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Impact of transhumant grazing on physical and chemical properties of soils in temperate pasturelands of Kashmir Himalaya

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Abstract

Lack of data on the soil component of pastures in Kashmir Himalaya is a strong limitation to assess the impact of transhumant livestock on it. During present study the data has been raised for physico-chemical properties of such soils among different grazing intensities designated as lightly grazed (LG), moderately grazed (MG) and heavily grazed (HG). Besides, physical properties like bulk density (BD) and texture, chemical properties like (OC), total N (TN), P, K, Ca, S, Mg, pH and electrical conductivity (EC), which are a function of these cations were worked out. Energy dispersive X-ray fluorescence (ED-XRF) and other relevant techniques have been used to analyze the various parameters of soil, which are mostly effected by grazing. Soil OC, Ca and Mg content were observed to decrease with increase in the grazing intensity at sampling depths 0-10 cm. Conversely, total N, P, S and K showed an increase in the total concentration in areas with increased grazing pressures. The uneven grazing intensity (an inherent feature of a transhumant grazing system) makes the soils susceptible for degradation. We need to find the proper balance between light to heavy grazing intensity through proper grazing management and in some cases using judicious herding to distribute livestock.

Keywords: Bulk density, Grazing intensities, Himalaya, Pasturelands, Soil component

Introduction

It is rightly said that the Himalayan ecosystems have evolved without man and hoofed animals as its component. However, since time immemorial, the tribes in the region practise a subsistence livelihood that is mainly based on animal farming. The huge circulation of their livestock in the adjoining ecologically climax ecosystems cause the change in chemical and physical properties of soils. The present study was aimed to highlight the impact of transhumant activities on proper-ties of upper most layers of soil.

Himalayas are bestowed with vast grassy tracts of immense forage importance. The grazing lands of the region provide goods and services of economic and social importance. The biomass resource in study area supports nearly 20% of the total human population and 80% livestock population of adjoining regions. Thus, an old ethnic practice of resource use in terms of grazing is operating at an alarming rate (Casimir and Rao, 1985; Dad and Khan, 2010; Maiti *et al.,* 2015). Major fraction of the population is concerned with grasslands and practise pastoral way of life with transhumance in vogue. Although, there are many reasons for degradation of grassland soils, however, livestock overgrazing by transhumant flocks in the region is one of the major cause. All pasturelands of study area, except a few alpine areas are heavily overgrazed causing large-scale degradation of the soil resource. Livestock grazing represents a major biotic disturbance in Himalayas, and its impacts on the plant communities have been highly debated (Dad and Khan, 2010). It affects numerous ecosystem functions, which influences the environmental quality at multiple and spatial scales (Schlesinger *et al.,* 1990). The nutrient enrichment is a common feature of natural grassland soils (Mountford *et al.,* 1993; Bobbink *et al.,* 1998; Stevens *et al.,* 2004) because heterogeneous grazing and excreting patterns have a marked effect on the uneven patterns of soil nutrient status and botanical composition (Güsewell *et al.,* 2005).

The severity of the problem has increased due to increasing number of people involved in transhumant activities. Furthermore, grazing may contribute significantly to soil degradation because of soil compaction and reduction, or even loss of grass cover. The human transformation process of resource-use practices has brought drastic changes in the biophysical components and land use pattern of the region. In the present study, micro level approach has been attempted in a part of middle Himalayan region (i) to assess physical and chemical properties of soil (ii) to understand the difference between characteristics of highly grazed, moderately grazed and lightly grazed soils.

Materials and Methods

Study area: Transhumant communities of the Jammu and Kashmir state *viz*., buffalo herding *Gujjar*, goat and sheep herding *Bakarwal*, and local *Pohal,* continue a long-standing tradition of migrating up to the alpine pastures for the summer and descending to the low-lying foothills in the winter. One of the Kashmir valley regions most explored by these ethnic groups is Liddar (or Lidder) valley, located towards east of the summer capital Srinagar. Total area of this catchment is 1248 km^2 but only 627 km^2 have been taken for the study which is situated between 34^0 00' 00" N to 34^0 15' 35" N and 75^0 06' 00"E to 75^0 32' 29" E. It gradually rises in elevation from 2700 m in south to 5400 m in North and may be documented as northern Liddar valley.

Owing to its wide altitudinal gradient and varied edapho-climatic and physiographic features, the region harbors wide array of habitats including terraced table lands, wastelands, montane slopes, pastures, rocky outcrops and permanent glaciers etc. The low unapproachability of these areas by means of roads necessitates large number of people to observe transhumance through the route mentioned in Figure 1. The people practising transhumance are called as transhumants.

The change of vegetation on exposure to different grazing pressures is perhaps nowhere as evident as in the pasturelands of the study area. For the convenience of the study, areas of pastoral migration have been considered for the investigation of the soils with following grazing intensities.

Sampling

The soil sampling has been carried out in the three grazing intensities (Table 1) with uniform topography and soil types but different plant cover and grazing pressures. Core tube method was followed for collection of soil samples (7.62 cm diameter x 10 cm deep). Eight major sites were selected within the area on the basis of types of habitats for plants, use by grazing animals and the degree of disturbance. Transects in each grazing treatment *viz*., lightly grazed (LG), moderately grazed (MG) and heavily grazed (HG) have been laid across the valley at different sites. Within each transect three sampling units were selected at a distance of 10 m accounting for three sampling units for every grazing intensity zone as mentioned in Table 1. Overall 8 x 3 x 3 samples were collected from the study area. However, three samples collected from a single transect were composited and analyzed for various parameters. Two cores were collected at each point where first one was dried, sieved, and analyzed for various parameters while other one was subjected to investigation of physical parameters.

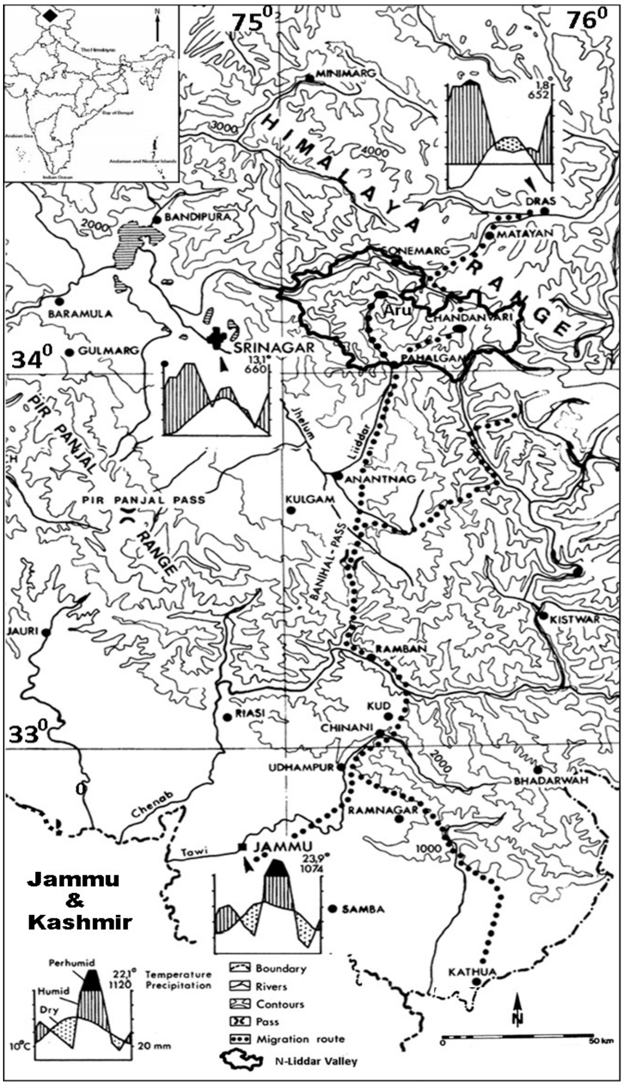

Fig 1. Map with remarkable camping sites along migration route to northern Liddar valley (Jammu Bharak → Triyath → Porokotla → Ikni → Gaibass → Kunala Chorusira→Panjigali→Banna→Sungri→Balmatkot→Brahmi Dam→ Didamgali → Zaijmarg → Trajan → Nandimarag → Khul Anantnag → Aishmuqam → Pahalgam - Chandanwari and Aru)

Table 1. Various grazing intensity zones with different floral communities in areas of pastoral migration in northern Liddar valley

Zone	Vegetation	Altitudinal Range	Identification
Lightly grazed (LG)	*Anaphalis triplinervis; Geum elatum; Potentilla atrosanguinea; Potentilla curviseta; Sibbaldia cuneata; Trifolium repens.*	Discretely preserved patches for ethical or state purposes.	Full herbaceous growth, intact soil cover
Moderately grazed (MG)	*Fimbristylis dichotoma; Plantago ovate; Sibbaldia cuneata; Taraxacum officinale; Trifolium repens.*	3250 m upwards.	Herbaceous cover removed above ground, Discrete dung deposition
Heavily grazed (HG)	*Cirsium falconeri; Polygonum aviculare; Rumex nepalensis; Sambucus wightiana.*	2700 - 3250 m.	Fresh dung deposition, Bare soil, Loose soil

Soil parameters

Soil bulk density was determined by core tube method using a cylindrical steel core tube approximately 10cm long and 7.62 cm internal diameter with wall thickness approximately 0.3 cm, as determined by Van Haveren (1983). Hydrometric method was used for determination of different soil separates using sodium hexa-metaphosphate as a dispersion agent (Jackson, 1973).

The organic carbon was determined by Walkley-Black potassium dichromate oxidation procedure (Walkley and Black, 1934). Soil pH and electrical conductivity (EC) were determined by potentiometric method in 1:5 soil–water aqueous extract (Multiline F/SET-3, Germany). Total N was determined with the Kjeldahl method, which consists of digestion, distillation and quantification (Jackson, 1973). Other than Organic carbon and total nitrogen, elemental mapping of soil samples was carried out by energy dispersive X-ray florescence using SPECTRO XEPOS ED-XRF-Hong Kong, in which five g of soil samples were subjected to analysis. The enrichment factor (EF) of macronutrients was calculated using EF = Cn/Bn.

Where, Cn: concentration of examined element in the examined sample; Bn: Background concentration of the element.

One-way ANOVA analysis was conducted for soil characteristics among the three types of grazing meadows. Post-hoc com-parisons were performed using LSD. All of the variables met the statistical assumptions (residuals normality, homoge-neity of variance and data linearity). Significant differences for all of the statistical tests were evaluated at the level of $p \leq 0.05$. Duncan test followed by ANOVA has been carried out to compare the site differences (LG vs. MG vs. HG) for understanding the significant difference. All of the statistical analyses were performed using the SPSS ver.12.0.

Results and Discussion

***Soil physical properties*:** The particle size distribution showed sand fraction as 4.264% in lightly grazed, 5.43% in moderately grazed and 13.74% in heavily grazed sites. Total silt and clay content in the top 10 cm soils under LG and MG were 95.92% and 94.56%, which was higher than that in HG (86.24%) at $p \leq 0.05$ (Table 2). The sand and silt content was highest in HG (32.8%) and lowest in LG (11.72%), conversely clay fraction was highest in LG (88.48%) followed by MG (83.95%) and HG (67.18%). These facts highlight that traffic by grazing animals change the physical properties drastically which in-turn changes the chemical properties of soil. Grazing influences bulk densities (BD), and showed significant difference ($p \leq 0.05$) between low grazed (LG) and heavily grazed (HG) sites and has been estimated as 1.04 g/cm^3 for LG, 1.05 g/cm^3 for MG and 1.07 g/cm^3 for HG. Plots with lower grazing intensities showed significantly ($p \leq 0.05$) lower bulk densities compared to heavily grazed plots. Thus, the increase in BD of soil can be attributed to the increase in sand fraction of soil.

Soil bulk densities were significantly greater in the HG pastures than those in the LG and MG pastures due to trampling because animal hooves can exert pressure up to 200 kPa, which is considerably greater than the pressure exerted on the soil surface by a tractor that ranges from 30 to 150 kPa (Proffitt *et al.,* 1993). The physical impact by animals is believed to chip or churn the soil and expose the inner sandy layers thereby compacting the soil (Savory and Parsons, 1980). The presence of moisture with spring thaw (During onset of transhumant migration to summer pastures in April-May months) alleviates the effect of animal trampling on soils (Abdel-Magid *et al.,* 1987). Trampling of dry soil (During return to winter pastures in Oct - Nov months) chip and churn the soil surface but with less intensity. Similar observations have been made in Alberta where same climatic conditions persist (Warren *et al.,* 1986).

The hoof action reduces the size of naturally occurring soil aggregates and increases density of the surface soil layer. Other studies found trampling associated with heavy grazing caused significantly greater bulk densities in the top 7.5 cm (Naeth *et al.,* 1990; Chanasyk and Naeth, 1995) and 2.5 – 3 cm of soil (Dormaar *et al.*, 1989; Mapfumo *et al.,* 1999). Furthermore, properties such as texture, organic matter, water content and other environmental conditions govern the degree to which compaction occurs (Mapfumo *et al.,* 1999). Previous literature and present study confirms the inverse relation of organic carbon and bulk density. Thus, stocking rate in lightly grazed pasture may have reduced trampling effects on the soil.

Table 2. Physical properties of the top 10 cm soil in different grazing intensities in northern Liddar valley

Soil fraction	**Grazing intensity group**		
	LG (Mean ±S.E)	**MG (Mean ±S.E)**	**HG (Mean ±S.E)**
Sand (%)	4.264a ±(1.27)	5.43ab ±(1.25)	13.74b ±(4.16)
Silt (%)	7.454a ±(1.25)	10.6ab ±(2.40)	19.064b ±(5.29)
Clay (%)	88.48a ±(2.38)	83.95a ±(3.04)	67.18b ±(8.07)
Bulk density (g/cm^3)	1.04a ±(0.10)	1.049ab ±(0.04)	1.08b ±(0.08)

**Within rows, means of parameters followed by different letters represent statistically significant differences at p<0.05, determined from LSD following ANOVA at d.f. = 7. Standard errors are given in parentheses.*

Soil chemical properties

Grazing being an anthropogenic agent has been witnessed to alter the chemical characteristics of soils in extensively grazed regions. Keeping this fact in mind the data has been generated for comparative purposes to highlight the impacts of transhumant grazing and their implications on the Himalayan pastures.

The pH values among three grazing intensities were 7.43 for LG, 7.44 for MG and 7.47 for HG and showed significant differences ($p \leq 0.05$). Overall differences between the plots were small with a small standard deviation (Table 3). However, the possible reason for more deviation in (HG) is due to varied livestock intensities that have in turn varied effects on the chemical properties of soil. Similarly, electrical conductivity (EC) of soil samples showed a similar trend of increase from LG to HG.

Organic carbon was found very high in lightly grazed (LG) 7.54%, low in moderately grazed 6.75% and very low (6.52%) in heavily grazed areas. The mean value of organic carbon of all samples has been 6.94% (Fig. 2). It means that grazing causes overall loss of organic carbon in the Himalayan soils. In present study, it has been observed that grazing decreases the levels of OC in MG and HG compared to LG and, is consistent with the findings of other researchers like Schuman *et al.* (1999). It can be inferred that low grazing is essential for increase in soil carbon stores because higher litter accumulation appeared in the LG relative to MG and HG treatments (Gao *et al.,* 2007).

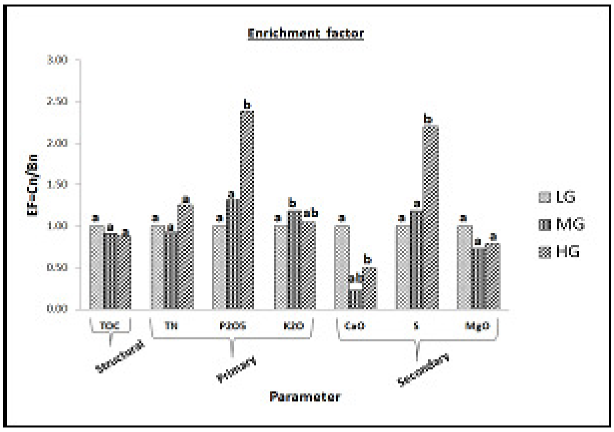

Fig 2. Enrichment factor for the soils under varying grazing pressures in northern Liddar valley of Kashmir Himalaya

TOC: Total organic carbon; TN: Total kjeldahl nitrogen. Different letters placed on the bars represent statistically significant difference at $p \leq 0.05$.

Total nitrogen was 0.08% for lightly grazed, 0.07% for moderately grazed and 0.10% for heavily grazed sites. The increase in the nitrogen with increasing grazing pressure in the soils of HG sites can be attributed to the uneven addition of fresh animal faeces and urine. The substantial amounts of nitrogen in the animal excreta cause the enrichment of sites (Fig. 2) where night camping occurs and ultimately results in the formation of sacrifice zones which are referred as HG in the study. These sites had the herds retained on plots overnight which results in return of greater amounts of Nitrogen to the soil than LG and MG. These responses are likely to happen in grazing treatments with a higher input from excreta. Though increased forage consumption in the

HG treatment resulted in a loss of above-ground plant N, it is estimated that 80 to 95% of consumed plant N is returned in the form of excreta (Peterson *et al.,* 1956; Kirkham, 2006).

Total P concentrations for the lightly, moderately, and heavily grazed paddocks are estimated to be 0.22%, 0.29%, and 0.52% respectively. The P added through excreta, remains in the mode of slow-release, which increases the P content of soils. Mature cattle produce an average of 25 kg of feces plus 9 kg of urine per animal daily. On the average, fresh cattle feces contain 0.18% P_2O_5, while fresh cattle urine contains approximately 0.01% P_2O_5 (Peterson *et al.,* 1956). Furthermore, there will be some loss of P in animal tissue and added to the soil (Kirkham *et al.,* 1996). Extensive studies have shown that maximum species-richness in grassland communities occurs within a narrow range of soil phosphorus levels, e.g. 1.1–5.0 mg P/100g (Jannssens *et al.,* 1998) or 4–15 mg P/litre (Critchley *et al.,* 2002) and that many more endangered species persist under P-limited than under N limited conditions (Wassen *et al.,* 2005).

Elemental scanning has revealed an enrichment of total sulphur content almost 2.21 times in HG as compared to the lightly grazed soils of the same area (Fig. 2). It accounts for 0.04% for lightly grazed, 0.05% for moderately grazed and 0.09% for heavily grazed soils. Total S concentration increases significantly with increasing grazing intensity (Table 2). The huge accumulation of S can be again attributed to uneven addition and distribution of feces to the soils observing heavy grazing (McLaren and Swift, 1977).

Total Ca and Mg are a function of organic carbon and a parallel trend has been found in these two nutrients as well. The highest concentration of total CaO was found in lightly grazed (5.18%) and lowest in moderately grazed (1.19%). The heavily grazed paddocks have (2.59%) of total calcium. Similarly, heavily grazed soils have less MgO (2.58%) content as compared to lightly grazed soils (3.26%) with lowest values in MG (2.38%). 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%. The values for the lightly grazed paddock were more than those of the moderately and heavily grazed ones. The loss of these two nutrients can be attributed to an uncontrolled trampling and removal of these elements by nomadic grazers. However, the increments of these nutrients through the addition of animal excreta during over night camping cause the heavily grazed places with higher concentrations (Shan *et al.,* 2011).

As grazing pressure increased from light to heavy, concentrations of K increased from 2.01% to 2.11%. The mean K_2O content in moderately grazed soils (2.38%) was significantly higher than lightly grazed (2.01%) and heavily grazed (2.11%) soils at $\leq$*0.05*. It has been found that feces are a rich source of potassium and hence moderately grazed and heavily grazed soils have elevated concentrations of K (Fig. 2). The majority of excretal K appears in urine, but virtually all K, whether in urine or of faecal origin, is water soluble and readily available to plants or leaching (Haynes and Williams, 1993). 90% of the K in farm animal manures is available for plant growth (Kirkham *et al.,* 1996). Livestock distribute the excreta heterogeneously at pasture, with high concentrations in camping areas thereby increasing nutrient addition to the levels that would exacerbate adverse effects on botanical composition and health of pastures (Kirkham, 2006).

Nutrient relationships

There were significant correlations ($p \leq 0.01$, $p \leq 0.05$) between different groups of nutrients. The correlations of S and P for total elemental scanning raveled by XRF analysis indicate their fair affinity with other nutrients and this may be the reason for their heavy accumulation in soils of Liddar valley (Table 4).

(LG): Phosphorus (P-N, P-S) and Nitrogen (N-S, N-P) showed positive correlations in lightly grazed (LG) soils though correlation of phosphorus and sulphur is more significant ($p \leq 0.01$) as compared to others and is highly documented in the literature. Table 4 gives a ready reference of all the complex relations in all grazing intensity soil types. A strong correlation exists between Ca and Mg and has been noted by Lewis and Sparrow, 1991; Barros Henriques and Hay, 1992; Karadavut *et al.,* 2015.

(MG): Number of correlations between various chemical nutrients decreases drastically as grazing intensity increases which clearly indicates that disruption of edaphic factors occur as grazing intensity increases (Table 4). However, in moderately grazed soils, sulphur and phosphorus are strongly correlated.

(HG): A strong correlation exists between Ca and Mg, which is highly documented in literature as well. However, a strong relationship of nitrogen with sulphur can be

Table 3. Chemical properties of the top 10 cm soil in different grazing intensities from Northern Liddar valley

Group	Constituents	Unit	Grazing intensity group		
			LG (Mean ±S.E)	MG (Mean ±S.E)	HG (Mean ±S.E)
Non-structural	EC	μs cm^{-1}	304.98a ±(23.97)	301.79a ±(20.01)	469.07b ±(49.46)
	pH		07.43a ±(0.08)	07.44ab ±(0.06)	07.47b ±(0.10)
	TOC	%	7.54a ±(0.69)	6.75a ±(0.70)	6.52a ±(1.0)
	TN	%	0.08a ±(0.12)	0.07a ±(0.01)	0.10a ±(0.02)
Macronutrients	P_2O_5	%	0.22a ±(0.02)	0.29a ±(0.6)	0.53b ±(0.07)
	K_2O	%	2.01a ±(0.10)	2.38b ±(0.16)	2.11 ab ±(0.13)
	CaO	%	5.18a ±(4.11)	1.19ab ±(0.13)	2.59b ±(0.90)
	MgO	%	3.26a ±(0.01)	2.38a ±(0.01)	2.58a ±(0.02)
	S	%	0.04a ±(0.72)	0.05a ±(0.06)	0.09b ±(0.28)

**Within rows, means of parameters followed by different letters represent statistically significant differences at p≤0.05, determined from LSD following ANOVA at d.f. = 7. Standard errors are given in parentheses.*

Table 4. Significant values of coefficient of correlation between various parameters of soil from Northern Liddar valley

Nutrient group	LG		MG		HG	
	r	*p*	*r*	*p*	*r*	*p*
TN–P_2O_5	0.714	0.05	***		***	
TN–S	0.783	0.05	***		0.865	0.01
P_2O_5-K_2O	***		0.766	0.05	***	
P_2O_5-S	0.955	0.01	0.862	0.01	***	
CaO-MgO	0.837	0.01	***		0.928	0.01

*r - Bivariate coefficient of correlation between the parameter in; p - Level of significance. LG: Lightly grazed; MG: Moderately grazed; HG: Heavily grazed; ***Not significant*

attributed to an indiscriminate deposition of nitrogen through urine and deposition of sulphur through feces (Peterson *et al.,* 1956; Kirkham, 2006). The addition of urine and sulphur to the grazing lands is supposed to cause terrestrial eutrophication, which in turn may affect the biogeochemical cycling of the nutrients and finally results in the formation of corrosive links.

Conclusion

The study area has high circulation of transhumant herders and the grazing lands are affected by trampling, consumption, deposition of excreta, export of soil nutrients by large transhumant flocks. The results indicate that heavy grazing resulted in soil coarseness, and low organic C concentrations. Major source of extra nutrients (NPSK) in the overgrazed soils is animal excreta interms of urine and dung. These extra nutrients cause enrichm-ent in the soils and change in nutrient pool causes the vigorous weed species to encroach. Apart from loss of soil organic matter, 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. Loss of fine fractions in soils will have major influences on properties like water-holding capacity, soil consistence, nutrient presence and availability. So, uncontrolled transhumant grazing has been found detrimental to the Himalayan environments.

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