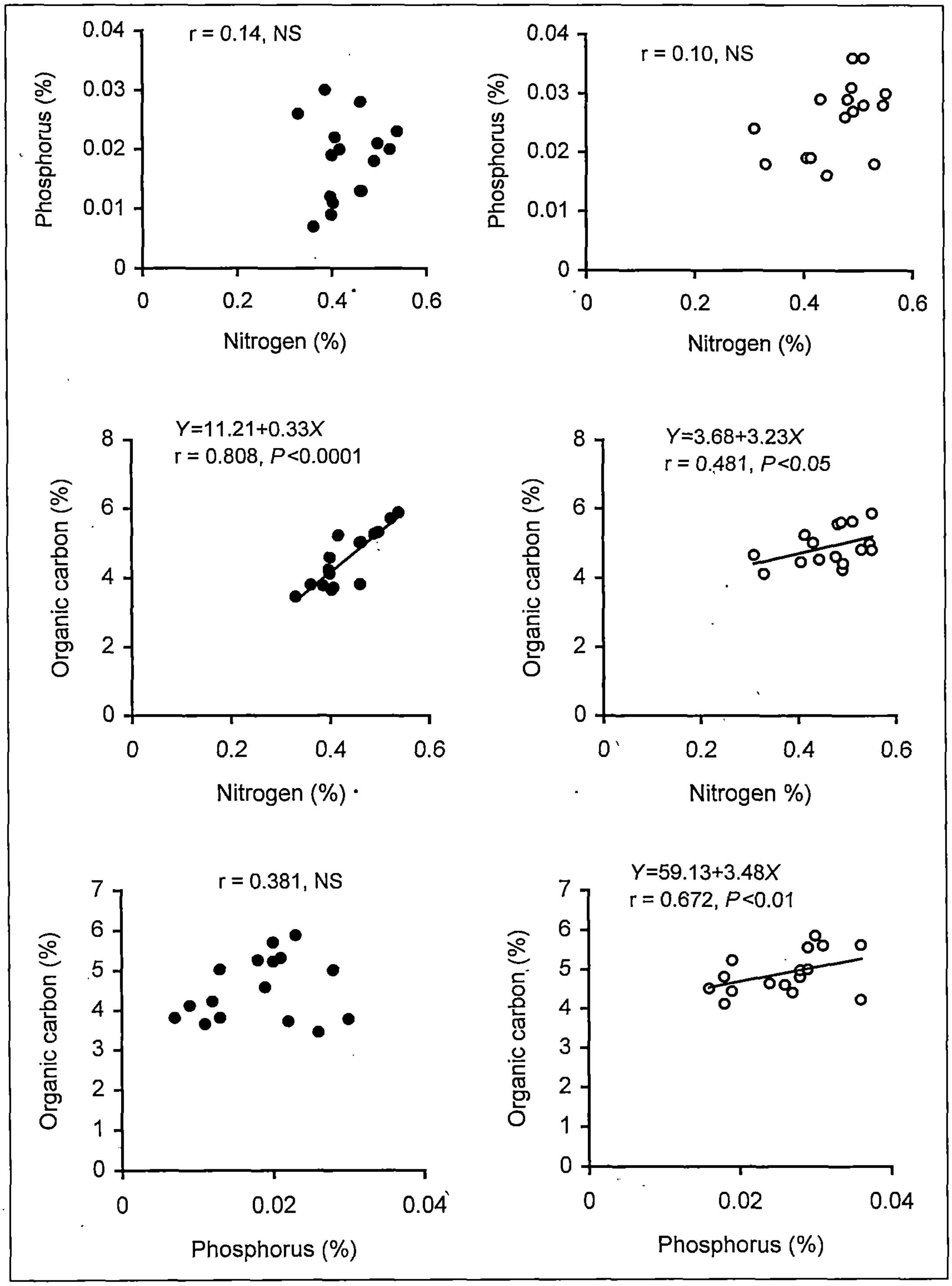

Fig. 7.1 Correlation between nitrogen and phosphorus, nitrogen and organic carbon and between phosphorus and organic carbon concentration of soils in livestock grazing exclosure (dark circle) and grazed (empty circle) plots at pastures of different elevations along the Yuksam-Dzongri trail.