Earth Systems and Environment
https://doi.org/10.1007/s41748-018-0056-8

ORIGINAL ARTICLE

Characterization of Piospheres in Northern Liddar Valley of Kashmir Himalaya

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Received: 4 January 2018 / Accepted: 13 June 2018

Abstract
Grazing in pastures results in the formation of degraded patches called piospheres. It alters soil composition and vegetation in the vicinity of the watering points, shade, mineral licks and sheepfolds. A comparative approach was adopted in Liddar valley of Himalaya to study soil and vegetation composition of piosphere patches using various techniques. Pasture soils were investigated for nitrogen (N), organic matter (OM), pH, electrical conductivity (EC), total phosphorus (P_2O_5), total potassium (K_2O), total calcium (CaO), total magnesium (MgO) and total sulfur (S) using energy dispersive X-ray florescence and physical properties like soil texture and bulk density were also studied using respective techniques. Importance value index and plant species compositions were studied using transect method along the weakening effect radiating outward from center of piosphere. The change in their spatial extent was also studied using remote sensing technique. The results indicate that there is an enrichment of nutrients in piospheres such as N (0.02%), P (0.30%), K (0.04%), S (0.04%), and reduction of others like Ca (0.30%) and Mg (0.38%). Soil fractions like clay decreased by (17.62%) coupled with increase of sand and silt portion by 9.83% and 7.78% respectively, which eventually resulted in increase of bulk density by 0.08%. Furthermore, number of species have decreased to half (31) in the piospheres as compared to non piospheres (64). Paired samples *t* test was performed to determine the differences existed between two grazing intensities. The enrichment of some nutrients especially P results in terrestrial eutrophication which becomes suitable for the encroachment of weedy and unpalatable plant species. Remote sensing data also indicates that the total area under these degraded patches increased from 2.07% in 1992 to 2.69% in 2010. The management perspectives degradation of pasturelands by piosphere formation needs an immediate attention which otherwise shall reduce the grazing area and economic value of grazing lands in Himalayas.

Keywords Compaction · Encroachment · Enrichment · Liddar valley · Piospheres · Unpalatable plant species · Livestock

1 Introduction

The term piosphere is defined as localized impact of grazing on vegetation and soils. The daily incidence of livestock concentrations at such points and in the immediate vicinity implies an uneven impact on the grassland. Lange (1969) coined the term piosphere, where "pios" is the Greek word for drink and "sphere" is representative of the weakening impact of the disturbance on available patch of resources. Local grazing patterns in Himalaya are complex and involve constant movement of livestock to make the best use of available pastures. Sheeps are mostly corralled at night near temporary hut around which various resources like water, shelter salt patch and water are found. Furthermore, economic activities like milking and shearing of sheep are carried around these huts and livestock is congregated during night hours to avoid attacks from wild animals allowing the

Electronic supplementary material The online version of this article (https://doi.org/10.1007/s41748-018-0056-8) contains supplementary material, which is available to authorized users.

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Published online: 28 June 2018

accumulation of dung at patches which are referred here as piospheres.

In the mountainous regions of Kashmir, seasonal grazing has been important to pastoral communities for production of food, fiber, and for income. Recent population increases are likely to put pastures under pressure. As per estimates, total livestock population in the State of Jammu and Kashmir has increased from 9.899 million in 2003 to 10.473 million in 2007 (18th Indian Livestock Census 2007). Because of increasing livestock pressures, the grazing lands at such places become susceptible to piospheric effects and alteration in the condition of the soil cover and vegetation may increase their spatial extent. However, for characterization of piospheres in this study, patch is defined as a relatively homogeneous area with a defined shape and spatial configuration that differs from its surroundings. Study focused on effects over soil and vegetation, exploring temporal trends with remote-sensing information.

In Himalaya, the impact of seasonal grazing by livestock (cattle, buffalo, sheep, goat, pack animals) of ethnic migratory groups (*Gujjar, Bakarwal* and *Pohol)* is seen as a potential agent for encroachment of such patches (Jaweed et al. 2015). These ethnic groups have been given customary rights over their grazing lands where they have earthen and wooden huts. On reaching pastures of Kashmir, flocks are driven to forage rich areas by a shepherd during the day and aggregated at a corral site near temporary hut in pasture for night hours. Equines and bovines are allowed to range freely for about 3 months, however, for medical treatment during delivery and illness they are put in the corral site. Thus, around the corrals animal pressure associated with deposition of feces and urine results in the formation of discrete patches characterized by loose soil, bare ground, poisonous and unpalatable plant species at the peripheries. These patches result in under-utilization of some areas at the expense of others and form the basis of the ecological impact of livestock grazing in the meadows. Nutrient enrichment in the vicinity of such patches can be attributed to the input of dung and urine followed by changes in plant community and soil along the grazing gradient.

On average, 75–80% of the nitrogen is added through animal excreta to the camping sites (Kirkham 2006; Whitehead 2000). The nitrogen added through this mode is a source of ammonia which is responsible for encroachment of invasive plants (Dormaar and Willms 1998; Kirkham 2006; Kotzé et al. 2013; Eldridge and Whitford 2009; Ndaimani et al. 2018). A gradual reduction in biomass, changes in species from palatable plants to unpalatable, repetitive trampling and soil compaction are the indications of piospheric patterns (Shahriary et al. 2012). Such patches lead to alteration of grazing land vegetation by seed dispersal through cattle feces (Rosas et al. 2008).

Sternberg (2012) described how a grazing gradient along watering points changed plant species composition and reduction of economic value of grasslands. Eldridge and Whitford (2009) have found that grazing and trampling alter soil and vegetation condition which often lead to substantial reductions in ecological function. Piosphere influence has been largely studied with a focus on large herds of wild herbivores like elephants (Landman et al. 2012; Ndaimani et al. 2018) by observing effects like declines in perennial plants and species richness (Egeru et al. 2015a; Landman et al. 2012). Furthermore, their influence on landscape degradation showed that vegetation changes along the grazing gradient are characterized with changes in plant cover, particularly perennial species being replaced by annual species (Macchi and Grau 2012; Oba 2012; Teka et al. 2013; Moreno García et al. 2014; Egeru et al. 2015a; Shahriary et al. 2018). Only a few rigorous studies (Gupta and Kachroo 1981; Dad and Khan 2009) of the effects of grazing on vegetation and soils exist on degradation process of Himalayan pastures. All these studies were carried leaving a big data gap regarding the effect and propagation of such patches in temperate pasturelands. Previous studies from semi-arid grasslands over the globe that focus on describing the changes along the gradient are not possible in the present study because Himalayan pastures undergo a complete rest of grazing for more than 6 months because of cold season and snowfall. Furthermore, rugged terrain homogenizes the various spheres of a traditional piosphere to a single patch. Thus, the design and comparison of two areas in present shall help to describe the formation of such patches.

Thus, the present study attempts to identify and characterize piospheres with its applicability in all regions observing seasonal migratory grazing and temperate climate.

However, analysis of soil and vegetation is lacking to highlight the effect of grazing on pasture ecosystems due to piospheres. These aspects are very important for assessment of the pasture conditions and the information could be scientifically beneficial for the pasture improvement. Thus, the present study aims at understanding (1) the difference between characteristics of piospheric and non-piospheric soils (2) the differences of plant composition between piospheres and non Piospheres and (3) the trend of encroachment by piospheres. This study of the localized impact of concentrated herds on the soil and vegetation of rangelands in the Liddar valley potentially provides useful information for understanding the impact of livestock on the alpine vegetation, particularly as the ecology of the region has not been comprehensively researched. Thus, valuable information for range management can be achieved by an extension of this work.

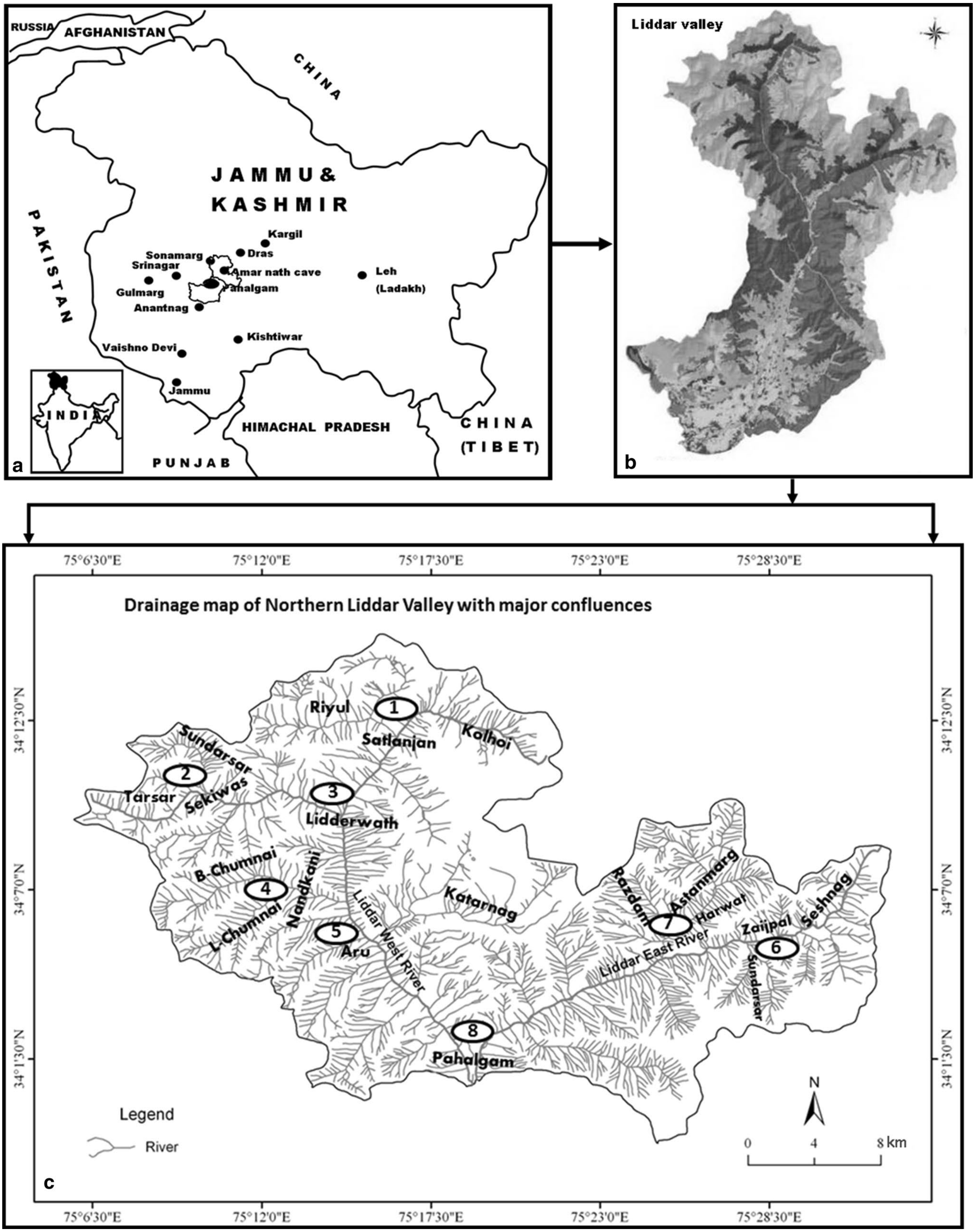

Fig. 1 Map showing location of study area and major confluences of streams which offer best pastoral resources like water, fuelwood, etc. Degradation starts from sheep holding pen located near temporary houses and water source in the sub valleys numbering from 1–8

2 Materials and Methods

2.1 Study Area

One of the Kashmir valley regions most explored by these ethnic groups is Liddar valley (Fig. 1b). Its total area is 1248 km^2 however, only 627 km^2 were taken for the study, which is situated between 34° 00′ 00"N–340 15′ 35″N and 75° 06′ 00″E–75° 32′ 29″E (Fig. 1c) and documented as Northern Liddar valley. The soils in the study area qualify for Mollisols with an organic matter rich Mollic epipedon and udic soil moisture regime (NBSS and LUP 1991; Najar et al. 2009). Action of glaciers, rivers, high altitude, and geophysical setting has bestowed it with 69.55% pastures (Forest working plans 1991). The area receives the highest rainfall in the month of March (208.8 mm) and the lowest in the month of October (45.9 mm). Such a climatic regime is a peculiar characteristic of the sub-Mediterranean type of climate. Moreover, 70 percent of its annual precipitation concentrated in winter and spring months in the form of rain and snow.

Pastoralism represents an optimal economic activity to meet the basic livelihood needs in this part of the valley. However, due to grazing practices associated with the pastoralism, the pasturelands are experiencing the formation of piospheres. Thus, we classify our study sampling plots into:

Non-piospheres Soils (NpS) are assumed that to have a complete absence of livestock pressure. This is difficult because livestock is freely dispersed in the space. However, a zone rich in continuous vegetation cover, presence of native plants like *Thymus linearis, Fragaria nubicola, Impatiens brachycentra* and *Sibbaldia cuneata* and less deposition of animal excreta were identified as NpS. These were arbitrarily preserved by the government or local people for ethical or state purposes throughout the study area.

Piosphere Soils (PS) are currently used by livestock, with fresh dung deposition, adequate water availability and temporary dwellings in the vicinity. Such patches are found along the low-lying migration routes and are areas of camping sites for cattle, sheep and buffaloes, where grazing animals assemble during night hours. These patches have huge grazing pressures for almost 12 h during night camping. Because of the heavy concentration of cattle around settlements, the pasturelands tend to deteriorate (Fig. 2). The species with the highest IVI have been documented as dominant species. Furthermore, sheep density has been mentioned in the table and other animals have been converted to sheep units using method adopted by (USDA 1997).

2.2 Sampling

The soil sampling has been carried out in the two grazing intensities NpS and PS (Fig. 3) with uniform topography. The piospheres (PS) were defined on the basis of discontinuities in soil and vegetation cover around enclosures used for concentrating the livestock. Both areas were sampled using Core tube method for collection of soil samples (7.62 cm

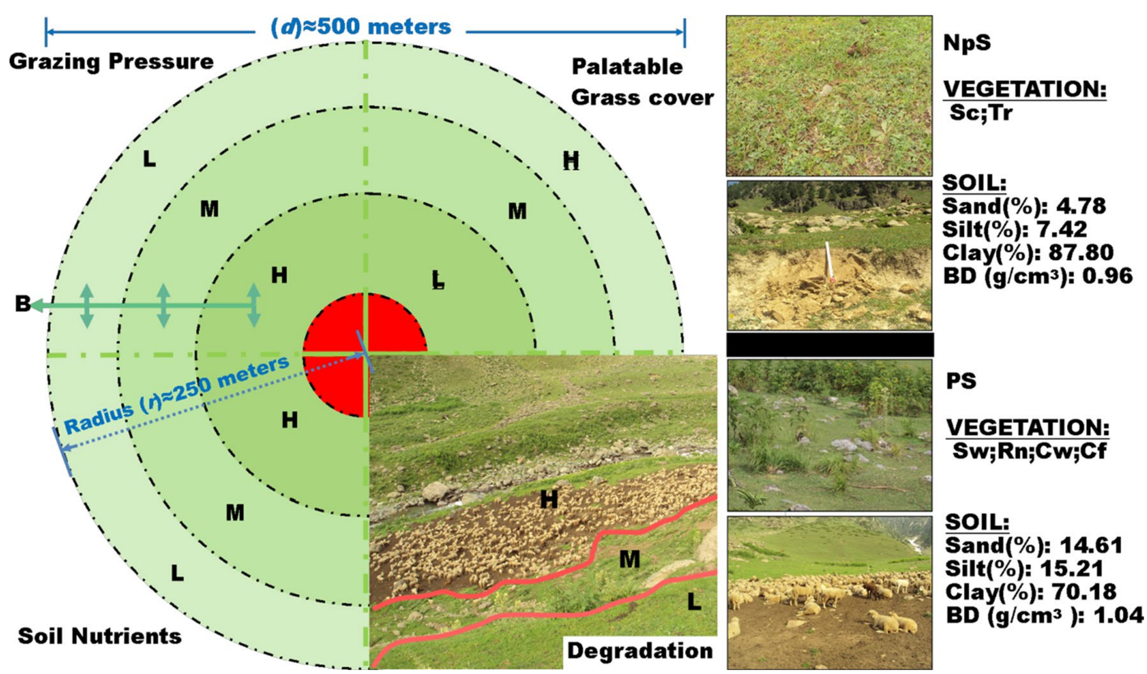

Fig. 2 Piosphere with various degrees of degradation, note that degradation in the figure started from a sheep holding pen located near a temporary house and water source. *L* Light, *M* Moderate, ***H*** High, *B* Barkhan chain, *NpS* Non Piospheres, *PS* Piospheres, *Sc Sibbaldia cuneata, Tr Trifolium repens, Sw Sambucus wightiana, Rn Rumex nepalensis, Cw Cirsium wallichii; Cf Cirsium falconeri BD* Bulk Density of soil

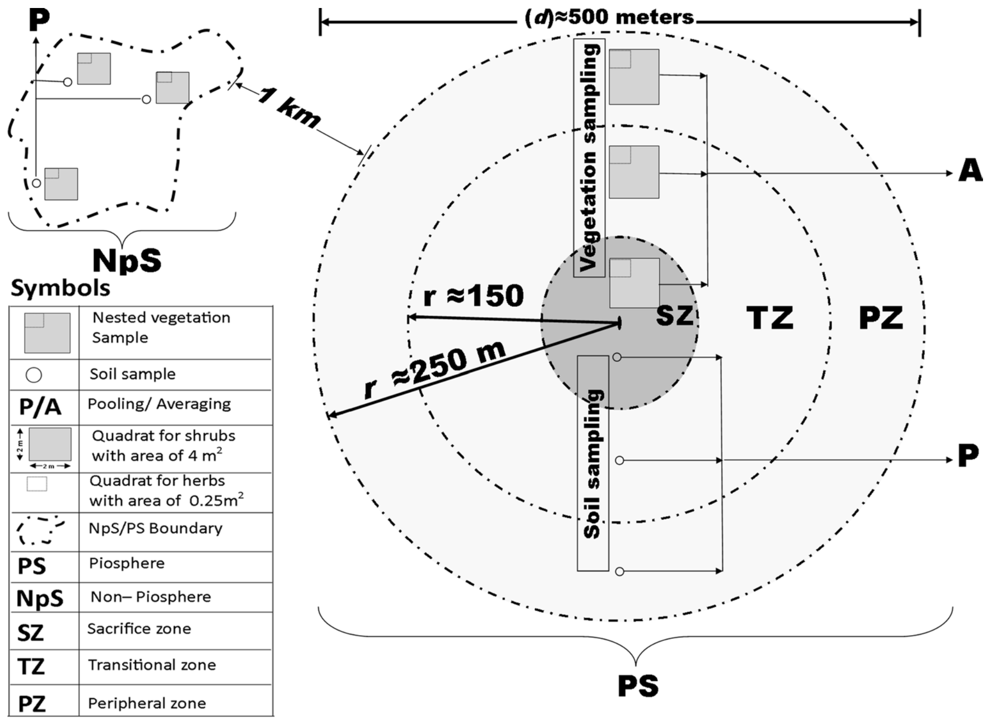

Fig. 3 Sampling strategy for Piospheres (PS) and Non Piosphere (NpS) at confluences representing major pastoral activity areas in Lidar valley of Kashmir Himalaya. Soil sampling and vegetation analysis have been carried out along transect from sacrifice zone (SZ) in the center to transitional zone (TZ) and peripheral zone (PZ)

diameter × 10 cm deep). The sampling sites were established on the basis of types of habitats for plants and use by grazing animals and degree of disturbance.

The Liddar valley has eight major confluences forming small valleys (Fig. 1c). Every confluence has a piosphere, temporary huts, camping sites and sheepfolds in the vicinity. Resources optimum for livestock and human populations are available at these places (Sheng et al. 2016). Thus, transects in piospheres (PS) were laid across the valley at eight sites. For the purpose of the study, soil samples were collected from a piosphere and a non-piosphere with a minimum distance of 1 km between the two (Fig. 3). Within each transect three sampling units were selected for every piosphere (SZ, TZ and PZ in Fig. 3) and the samples were pooled. Pooling of samples collected from zone SZ, TZ and PZ has been done instead of detailing variances within the piosphere to demarcate piosphere as a single patch. Thus, eight composite samples were analyzed, and each composite sample is the result of pooling the three zones around each piosphere. Paired sampling approach was used, i.e., pairs of PS and NpS sites examined at each of $n=8$ (NpS and PS). Two cores were collected at each point; each of them was pooled for chemical and physical analysis, respectively. For bulk density, three separate measurements were conducted and then averaged. Thus, three samples each were collected from NpS site and PS in each valley and replicates were mixed thoroughly, air dried and passed through a 2 mm mesh.

Vegetation measurements were conducted along a transect (Fig. 3) for three randomly placed quadrats in each site similar to soil sampling (three for herbs and three for shrubs). Within each transect three sampling units were selected for every piosphere (SZ, TZ and PZ in Fig. 3) and averaged to demarcate piosphere as a single patch and compared against paired nonpiosphere areas nearby. The classification of palatable and unpalatable plant species has been adapted from the previous literature (Ranjeet et al. 2010). Furthermore, pastorals were interviewed to know the changes plant species of the pastures.

Change in spatial extent using Landsat TM data has been carried out using remote sensing images over a period of two decades. Ground truthing for classification of remotely sensed data was determined based on simple randomized sampling technique wherein the number of sample points selected for ground truthing was calculated using the formula given by Snedecor and Cochran (1967).

$$n = \frac{p \times q}{d^2}$$

where p is the desired proportion of estimated accuracy; q is 100-p; d is the standard error (five percent), where p, q and d are expressed in percent. At $p=95$ percent and $d=5$ percent, the number of sample points (n) to be selected, works out to be 19. These were selected after laying 2 km grids on the base map. It was ensured that every land use type is represented during ground truthing. Furthermore, lack of high resolution data for the study of small piospheres delimited the study for not using Geostatistics (kriging) which could have been more proper to determine spatial variation in the soil and plant properties affected by different stocking density.

2.3 Techniques

2.3.1 Determination of Soil Physical Properties

Texture refers to the size of the particles that compose the soil. The terms sand, silt, and clay refer to relative sizes of the soil particles. The percent course fraction was calculated as a portion of the weight of the total weight. Based on these proportions soils are classified into the following textural classes: sand (2.0–0.050 mm), silt (0.050–0.002 mm), and clay (< 0.002 mm). Hydrometric method was used for determination of different soil separates using Sodium hexa-metaphosphate as a dispersion agent (Jackson 1973) after manually removing visible root remnants. Bulk density is defined as the mass (weight) of a unit volume of dry soil. This volume includes both the pore space and the solid space. Using a known volume of soil the bulk density was calculated by oven drying to remove any capillary and hygroscopic water. It was determined by core tube method using a cylindrical steel core tube approximately 10 cm long and 7.6 cm internal diameter with wall thickness approximately 3 mm, as determined by Van Haveren (1983).

2.3.2 Analysis of Chemical Properties

The organic carbon was determined with the Walkley–Black Potassium dichromate oxidation procedure (Walkey and Black 1934). Soil is oxidised by 1N $K_2Cr_2O_7$ solution and reaction is assisted by the heat generated when two volumes of H_2SO_4 are mixed with one volume of the dichromate. The remaining dichromate is titrated with ferrous sulphate using Diphenyl amine as Indicator. 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* and was determined with the Kjeldahl procedure (Jackson 1973). The method consists of three basic steps: (1) digestion of the sample in sulfuric acid with a catalyst, which results in the conversion of nitrogen to ammonia; (2) distillation of the ammonia into a trapping solution; and (3) quantification of the ammonia by titration with a standard solution.

Other than Organic carbon and total nitrogen, elemental mapping of soil samples was carried out by Energy Dispersive X-Ray Fluorescence using SPECTRO XEPOS ED-XRF-Hong Kong, in which five g of soil samples were subjected to analysis. The samples were collected and prepared using plastic equipments to avoid addition of minerals. It has the advantage that analysis can be performed for various elements and limit of detection is approximately 10–8 µg.

2.3.3 Vegetation Survey

Quadrat method was used with the size of the quadrats used as 50 × 50 cm (0.25 m^2) for herbaceous species and 2 × 2 m (4 m^2) for shrubs determined on the species–area curve which remains standardized by Dad and Khan (2009) for such meadows. Within each quadrat, the number of plants was counted for species to estimate the average value. Plant samples were identified with the help of local floras (Polunin and Stainton 1988). Importance value index (IVI) of each plant species was calculated for each site to examine dominant species. Vegetation composition was evaluated by analyzing the frequency, density, abundance and IVI (Shannon and Weaver 1949; Magguran 1988; Curtis and McIntosh 1951), using the following formulae:

$$\text{Frequency} = \frac{\text{Total no. of quadrats in which the species occured}}{\text{Total no. of quadrats studied}} \times 100$$

$$\text{Relative frequency (\%)} = \frac{\text{Frequency of a species}}{\text{Frequency of all species}} \times 100$$

$$\text{Density} = \frac{\text{Total no.of individuals of a species}}{\text{Total no.of quadrats studied}}$$

$$\text{Relative density (\%)} = \frac{\text{Number of individuals of a species}}{\text{Number of individuals of all species}} \times 100$$

$$\text{Relative Dominance (\%)} = \frac{\text{Basal area of a species}}{\text{Basal area of all the species}} \times 100$$

IVI = Relative frequency + Relative density + Relative dominance.

Basal area is thought to be ecologically more significant than density or frequency because it is an estimate of how much a plant dominates an ecosystem (Greig-Smith, 1983). Basal area measurement was based on the following formula:

Total basal area = Mean basal area of a species × density of that species

$$\text{Mean basal area (MBA)} = \frac{C^2}{4\pi^2}\left(\text{cm}^2\right)$$

$$\text{Or MBA} = \frac{C}{2 \times 3.14}$$

where *C* is the average circumference of one individual of that species, and MBA is expressed as cm^{-2} $plant^{-1}$.

Species diversity (Shannon–Wiener diversity index; *H*') was calculated as:

$$H' = -\sum_{i=1}^{s} (\text{Pi} \ln \text{Pi}) \tag{1}$$

where S = number of species and Pi = proportion of species i.

2.3.4 Spatial Analysis

Landsat TM data of 1992 and 2010 procured from http://glcf.umiacs.umd.edu/data/landsat and datasets like ground survey observations, Survey of India toposheets and forest administration map with 1:50,000 scale were used to find spatial extent of piospheres. Both the Landsat images have been geometrically rectified and geo-referenced upon acquisition to UTM zone 43° North with WGS-84 Datum. The assessment of land use and land cover was done by adopting a classification scheme (Jaweed et al. 2014) for the Landsat images and carrying out a supervised classification (Maximum likelihood) based on ancillary data from thematic maps and other information and literature sources. Supervised classification of the Landsat TM 2010 data was carried out initially and area of interest (AOI) of the same places has been used for classification of Landsat TM 1992 data to carry out change detection analysis.

2.4 Statistical Analysis

Soil characteristics between the two types of grazing meadows (NpS and PS) were analyzed through paired samples t test. Variables used in the analysis included properties like percent sand, silt, and clay. While chemical properties include pH, EC, C, N, P, K, Ca, S and Mg. All of the variables met the statistical assumptions (residuals normality, homogeneity of variance and data linearity). Shapiro–Wilk test ($p \geq 0.05$) and a visual inspection of their histograms, Normal Q–Q plots (Razali and Wah 2011) showed that the residuals were approximately normally distributed for both NPS and PS. Significant differences for all of the statistical tests were evaluated at the level of $p < 0.05$. All the statistical analyses were performed using the SPSS Inc., Chicago software program, ver. 16.0.

3 Results

3.1 Soil Particle Size Distribution and Bulk Density

The movement of livestock and the continuous free grazing induces reduction of fine particles followed by increased coarseness of the soil especially in the top layer. Analysis of particle size revealed that sand and silt contents are higher in soils with high grazing pressures. These components have twofold increase in piosphere soils (PS) as compared to non piosphere soils (NpS) as shown in Table 1. There is 1.87 fold increase in sand content and 2.05 fold increase in silt content. Conversely, there is a significant decrease ($p < 0.05$) in clay content of piospheres. Increase in bulk density is a function of increase in sand percentage of soil thus, comparison of the two grazing systems indicates that piosphere soils have greater bulk density (more compacted) than the non-piosphere soils, which were 0.96 and 1.04 g/cm^3 for NpS and PS, respectively.

3.2 Soil Chemical Properties and Nutrient Enrichment

The soils from piospheres have less organic carbon (6.52%) as compared to non-piospheric soils (7.54%). Similarly, there is a significant difference between the total calcium and magnesium content of two soils, where piospheres have 1.40% and non piospheres have 1.70% total calcium content and PS have 3.06% and NpS have 2.68% total Magnesium.

Soil EC has a significant increase ($p < 0.01$) in piospheric soils. The change in soil EC is a manifestation of increase in

Table 1 Physical properties of the top 10 cm soil among two grazing intensities in Northern Liddar valley—Kashmir

Physical property	Unit	Grazing intensity	Paired sample descriptive characteristics					Comparisons	Paired differences at 95% confidence interval of the difference			
			Mean	Median	Std. deviation	Minimum	Maximum	Mean difference (NpS-PS)	Lower	Upper	t value	p value
Sand	%	NpS	4.78	4.05	3.33	0.80	9.90	−9.83	−17.02	−4.90	−4.28	0.00
		PS	14.61	14.8	3.29	10.20	20.90					
Silt	%	NpS	7.43	7.00	3.26	3.70	12.30	−7.78	−11.82	−1.51	−3.06	0.01
		PS	15.21	12.8	5.09	11.30	23.90					
Clay	%	NpS	87.80	90.4	6.22	78.60	94.80	17.62	12.85	22.40	8.73	0.00
		PS	70.18	71.6	5.14	60.60	76.70					
Bulk density		NpS	0.96	0.95	0.07	0.88	1.08	−0.08	−0.016	−.00001	−2.42	0.04
	g/cm^3	PS	1.04	1.02	0.04	0.97	1.10					

Paired samples test significant differences at $p < 0.05$, at d.f = 7 the total content of Potassium in PS (2.16) as compared to NpS (2.09). Enrichment of K has a direct effect on increase in pH as well.

Significant enrichment of phosphorus ($p < 0.000$) is restricted to the PS (0.52%) as compared to NpS (0.22%). Concentration of faeces deposition (during the night) seems to be an obvious reason for the higher P concentration in PS compared to NpS (it would appear that cattle are more effective conduits for phosphorus). Furthermore, experiments have shown that the addition of excreta increased the total amount of sulfur in PS (0.08%) as compared to NpS (0.04%). Similarly, there is a significant increase in total nitrogen in piospheres. The estimated mean differences were more likely to have been a result of the livestock concentration and present attempt has highlighted these changes in situ (Table 2).

3.3 Changes in Plant Distribution

Number of species has decreased to half (31) in the piospheres as compared to non piospheres (64). Similarly, the number of families was reduced from 29 in NpS to 19 in PS. Furthermore, decrease of palatable plants in PS and encroachment of unpalatable plants in NpS has resulted in a change in diversity index (*H*') of grasslands (Table 3). A significant change in diversity index is due to the fact that most of the dominant plants (appendix S1) like *Fragaria nubicola, Impatiens brachycentra*, *Juncus thomsonii*, *Poa annua*, *Rumex nepalensis*, *Sibbaldia cuneata*, *Taraxicum officinale*, *Trifolium repens,* etc., are damaged due to piospheric effects.

Thus, the properties of these zones are summarized in Table 3.

3.4 Spatial Extent of Piospheres

The remote sensing analysis of the study site shows that the area of grazing land (Alpine, subalpine and Piospheres) was initially 249.33 km^2 in 1992 which accounts 39.77%, it gradually increased to 258.55 km^2 in 2010 (41. 24%). Among these lands, changes in piospheres with a total extent of 2.07% (12.98 km^2) in 1992 and 2.69% (16.87 km^2) in 2010 has been highlighted through Fig. 4.

4 Discussion

In Himalayan pasturelands, sites currently used by livestock camping with fresh dung, water source, tent dwellings and sheepfolds in the vicinity can be called as piospheres. By definition then a piosphere may occur at any point in the landscape where there exists a resource for animals. Closer to the sheepfold (2–3.5 m) there develops a belt of degradation (Figs. 2, 3) associated with soil compaction, is a most important factor for encroachment of piospheres and is also associated with increase in sand and silt content and decrease in clay content. The texture of the soil is expected to change along a grazing gradient because the finer fractions of the soil are lost first resulting in the increase of soil density (Jawuoro et al. 2017). Furthermore, increase in Bulk density tends to occur by the trampling of the moist soil by animals causing removal of the protective plant cover. The loss of herbaceous cover and increased run-off results in a higher rate of soil erosion. Venter (1990) estimated that 2.55 million tons of soil have been lost by wind erosion at a single piosphere in the Kruger National Park. The compacted soil becomes altogether different biotope which invites poisonous and unpalatable plants and reduces economic value and ecosystem services of pastures. The grazing pressure diminishes with distance from center, forming a gradual change in vegetative cover, species composition and soil properties. These spheres of varied degradation along the grazing gradient are called as “Barkhan chains”. The central most part of the piosphere hitherto referred as sacrifice area is called as “Sore spot” by foresters because of its color. However, the sore spot is a misnomer because the patch has elevated pH and EC which are supposed to be changed by the addition of Na^+ and K^+ through animal urine.

Since the total carbon content of the NpS soil was higher than that of PS soil. The lower annual input of carbon from biomass due to increase in sand percentage seem to be the main reasons for the lower organic carbon content in topsoil of the piospheres as compared to those of the non-piospheres. Smoliak et al. (1972) showed similar changes in *C* content which were due to increase in amount of sand content thereby increase in bulk density. Thus it is evidence that soils were more or less compacted as a result of livestock concentration resulting from the hooves of grazing animals pounding down the soil too often in the same area which becomes difficult to correct (Jawuoro et al. 2017). Furthermore, organic matter in soil can absorb and store much more water than can inorganic fractions. It acts like a sponge, taking up water and releasing it as required by plants. It also helps bind soil particles into larger aggregates, or crumbs. Soils with high carbon are very resistant to erosion. Conversely, nearly all soils containing little or no organic matter after heavy grazing are very susceptible to loss of clay fraction. The continued trampling of numerous animals in a pastureland will act to accelerate the death of plants and vegetation cover (Egeru et al. 2015b). This is because the animals will graze even on the slightest shoots of new growth. Without the plants or vegetation cover, the soil is left bare and exposed to harsh weather such as heavy downpour followed by churning effect of hooves during browsing, carries the topsoil away. Thus, animal induced soil detachment (aggregate disruption by trampling) makes

Table 2 Chemical properties of the top 10 cm soil among two grazing intensities in Northern Liddar valley—Kashmir

Group	Sub-group	Chemical property	Unit	Grazing intensity	Paired sample descriptive characteristics					Comparison	Paired differences at 95% confidence interval of the difference			
					Mean	Median	Std. deviation	Min.	Max.	(NpS–PS)	Lower	Upper	*t* value	*p* value
Non-structural	Non-structural	EC	$\mu s\ cm^{-1}$	NpS	302.11	302.10	61.16	230.52	400.08	−169.22	−295.62	−42.81	−3.17	0.01
				PS	471.32	471.32	138.58	316.20	677.28					
		pH		NpS	7.43	7.38	0.04	7.39	7.53	−0.03	−0.05	0.00	−2.30	0.05
				PS	7.46	7.47	0.03	7.40	7.50					
Macro Nutrients	Structural nutrient	TOC	%	NpS	7.54	7.7	0.25	7.27	8.06	1.02	0.46	1.57	4.33	0.00
				PS	6.52	7.05	0.72	5.90	8.20					
	Primary nutrients	TN	%	NpS	0.08	0.08	0.01	0.05	0.09	−0.02	−0.05	0.00	−2.30	0.05
				PS	0.10	0.08	0.03	0.05	0.15					
		P2O5	%	NpS	0.22	0.24	0.07	0.11	0.33	−0.30	−0.42	−0.19	−6.36	0.00
				PS	0.52	0.54	0.12	0.32	0.71					
		K2O	%	NpS	2.09	2.14	0.02	2.07	2.11	−0.07	−0.10	−0.03	−3.92	0.00
				PS	2.16	2.14	0.04	2.08	2.22					
	Secondary nutrients	CaO	%	NpS	1.70	1.33	0.22	1.39	1.98	0.30	0.11	0.49	3.64	0.00
				PS	1.40	1.47	0.19	1.04	1.58					
		MgO	%	NpS	3.06	2.89	0.28	2.38	3.24	0.38	−0.00	0.77	2.35	0.05
				PS	2.68	2.48	0.41	2.13	3.49					
		S	%	NpS	0.04	0.04	0.01	0.02	0.05	−0.04	−0.07	−0.01	−3.27	0.01
				PS	0.08	0.07	0.03	0.03	0.12					

Paired samples test significant differences at $p < 0.05$, at d.f = 7

EC electrical conductivity, *TOC* total organic carbon, *TN* total nitrogen

Table 3 Plant species richness diversity and animal preferences among two grazing intensities in Northern Liddar valley Kashmir

Variable	NpS	PS
Number of species	64[a]	31[b]
Number of families	29[a]	19[b]
Shannon–Wiener's diversity index (H')	3.03[a]	2.51[b]
Palatable plants	38[a]	12[b]
Un-palatable plants	25[a]	19[b]
Sheep density/km^2	100	1500
Dominant vegetation	*Sibbaldia cuneata Trifolium repens*	*Sambucus wightiana Rumex nepalensis Cirsium wallichii C. falconeri*
Visual identification	Full herbaceous growth, intact soil cover	Fresh dung deposition, Bare and loose soil

Within rows, means of parameters followed by different letters represent statistically significant differences at $p < 0.05$, determined from paired samples test at d.f. = 7

Himalayan grasslands at stake. It is highlighted through the results of this study that piospheres have influence on soil physical and chemical properties. This effect is however, not yet very dramatic; this could be due to the fact that most of the piospheres are still fairly young in age and undergo a rest for winter months.

Uneven dung and urine distribution during grazing time (Mid-April–Mid-October) near herder's camps implies that the enrichment of soil occurs due to the centripetal movement of primary nutrients and sulfur (Table 2) from the area over which animals graze. The primary nutrients like nitrogen, phosphorus, potassium and secondary nutrient like sulfur are principally deposited through animal excreta (Kirkham 2006). Such enrichment occurs because grazing animals harvest plant nutrients (N, P, K, S, and micronutrients) from a wide pasture area and concentrate them on a limited area. A small proportion of these nutrients are used by the animal for meat and milk production, remaining portion being returned to the pasture in a concentrated form in the dung and urine. The grazing process, therefore, results in the pastures having a mosaic of very high fertility patches against a background of lower (uniform) fertility.

About 90% of the potassium excreted by the animal is in the urine (Kirkham 2006; Egeru et al. 2015b). This results in enormous concentration of potassium in urine patches. Similarly, in Liddar valley, areas around stock camps and other places for animals to congregate can become enriched by potassium resulting in increase of pH and electrical conductivity. Furthermore, it would be worth to state that the process of salinization occurs by uncontrolled grazing which in turn increases the pH and EC. Increase in pH of soil solution is coupled with increases the solubility of soil organic matter (Kirkham 2006; Egeru et al. 2015b). The enrichment of nutrients like K and S is associated with the un-palatability of plants. Thus, floral component of the Himalayan grasslands is modified by anthropogenic agents in terms of livestock by grazing. Similar centripetal trends of soil nutrients were also found in central Mongolia and other grazing lands (Augustine 2003).

Much of the Ca and Mg is displaced (salting out) off the soil cation exchange sites by K^+ from hydrolysis of the urea. Leaching of calcium (Ca) and magnesium (Mg) from urine patches in grazed grassland represents a loss of valuable nutrients. The loss of Ca^{2+} and Mg^{2+} from soil is not an environmental concern; however, both have a primary function of soil strength. With the loss of Ca and Mg from piospheres, the soil profile is disturbed resulting in carbonates being closer to the surface and increase in soil pH and EC (Di and Cameron 2004).

A gradient of utilization pressure develops which is greatest near the resource point and decreases with distance from it. Species composition is impoverished following the destruction of palatable plants. An undesired restructuring of the plant association takes place whereby the most common plant species lose ground to less useful species of some selected families like Labiatae and Compositae. Other than changes in vegetation cover and soil chemistry, the impacts of piospheres include increased levels of exotic and unpalatable plant species. The utilization of vegetation by herbivores in the vicinity of newly constructed resource patches declines various plant species particularly palatable species that are preferred by livestock (Jawuoro et al. 2017; Shahriary et al. 2012). The unpalatable and weedy plants like *Cirsium falconeri, Cirsium wallichii, Euphorbia wallichii, Rumex nepalensis, Stipa sibirica* and *Urtica diocia* have increased (Fig. 5). Species diversity has declined near PS areas. At a short distance from sacrifice area, unpalatable species like *Rumex nepalensis* and *Sambucus wightiana* develop which are virtually untouched by livestock. It has been studied that high nutrient levels due to increase in cattle feces and urine may allow these plants to establish (Wassen et al. 2005; Jawuoro et al. 2017) and the increased disturbance from hoof action can also increase probability of exotic species to establish their seeds which have growth

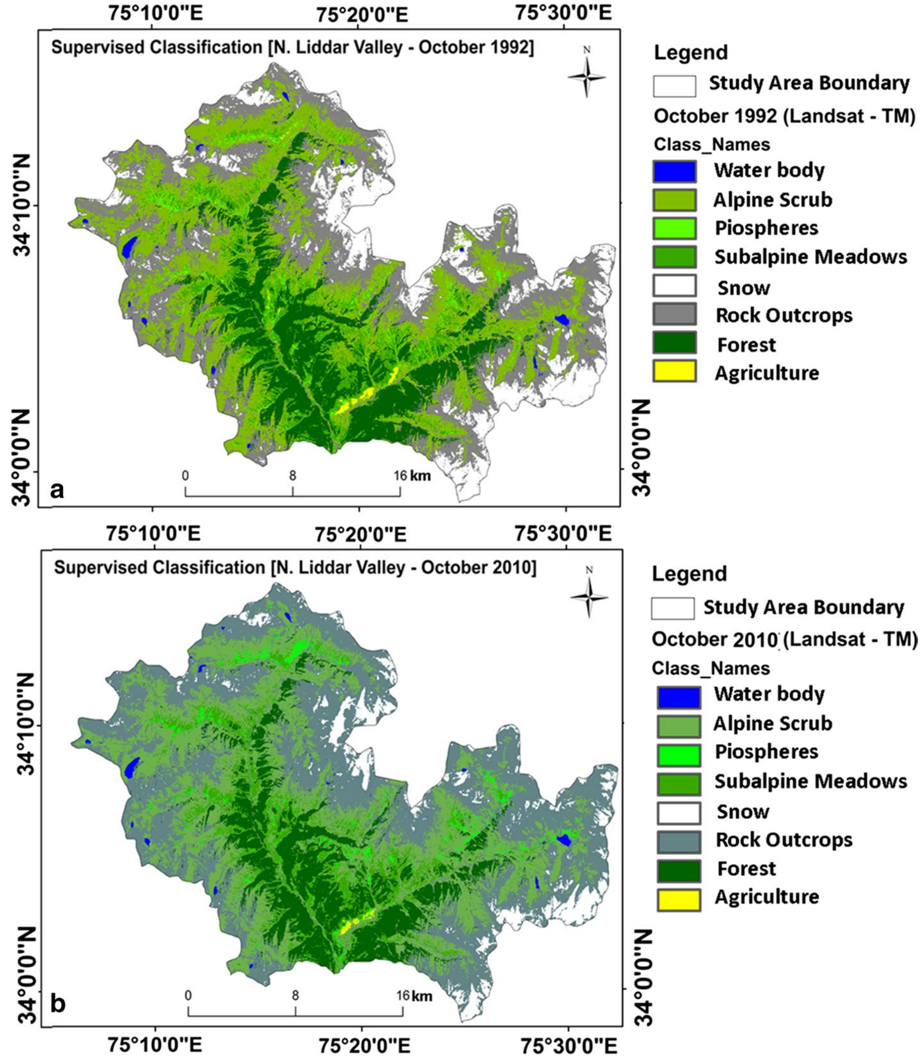

Fig. 4 Classified images from Landsat-TM data of 1992 and 2010. The comparison depicts change in spatial extent of Piospheres. Their bright reflectance because of weedy growth helps for their identification and classification

strategies very much opposite to that of naturally inhibited plants (Thrash 1997).

This study has established the persistence of some annual herbaceous species around the piospheres is indicative of degradation. Influence on the degradation at landscape level is however mixed and the impact has produced an invariably composite, complex and spatially diverse heterogeneous landscape. This will have an impact on the composition and abundance dynamics of desirable forage species in the sub-region.

These changes result in alterations of plant community composition by decreasing proportion of native species (decreasers) and increasing proportion of grazing-tolerant species (increasers and invaders). These changes are followed by gradual alterations in species composition from palatable plants to unpalatable, disturbance of soil through increased trampling and higher nutrient concentrations (N, P, S) by deposition of urine and feces along the distance gradient as shown in Fig. 2. The present rate of deterioration is also as a result of continued misuse by non pastoralists, which has resulted into proliferation of noxious and poisonous weeds. The denudation has also been caused by the nomads on the specified routes of their actual transhumance. The mapping of such areas is an early indication for their existence in Himalaya, never been researched and documented before. Their increase is exacerbated by the present increase in livestock population and phenomenal commercialization of subsistence pastoralism.

With the substantial increase in human and livestock population in the past few decades, there is a continuous, unrestricted and excessive grazing pressure on our pasturelands and has resulted in their degradation. As a result, more than 15% of the study area and 50% of forest area of the Jammu and Kashmir state is degraded (Jaweed et al. 2014) and infested with weeds which makes it difficult to sustain the continuous supply of good quality fodder for livestock population of about 10.99 million in the state. Our forests are open to grazing except in some closed areas (Tak 2010). The

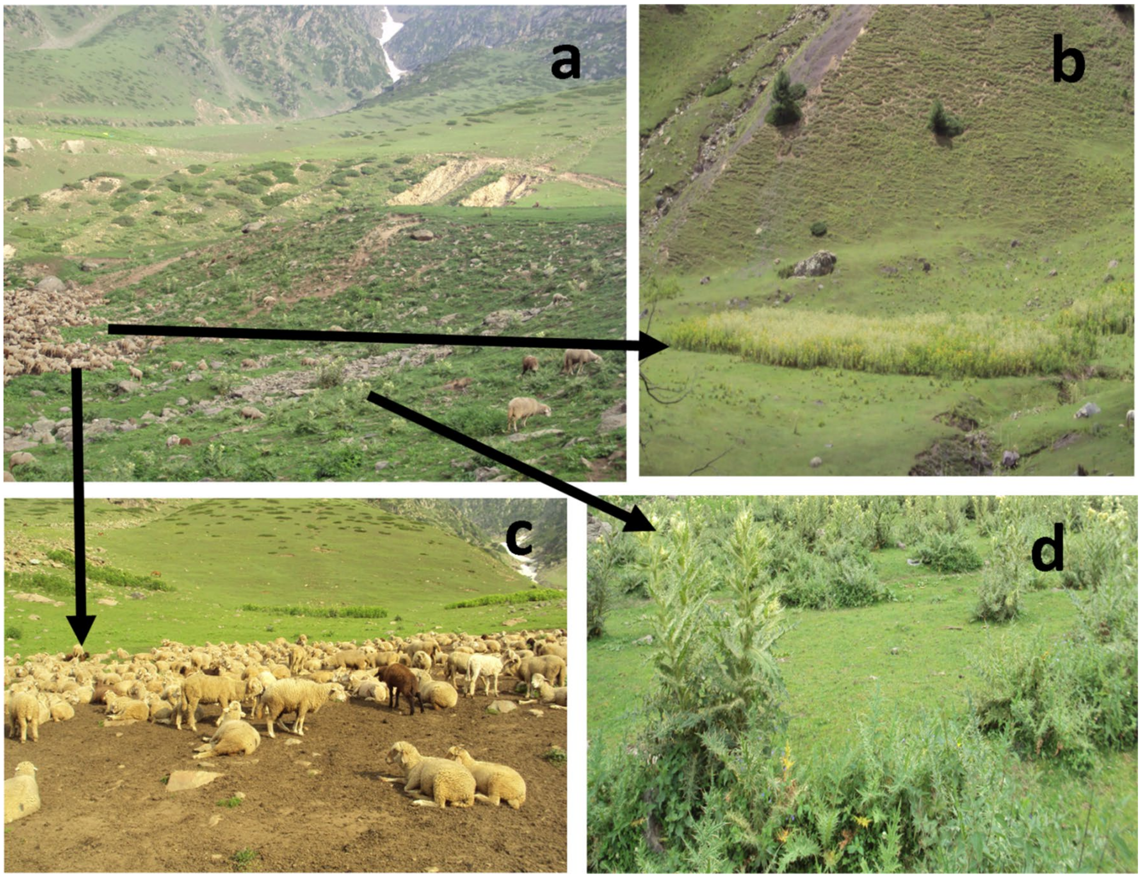

Fig. 5 Effect of grazing on Himalaya **a** Piosphere syndrome in pasturelands **b** Infestation of weeds like *Rumex nepalensis* and *Sambucus wightiana* **c** conglomeration of sheep and cattle at a piosphere around a dwelling hut. **d** The unpalatable and weedy plants like *Cirsium falconeri, Cirsium wallichii, Euphorbia wallichii, Rumex nepalensis, Stipa sibirica* and *Urtica dioca,* etc

rural population depends mostly on pasturelands for fodder requirements and forage, as 73% of population living in rural areas is associated with agricultural and allied sectors having livestock rearing as main occupation. Thus, the degradation of pasturelands in Kashmir needs an immediate priority for sustainable animal husbandry.

The area of piospheres remains from 0.15–0.20 km^2, which is very small as compared to piospheres formed in Australian grazing lands. In the present study, the problem is not intense to that extent because the meadows undergo a complete rest from grazing during winter months (Mid-October to Mid-April) which increases the resilience of these ecosystems.

5 Conclusion and Recommendation

Studies have utilized remote-sensed data to examine land changes with conclusions showing expansion and development of Piospheres. Uneven grazing intensity is an inherent feature of pastoral grazing system in Himalaya, posing a risk of piosphere formation. Thus, present situation demands comprehensive restoration planning for such areas with systematic treatment for weed eradication and to restore the natural mix of vegetation. The sustainable grazing in pastures can be achieved by avoiding the act of grazing too early in the rainy season (spring) so that there is enough grass in the dry periods (summer). The rest from grazing during the early summer helps retain the clay portion which otherwise is lost with water after churning with hoof action of cattle. Thus, propagation of grass species like *Phleum pratense, Lolium perenne, Dactylis glomerata, Festuca kashmiriana* and *Phleum alpinum* must be encouraged. These plants shall not only help the sustainable grazing but shall conserve the fragile soil of these pastures. The government of Jammu and Kashmir has started taking a keen interest in development and improvement of pastures (http://jksheephusbandrykashmir.nic.in/Forage_Production.html). Pastoralists need to be encouraged to participate in pasture development by way of providing them free inputs including chemicals and necessary machinery on subsidized rates for pasture development.

Acknowledgements The authors express their deep sense of gratefulness to an anonymous reviewers and the editor for their many fruitful suggestions that helped to improve the manuscript. We also thank USGS for providing Landsat and ASTER data at no cost. We are thankful to Indian army (14-G) and Jammu Kashmir Police (14-C) for logistics during the study. The study was financially supported by Jawaharlal Nehru Memorial Fund (JNMF) - New Delhi.

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