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Impact of livestock grazing on soil nutrient dynamics in three alpine meadows of the Munsyari region of Pithoragarh District Uttarakhand

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Abstract
Livestock Grazing means utilization of the aboveground biomass, but the intensity of grazing may inversely affect the soil's physicochemical properties. Soil Nutrients like Potassium, Calcium, Magnesium, Sodium, and Phosphorus are essential nutrients and thus needed for floral development. We studied the effect of livestock grazing on the soil exchangeable cations (Calcium, Magnesium, Sodium), Soil Potassium, and Phosphorus in three alpine meadows of Munsyari. Soil Sodium concentrations were higher in Janthri which experienced no grazing pressure (NG). Our results indicate that Available Potassium shows an increase of 49.51% at 0-10 cm depth in a moderate grazed site (Balmiya top) than Janthri (having no grazing). Soil total phosphorus, Calcium, and Magnesium were higher in Moderate-grazed sites and decreased with an increase in depth.

Keywords: Alpine meadows, livestock grazing, exchangeable cations, potassium, phosphorus

Introduction

In alpine ecosystems, soil nutrients are mostly received by precipitation and released through decomposing roots, animal excrement, and in limited quantities, litter decomposition. These nutrients are eventually broken down and released into the soil, where they are gradually absorbed by plants and retained in their biomass (Rawat *et al.* 2010) [23]. Soil is one of the most important component systems of the earth's ecosystem. Soil is the source of food and moisture content for pasture plants (Zarekia *et al*.2012). Grazing is one of the phenomena of the utilization of above-ground vegetation by grazing animals. Livestock grazing not only browses the aboveground vegetation but also provided the chance for dwarf plants to grow in the absence of tall and dominant plants. Animals grazing have a positive effect (Li *et al.* 2011; Gao *et al*. 2008 [7]; Kröpfl *et al.* 2013) [15], a negative effect (Eniolorunda 2019 [5]; Dong *et al.* 2012 [4]; Lu *et al*. 2017; Li *et al.* 2018; Hao and He 2019) [9] and no effect (Mathews *et al*. 1994; and Lin *et al.* 2010) [21, 19] on the soil properties. Livestock grazing impacts on the vegetation structure and composition and also on soil surface condition, soil physicochemical, and hydrological properties, and overgrazing is very often been associated with the appearance of bare soil, primarily in such sites as pens (Sharma *et al*. 2021). Among the soil physiochemical properties soil organic carbon, Soil total nitrogen, and pH of soil play important roles in plant development.

Potassium in the soil presents a much different picture as compared to other exchangeable cations such as calcium (Ca+) or hydrogen (H+). Only a small portion of the total K is held in an exchangeable form, while the rest remains in fixed or non-exchangeable form. The grazing exclusion significantly increased species diversity, richness, coverage, above- and belowground biomass, and, soil properties like total nitrogen, soil organic carbon, total phosphorus TP, soil-available potassium, and soil-available phosphorus (Cheng *et al.* 2016) [3]. Livestock grazing is a complex factor, whose influence is probably reconciled with the intricate inter-reactions between plants and the environment (Shan *et al.* 2011; Abdalla *et al.* 2018) [26, 1]. Livestock grazing at high intensity but for a short period of time was effective in terms of increasing soil organic matter and diversity in forage species composition (Russell *et al.* 2013) [25]. While overgrazing destroys above-ground vegetation and soil and loss of fertile topsoil, especially where precipitation is low and evaporation is high (Xie and Wittig 2004). Soil Phosphorus is mainly derived from the weathering of rocks rather than from organic matter decomposition (Jiao *et al.* 2016) [14]. Phosphorus is crucial for plant growth and is usually a limiting factor due to fixation in soils and low availability to plants (Wang *et al.* 2017)

Among the soil properties soil organic carbon, soil total nitrogen, and their relation in terms of livestock grazing pressure were extensively studied in different parts of the world, but the effect of Livestock grazing on soil Phosphorus, Potassium, and on exchangeable cations like Sodium, Calcium, and Magnesium were least studied till date. The present study was aimed to examine the Livestock grazing effect on the soil exchangeable cations and on the soil Potassium and Phosphorus. These soil nutrients play a vital role in soil community and plant growth development.

Material and methods

1. Study area

The study was carried out in three alpine meadow sites in the Munsyari region of Pithoragarh district of Uttarakhand, Western Himalaya. The study sites are located at an altitude above 3200 meters amsl, and between N=30º088′46″and E= 80º17.935′. The study sites differ in the magnitude of grazing pressure, with Balmiya top (MG) experiencing Moderate grazing pressure, Rukhiyan (HG) with relatively high grazing pressure, and Janthri (NG), experiencing no grazing pressure (Figure 1) and grazing pressure calculated as per Sharma *et al* 2021. (Table 1). The ambient temperature recorded was between 7-8ºC, while the average humidity was around 50% which varied between a minimum of 26% and increased to 83%.

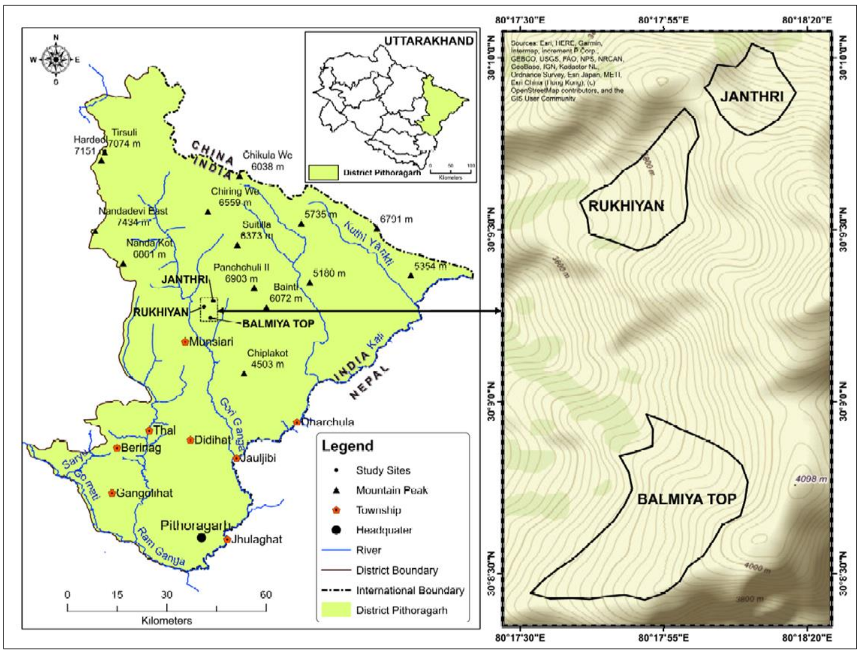


Fig 1: The study sites- Janthri, designated as control site with no grazing pressure; Balmiya and Rukhiyan, both experiencing grazing pressure, with relatively more in case of Rukhiyan, primarily on account of the relatively smaller area than in case of Balmiya Top.

Table 1: Statement of grazing pressure in the two study sites (*the adjacent study site- Janthri experiences no grazing pressure)

Study site	Class of animal	Number (A)	AUE* value (B)	Total AU (A x B)	Grazing pressure (AU/Area)
Balmiya top	Sheep	2010	0.3	603	12.53
	Horse	20	1.25	25	0.52
Total					**13.05**
Rukhiyan	Sheep	1680	0.3	504	**26.52**

* AUE- Animal Unit Equivalent. The site Janthri experiencing no grazing pressure, hence not included in the table. (Adopted from Sharma and Negi 2022).

2. Methodology

2.1 Measuring grazing pressure

$$\frac{\text{Number of livestock x Duration of stay (in days)}}{\text{Area of the study site}}$$

Grazing pressure was calculated as: Grazing pressure was calculated, as an animal unit divided by the total grazing area (Sharma *and Negi* 2022).

2.2. *Soil exchangeable cations (Calcium, magnesium, Sodium), Potassium, and Phosphorus*

Soil samples were collected at different depths (0–10, 10-20, and 20-30 cm) from the 5 quadrates in each sampling plot of each grazing-intensity meadow after the above-ground material has been harvested, or removed. In each quadrate, the soil will be randomly collected from three points (3.8 cm in diameter) using a bucket auger and mixed into a single soil sample. All of the soil samples will be then carried back to the laboratory in airtight plastic bags.

The following standard methods were used for the estimation of given parameters: (i) Exchangeable cations (Estefan *et al.* 2013) [6] (ii) Total Phosphorus (Bray and Kurtz 1945) [2] (iii) Available Phosphorus (Olsen *et al.* 1954) [22] (iv) Total potassium (Jackson 1958) [10] and (V) Available potassium (Anonymous 1999).

2.3 *Statistical Analysis*

A one-way analysis of variance (ANOVA) followed by post-hoc test comparisons using LSD (least significant difference) to compare differences between the three study sites. All the statistical analyses were performed by using IBM SPSS software (version 23), and statistically significant differences were applied for P values < 0.05.

Results

1 Soil Total Potassium

Soil total potassium in three soil depths (0-10, 10-20, and 20-30 cm) in three study sites is likely to vary (Figure 2), but the overall (0-30 cm) averaged value of total potassium was higher in Rukhiyan (HG), followed by Janthri (NG) and Balmiya top (MG) (10.96±1.36, 10.52 ±1.67 and 9.88±1.38). Although the values are not significant (P>0.05).

2. Soil Available Potassium

Soil available potassium in Balmiya top (MG) decreased as the soil depth increased but in the case of Rukhiyan (HG) and Janthri (NG), soil available potassium firstly decreased at the depth of 10-20 cm then increased at the depth of 20-30 cm (Figure 2). Although the soil available potassium was significantly higher ($P<0.05$) in Balmiya top (MG) as compared to the Janthri (NG) at the depth of 0-10 and 10-20 cm, there was no significant difference in the three study sites at the depth of 20-30 cm ($P>0.05$).

3. Soil Total and Available Phosphorus

Soil total phosphorus was higher in Balmiya top (MG) followed by Rukhiyan (HG) and least in Janthri (NG) (Figure 2). Although we cannot find any significant differences in Balmiya top (MG) and Rukhiyan (HG) at 0-10, 10-20, and 20-30 cm soil depths. But Balmiya top (MG) and Rukhiyan (HG) show higher significance ($p<0.05$) with Janthri (NG) at 0-10, 10-20, and 20-30 cm soil depths.

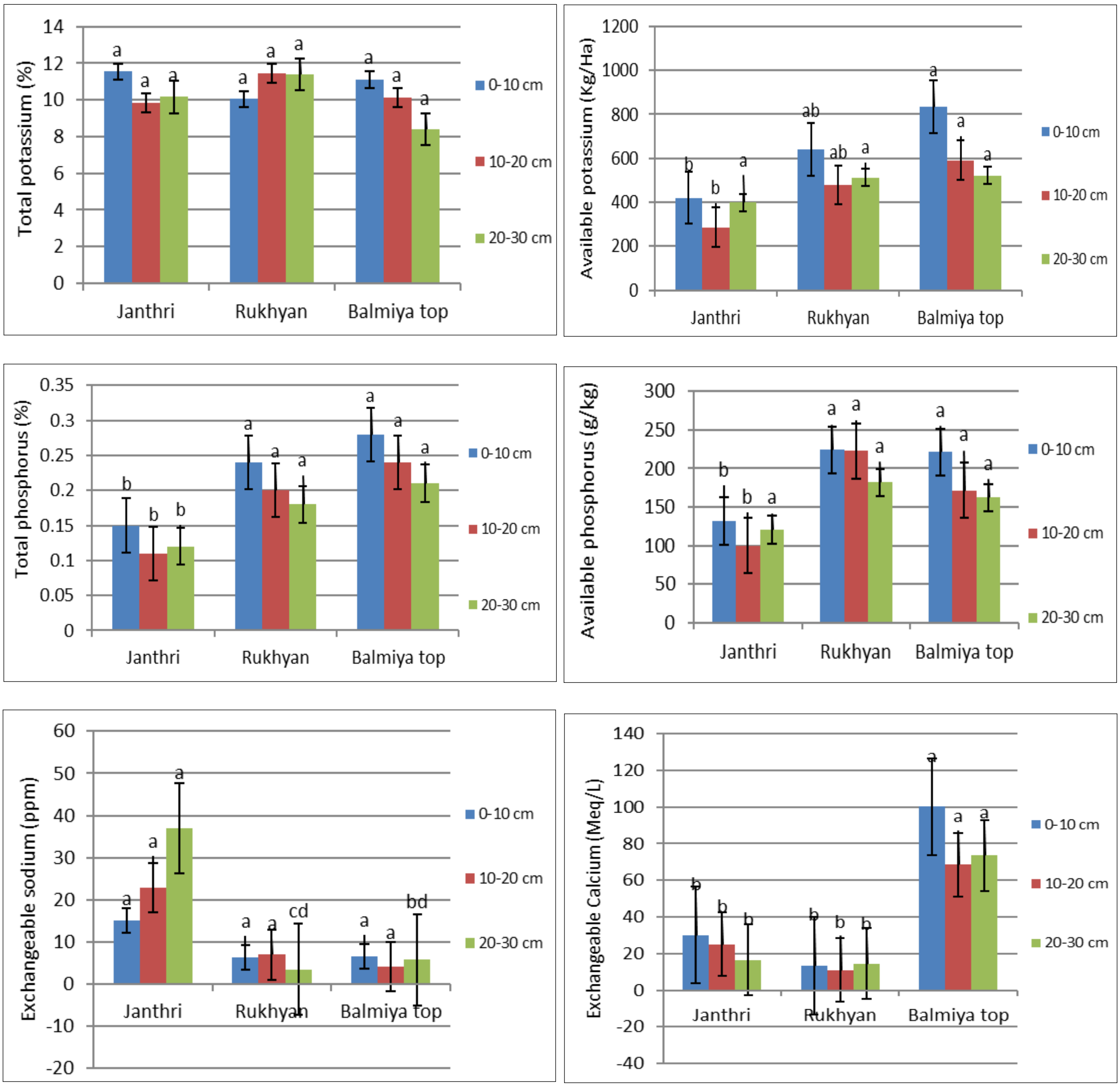
While Soil Available Phosphorus shows similar results as that of Soil total Phosphorus (Figure 2). Both Balmiya top (MG) and Rukhiyan (HG) show higher significance ($P<0.05$) with Janthri (NG) at three (0-10, 10-20, and 20-30 cm) soil depths. While the differences between Balmiya top (MG) and Rukhiyan (HG) are not significant ($P>0.05$).

4. Soil Exchangeable cations (Sodium, Calcium, and Magnesium)

Soil sodium concentration in Janthri (NG) was higher than the Rukhiyan (HG) and Balmiya top (LG) in three soil depths of 0-10, 10-20, and 20-30 cm (Figure 2). But upon comparison, soil Sodium in Janthri, Balmiya top, and Rukhiyan at the depth of 0-10 and 10-20 cm does not show any significant differences ($P>0.05$). While Soil Sodium at the depth of 20-30 cm in Janthri shows a significant difference ($P<0.05$) with Balmiya top and Rukhiyan.

Soil Calcium in the Balmiya top (LG) was higher than the Rukhiyan (HG) and Janthri (NG) at the three soil depths and the differences are significant ($P<0.05$). While the differences between Rukhiyan (HG) and Janthri (NG) were not significant (Figure 2).

In the case of soil Magnesium Balmiya top (LG) shows high magnesium level than Rukhiyan (HG) and Janthri (NG) but the differences are not significant ($P>0.05$) among the three sites across the three soil depths (Figure 2).



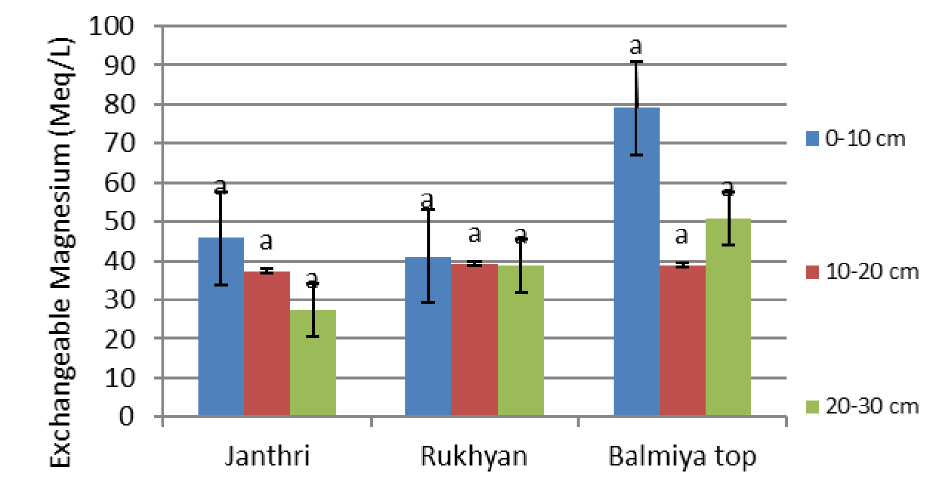


Fig 2: Soil total and available Potassium, total and available Phosphorus and Soil exchangeable cations (Sodium, Calcium and Magnesium) with standard error bars across the three study sites

Discussion

1. Soil Total and available Potassium and Soil Total and available Phosphorus

Ji *et al.* 2020 [13]; found no effect of livestock grazing at different grazing treatments on soil total potassium and concluded that grazing management of alpine meadows in the study sites probably led to the mineralization of K and similar results were observed in the present study.

Although the available potassium in Balmiya top experiences Moderate grazing (MG) was higher followed by the Rukhiyan having high grazing (HG) and least in the Janthri having no grazing (NG). This is because the flourishing vegetation affects the absorption and utilization of available nutrients in the soil under light trampling by livestock (Li *et al.* 2011b) [17].

Some studies have reported a positive impact of grazing on the soil (Li *et al.* 2011) while others reported a negative impact (Hao and He 2019) [9]. Rui *et al.* 2012 [24] reported that grazing did not affect STP due to a faster return of P to the soil via urine and faces deposition. Our results show that soil phosphorus was higher in grazed sites (Light and heavily grazed sites) than the non-grazed sites which is consistent with studies (Ji *et al.* 2020, Li *et al.* 2011 [16], and Jaweed *et al.* 2015) [11]. Soil available phosphorus was least in the Janthri (NG) whereas highest in the Rukhiyan (HG). The result shows that Soil available phosphorus was increased with an increase of grazing pressure because, under situations of mixed warming and grazing, the microbial mineralization of soil organic Phosphorus may be an effective response due to increased plant demand for phosphorus and enhanced microbial activities (Rui *et al.*2012) [24].

2. Soil exchangeable cations (Sodium, calcium, and Magnesium)

As grazing pressure increased from light to heavy, concentrations of Ca decreased from 5.18% to 2.59%, and Mg from 3.26% to 2.58% and this loss of Calcium and Magnesium due to frequent trampling by sheep and cattle, the ground surface at the heavily grazed sites became bare and exposed to water erosion (Jaweed *et al.* 2015) [11]. Our study shows similar results and the possible reason for this phenomenon is the loss of these two nutrients can be attributed to an uncontrolled trampling and removal of these elements by nomadic grazers while an increase in these nutrients through the addition of animal excreta (Shan *et al.* 2011) [26].

Jeddi and Chaieb 2010 [12]; reported that sodium concentration, electrical conductivity, and pH show a decreasing trend with increasing grazing exclusion duration in the arid environment. This simply means that livestock grazing enhanced the soil sodium concentration but contradictory results were observed in the present study conducted in the alpine meadows. Janthri (NG) has the highest concentration of Sodium than the Rukhiyan (HG) and Balmiya top (MG) and this is due to the excess amount of organic matter present in the non-grazed site.

Conclusion

Essential nutrients are vital for a plant's growth and development. Any change in the concentration of such micronutrients inversely affects plant life. Livestock grazing affects differently on different environmental conditions. Alpine meadows are ecologically sensitive and have limited carrying capacity beyond the carrying capacity alpine meadows soil is susceptible to degradation. Our finding indicated that Light grazing at the Balmiya top has increased the amount of Calcium, Magnesium, Available Potassium, and Total Phosphorus as compared to the other two sites. While soil available Phosphorus showed an increasing trend with an increase in grazing pressure. Thus we concluded that light grazing in a managed manner enhanced most of the soil nutrients but non-grazed sites have the stable nutrient concentration.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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