eco.mont – Volume 10, Number 1, January 2018
ISSN 2073-106X print version – ISSN 2073-1558 online version: http://epub.oeaw.ac.at/eco.mont
https://dx.doi.org/10.1553/eco.mont-10-1s46

From natural forest to cultivated land: Lichen species diversity along land-use gradients in Kanchenjunga, Eastern Nepal

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Keywords: canopy openness, Canonical Correspondence Analysis, Ghunsa valley, hemispherical photography, land-use change, lichen diversity

Abstract

This study aimed to evaluate the effects of elevation, land use and canopy openness on species richness and composition of lichens in Ghunsa valley of Kanchenjunga Conservation Area, Eastern Nepal. At five elevational levels, from 2200 m to 3800 m, transects were established in four land-use types – cultivated land, meadows, exploited and natural forests. Detrended Correspondence Analysis (DCA) and Canonical Correspondence Analysis techniques were used to explore the lichen species distribution patterns. Generalized linear models were applied to analyse the impact of elevation and canopy openness on lichen species richness. Canopy openness was measured by hemispherical photography. A total of 229 species belonging to 71 genera were recorded. The length of the first DCA axis of 8.01 SD units indicated a complete species turnover and high beta diversity along the elevation gradient. Exploited forests with lower canopy openness supported higher lichen diversity than open meadows and cultivated areas. Significant differences in lichen species richness were found for different land-use types, along the elevation gradient, and with varying canopy openness. A gradual increase of lichen species richness from cultivated land to forests was observed. We concluded that substrate types that depend on land-use types as well as canopy openness significantly affect the distribution of lichen communities.

Profile

Protected area

Kanchenjunga Conservation Area

Mountain range

Himalaya

Country

Nepal

Introduction

Lichen diversity along elevational gradients has been analysed intensively in recent years (Bruun et al. 2006; Grytnes et al. 2006; Pinokiyo et al. 2008; Cobanoglu & Sevgi 2009; Baniya et al. 2010; Rai et al. 2011; Baniya et al. 2012) as well as lichen diversity along land-use gradients (Bergamini et al. 2005; Motiejûnaitë & Faùtynowicz 2005; Stofer et al. 2006; Wolseley et al. 2006; Giordani et al. 2010). Similarly, some recent studies are concerned with the influence of canopy openness on species richness, diversity and distribution of lichens (Li et al. 2011; Marmor et al. 2012; Li et al. 2013b, 2013a). However, effects of land-use related canopy openness on species richness and composition of lichens have rarely been studied.

Land-use change determines vegetation cover, species composition and distribution patterns of plant communities (Tasser & Tappeiner 2002) and, consequently, the variation in key characteristics of host tree species, like their density, age and diameter, which all influence the composition and distribution of epiphytic lichen communities (Löbel et al. 2006; Mežaka et al. 2008; Cobanoglu & Sevgi 2009; Li et al. 2011; Mežaka et al. 2012; Odor et al. 2013). Land-use changes, habitat loss and degradation often decline lichen populations (Scheidegger & Werth 2009). Compared with other factors, changing light and moisture conditions are often the dominant factors to explain differences in lichen diversity and abundance (Li et al. 2013a).

Nepal is a mountainous country in the central Himalayas with an area of 147181 km². It is situated between China in the north and India in the east, south and west. The elevation ranges from 60 m above sea level in Terai to 8848 m at Mt Everest, the highest peak in the world (Chaudhary 1998).

In Nepal, lichens are found in all climatic zones. However, floristic and ecological studies on lichens are largely missing. The latest physiographic data of Nepal showed 29% of the total land area covered by forests, 10% by shrubs and degraded forests and 21% by cultivated land (MFSC 2009). Land-use and land-cover change are substantial in Nepal; especially the forest cover shows a drastic decline – even in protected areas. For the Kanchenjunga Conservation Area (KCA), for instance, Gautam and Watanabe (2004) found a decline in forest land cover by 14.9% and grazing land cover by 77.9% between 1979 and 1992. This was the result of an increase in cultivated land by 4.9% and shrubland by 19.7%. KCA is a community-managed protected area established in 1997 and handed over to the KCA Management Council by the government of Nepal in 2006. The shifting cultivation is a common traditional farming system practiced in this protected area by the local ethnic groups as their traditional oc-

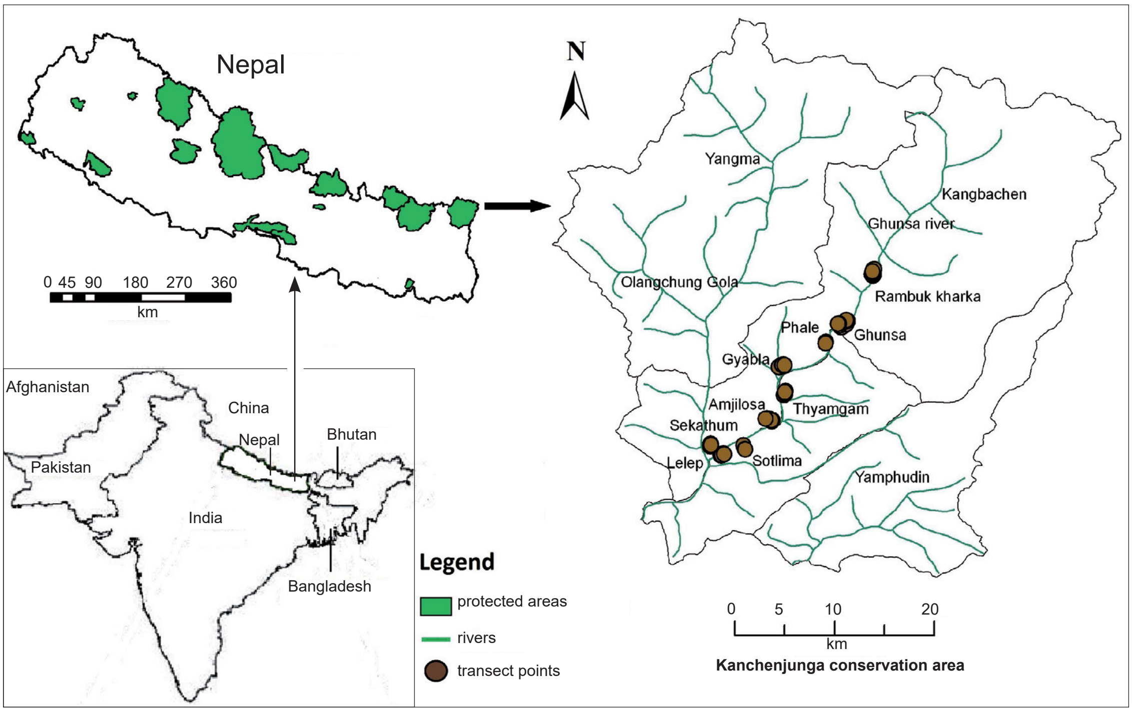

Figure 1 – Map of the study area showing the locations of the study sites.

cupation and livelihood. It also falls within the Sacred Himalayan Landscape being developed by WWF Nepal (Aryal et al. 2010).

The main objective in the present study, therefore, is to evaluate the effects of different land-use types, canopy openness on species richness and composition of lichens along the elevational gradient in KCA, Eastern Nepal. We hypothesized that (a) lichen diversity generally decreases from forests to open land and (b) highest lichen diversity is reached in forests under intermediate canopy openness.

Materials and methods

Study area

This study was carried out in Ghunsa of Eastern Nepal between 2200 m and 3800 m (Figure 1). Ghunsa lies towards the north-eastern part of Nepal in the KCA. KCA is located between 27º 24'–27º 57' N latitudes and 87º 39'–88º 12' E longitudes, close to the boarders of China in the North and India in the East. KCA covers an area of 2035 km² between the Middle Mountains and the high Himalayas, with an elevational range from 1200 m (Thiwa Khola) to Mt Kanchenjunga (8586 m), the third-highest peak in the world. The area includes three river valleys: Simbua, Ghunsa, and Tamur (Anonymous 2011). KCA has diverse climatic zones, including subtropical monsoon at 1200 m to alpine forests (above 4000 m), where June to August are the warmest months, with monthly maximums of 24.73°C to 24.81°C, and January is the coldest month, with a maximum temperature of 13.8°C (Shrestha & Ghimire 1996). KCA receives a good amount of monsoon rainfall from April / May to September / October, with a mean annual precipitation of 2013 mm / yr (Anonymous 2009).

Field methods and data collection

Land-use types were classified according to land cover, disturbance frequency and intensity. At each elevational level, land-use gradients were stratified into four land-use types (Scheidegger et al. 2010).

1. Natural forest: Forested area with very little or no human disturbance. It includes mainly broad-leaved trees and pine trees. This land-use type is often several hours walking distance away from human settlements.
2. Exploited forest: Disturbed and / or exploited forests used for extensive grazing and / or the collection of fodder and firewood, which are close to human settlements.
3. Meadow: Areas dominated by grasses and scattered trees and shrubs. Grazed by domestic livestock like sheep, goats, buffaloes, cows, yaks, and horses.
4. Cultivated land: Land extensively used for cultivation and including terraced fields. These arable fields are often irrigated and fertilized.

Fieldwork was carried out in April 2012. Five elevation levels, from 2200–3800 m, with an interval of approximately 400 m were selected for the study. At each level, the four land-use types were selected on both sides of the Ghunsa river valley and two transects of 2.5 m × 25 m each were studied at each land-use type on both sides of the valley, which showed south-east and north-west facing aspects. A total of 72 of 80 planned transects were established, because not all land-use types were found at each elevation level. The distance between two transects within the same land-use type was at least ten meters.

On each transect, elevation was recorded by Global Positioning System (*Garmin, GPSmap60CSx*) and slope, and the direction of the slope was recorded by a clinometer (*Silva, Ranger*). The growth form and substrate types were recorded. We considered the growth forms crustose, foliose, fruticose and leprose, and the substrate types corticolous (on bark), saxicolous (on rock), muscicolous (on moss) and terricolous (on soil) (Hale 1983). Hemispherical photographs were taken using a digital camera (*Coolpix995 Nikon*) and fish-eye lens (*Fish-eye converter FC-E8 Nikon*). The camera was mounted at a height of 1.5 m above the ground on a tripod and levelled with a bubble level.

Lichen identification and image analysis

Collected lichen specimens were examined at the Laboratory of the Central Department of Botany, Tribhuvan University, Kathmandu, Nepal, and at the Swiss Federal Research Institute, WSL, Switzerland. Identification of lichens was carried using the relevant keys and checklists (Awasthi 1991; Sharma 1995; Awasthi 2007; Singh & Sinha 2010). Identified specimens were deposited at the Swiss Federal Research Institute WSL, Switzerland.

Lichen species were categorized according to family, growth forms, substrate type and photobiont types, i.e. cyanobacteria or green algae, following the recent updated taxonomical classification (Lücking et al. 2016). Data were organized in a relational database (MS Access). Hemispherical photographs were converted to binary (black and white pixels) following the image analysis manual described by Frazer et al. (1999). All image analyses were performed using image-processing software, Gap Light Analyzer (GLA Version 2.0).

Statistical analysis

We calculated Pearson correlation coefficients between variables such as total lichen species richness, growth forms, substrate types and photobiont types (i.e. green algal and cyanobacterial lichen species richness) and canopy openness. TukeyHSD multiple comparison tests were used to test the effect of particular land-use types on species richness of lichens. Generalized Linear Models (GLMs; McCullagh & Nelder 1989) with quasi-poisson error distribution were performed for modelling lichen richness. We build models with linear only and linear and quadric predictor terms and chose the final model parameterization according to the significance of the quadratic term. Graphics were made only for statistically significant models by using GLM. GLMs were not built for species richness of leprose, terricolous and muscicolous lichens because of the scarcity of occurrence data.

Detrended Correspondence Analysis (DCA; Hill & Gauch 1980) was used to determine the lengths of the main gradient in species composition based on the sample by species data matrix. We performed DCA with downweighting of rare species and found a gradient length 8.01 standard unit (SD) for the first axis. This indicated the use of Canonical Correspondence Analysis (CCA) (Lepš & Šmilauer 2003) and its implied unimodal response model over a linear model like in Redundancy Analysis (RDA) to analyse the relationships between species co-occurrence and environmental variables (i.e., elevation, land-use type and canopy openness). All environmental variables were permuted 199 times during CCA to test for significant environmental variables. Direct correlations of environmental predictors with CCA axes were also performed.

All statistical analyses were performed using the *vegan* 2.4-0 package (Oksanen et al. 2016) under the free statistical software environment R version 3.3.1 (R Core Team 2016).

Results

A total of 518 lichen specimens were collected from 72 transects, which included 229 lichen species of 71 genera (Appendix 1). 95 species belonged to the foliose growth form, 87 species were crustose, 44 species fruticose and 3 species were leprose. With regard to the substrate preference, 157 species were corticolous, 55 saxicolous, 14 muscicolous and 3 terricolous species. Green algal photobionts were associated with 205 lichen species, while the remaining 24 lichen species were associated with cyanobacteria. A TukeyHSD test showed significant differences in lichen species richness between cultivated and other land-use types ($p < 0.05$) (Appendix 2a).

Species richness between land-use types

According to land-use types, 174 species were recorded from exploited forests with the highest number of foliose lichens (77 species), followed by 172 species on natural forests, dominated again by foliose lichens (70 species). Likewise, the highest number of corticolous species (151 species) was recorded from natural forests followed by exploited forests with 135 species.

Species richness and canopy openness

Total species richness showed a significant monotonic decline with canopy openness (Figure 2a). Such a monotonic decline of species richness was also found for specific growth forms, specific photobiont species richness and species richness of corticolous of specific substrate types (Figure 2, Appendix 3). As an exception, a significant monotonic increase was found for saxicolous species richness towards higher canopy openness (Figures 2e, Appendix 3). An optimum of total lichen richness was found at low canopy openness with 20.1 species predicted at 10 % canopy openness, with a gradual decline towards higher canopy openness (Figure 2a). Similarly, species numbers of crustose and fruticose lichens showed a decline towards higher canopy openness, with a predicted species number of 6.4 and 5.2 species at 10 % canopy openness respec-

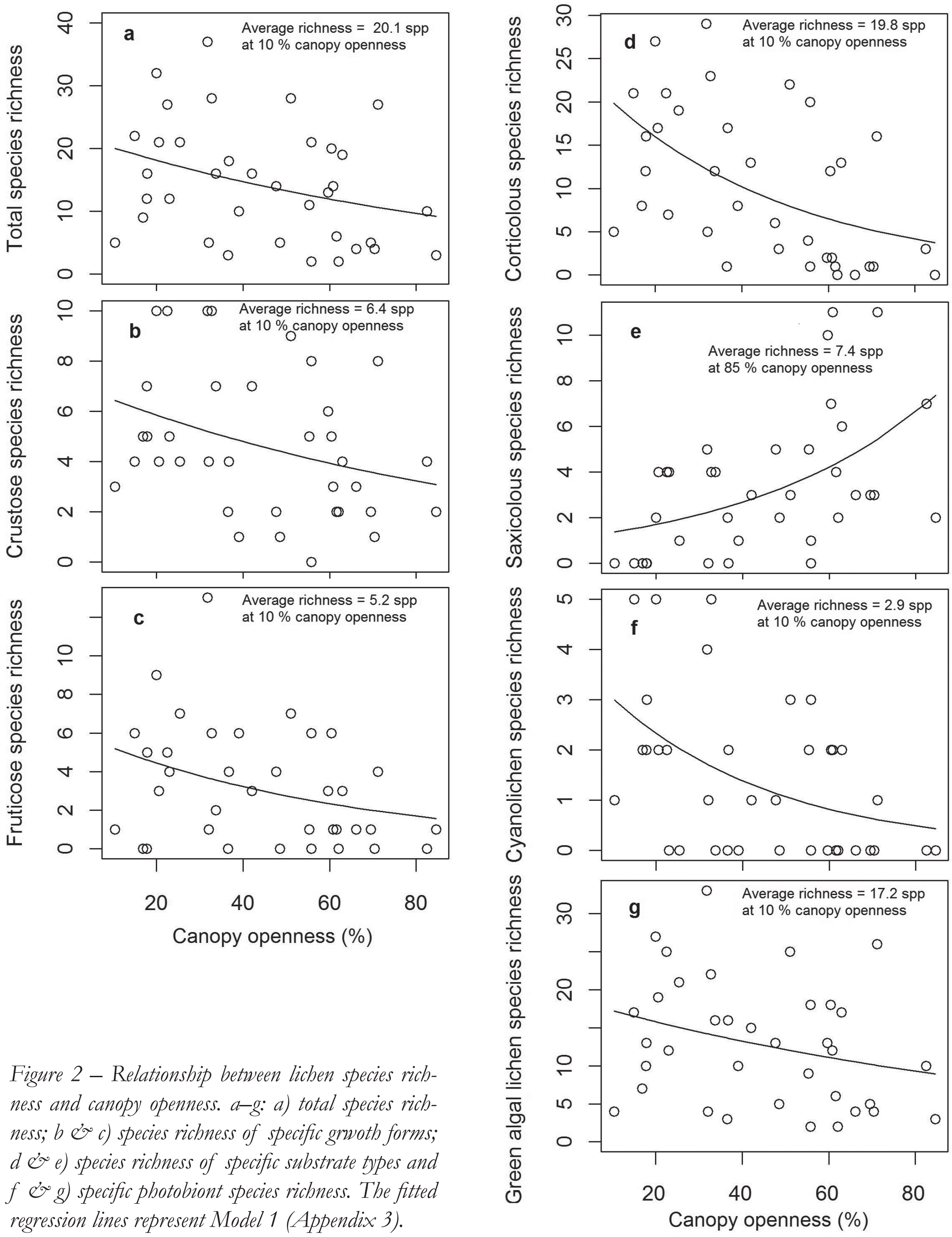

Figure 2 – Relationship between lichen species richness and canopy openness. a–g: a) total species richness; b & c) species richness of specific grwoth forms; d & e) species richness of specific substrate types and f & g) specific photobiont species richness. The fitted regression lines represent Model 1 (Appendix 3).

tively (Figures 2b & c). Regression analysis was not performed for the leprose growth form because only three species presented this feature. Regarding the four substrate categories, corticolous lichen richness also showed a gradual decline with increasing canopy openness, with an average of 19.8 species at 10% canopy openness (Figure 2d). In contrast, saxicolous lichen richness had a positive trend with increasing canopy openness with an average of 7.4 species at 85% canopy openness (Figure 2e). GLM was not performed for muscicolous and terricolous species as their number was too low (14 and 3 species respectively). With respect to photobiont type, both cyanolichens and green algal lichens exhibited a significant decrease with canopy openness, with an average of 2.9 species of cyanolichens, 17.2 species of green algal lichens at 10% canopy openness (Figures 2f & g) respectively.

Species richness along elevation

There is a significant correlation of the total lichen species richness with the elevation and canopy openness ($p \leq 0.05$). Total species richness of lichens and species richness of specific growth forms, specific substrate types and specific photobiont types, except species richness of leprose, muscicolous, terricolous lichens, showed a significant ($p \leq 0.05$) monotonic increase with elevation (Figures 3a-g, Appendix 3). A total richness of 21.9 species was predicted at 3 800 m with a predicted species richness of 6.3 crustose, 10.3 foliose, 5.2 fruticose, 16.5 corticolous and 2.4 cyanoli-

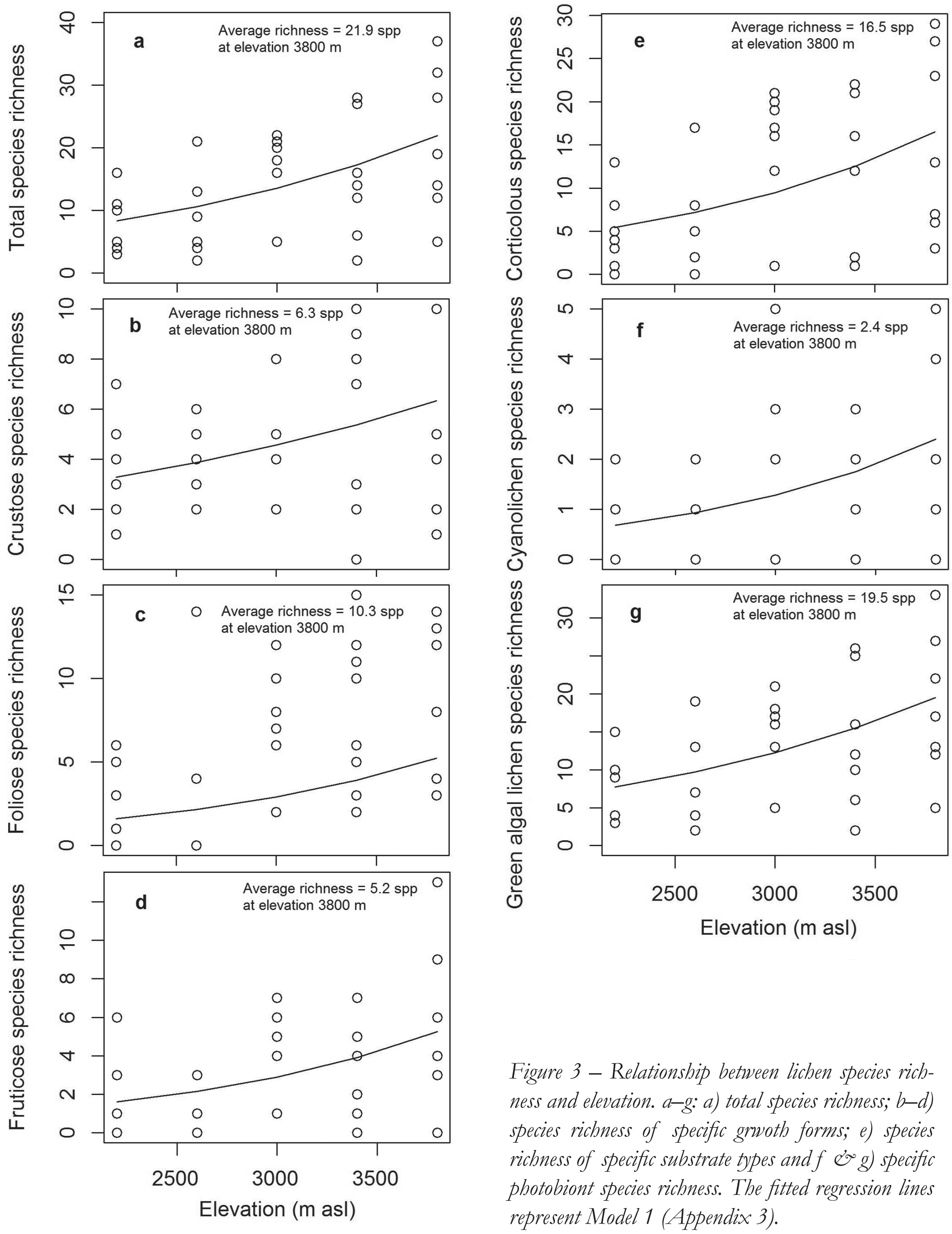

Figure 3 – Relationship between lichen species richness and elevation. a–g: a) total species richness; b–d) species richness of specific grwoth forms; e) species richness of specific substrate types and f & g) specific photobiont species richness. The fitted regression lines represent Model 1 (Appendix 3).

chens and 19.5 green algal lichen species at 3800 m (Figures 3a–g). The regression analysis results showing the best selected model for each response variable is shown in Appendix 3.

Species composition

The length of the first DCA axis was 8.01 SD units (Table 2) that indicated a high beta diversity with almost complete species turnover between transects. The first two DCA axes explained 12.3% of the total variance in the data matrix.

In CCA, the environmental variables elevation, canopy openness and land-use explained 21% of the total species variation variance (Table 3). CCA axis I was significantly correlated with elevation, while CCA axis II was highly correlated with canopy openness and land-use types (Figure 4, Appendix 2b). Along the CCA axis I, the highest abundance of *Aspicilia contorta, Chaenotheca chrysocephala, Evernia mesomorpha, Leptogium burnetiae, Umbilicaria indica* var. *indica* and *Usnea longissima* showed more preference towards high elevation, while species such as *Cladonia scabriuscula, Heterodermia comosa, Lecanora cenisia* showed high preference towards low elevation. Likewise, along the CCA axis II, species composition of *Aspicilia caesiocinerea, Coccocarpia erythroxyli, Phaeophyscia ciliata, Umbilicaria badia, Xanthoria fallax* showed higher abundance towards higher canopy openness, while species like *Caloplaca farinosa, Hypogymnia vittata, Cladonia crispata* var. *cetrariiformis, Usnea himalayana, Chaenotheca chryso-*

Table 1 – Environmental correlation coefficient matrix (Pearson correlation) among variables used during the study (p ≤ 0.05). elv = elevation, cano = canopy openness, spn = total species number, cru = crustose species number, fol = foliose species number, fru = fruticose species number, lep = leprose species number, cort = corticolous species, musc = muscicolous species, saxi = saxicolous species, terr = terricolous species, blgrn = blue green algae and grnal = green algae

	Elev	Canopy	Spn	Cru	Fol	Fru	Lep	Cort	Musc	Saxi	Terr	Blgrn	Grnal
Elev	0.00	1.00	0.06	0.85	0.06	0.47	1.00	0.26	0.65	1.00	1.00	0.81	0.07
Canopy	0.29	0.00	1.00	1.00	1.00	1.00	1.00	0.06	1.00	0.09	1.00	0.28	1.00
Spn	0.00	0.05	0.00	0.00	0.00	0.00	1.00	0.00	0.06	1.00	1.00	0.00	0.00
Cru	0.02	0.05	0.00	0.00	0.00	0.00	1.00	0.00	0.78	1.00	1.00	0.00	0.00
Fol	0.00	0.18	0.00	0.00	0.00	0.00	1.00	0.00	0.61	1.00	1.00	0.00	0.00
Fru	0.01	0.05	0.00	0.00	0.00	0.00	1.00	0.00	0.00	1.00	1.00	0.00	0.00
Lep	0.41	0.64	0.21	0.10	0.47	0.50	0.00	1.00	1.00	1.00	1.00	1.00	1.00
Cort	0.01	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.61	1.00	1.00	0.00	0.00
Musc	0.02	0.29	0.00	0.02	0.01	0.00	0.67	0.01	0.00	1.00	1.00	0.37	0.07
Saxi	0.27	0.00	0.16	0.33	0.04	0.84	0.32	0.55	0.36	0.00	1.00	1.00	1.00
Terr	0.68	0.09	0.58	0.31	0.97	0.38	0.60	0.44	0.83	0.34	0.00	1.00	1.00
Blgrn	0.02	0.01	0.00	0.00	0.00	0.00	0.93	0.00	0.01	0.56	0.51	0.00	0.00
Grnal	0.00	0.09	0.00	0.00	0.00	0.00	0.14	0.00	0.00	0.09	0.61	0.00	0.00

Table 2 – DCA summary of the study site.

DCA Axis	I	II	III	IV	Total inertia
Eigenvalues	0.63	0.50	0.40	0.33	9.16
Axis lengths	8.01	6.30	4.28	3.77	
Cumulative % variance of species data	6.87	12.32	16.71	20.30	

Table 3 – DCA analysis summary of the study site.

	Inertia	Proportion	Rank
Total	9.15	1.00	
Constrained	1.92	0.21	6
Unconstrained	7.23	0.79	29

cephala showed a higher abundance towards low canopy openness (Figure 4).

Similarly, species like *Phaeophyscia endococcina*, *Lecanora polytropa*, *Umbilicaria badia, Parmotrema subarnoldii* showed high abundance towards open habitats and cultivated land, while species like *Aspicilia cinerea, Hypotrachyna scytophylla, Parmelina quercina, Heterodermia obscurata, Stereocaulon paradoxum, Rhizoplaca chrysoleuca* showed high abundance in meadows. Likewise, *Hypotrachyna cirrhata, Hypotrachyna nepalensis, Cetrelia cetrarioides, Parmotrema pseudonilgherrense, Usnea compressula* showed high abundance towards exploited forest and species like *Lobaria retigera, Cladonia crispata* var. *cetrariiformis, Hypogymnia vittata, Caloplaca farinosa, Nephromopsis ahtii* showed high abundance towards natural forest landscapes (Figure 4).

Discussion

Lichen species richness and composition along gradients of land use, canopy openness and elevation

Our study indicated distinct effects of elevation, land use and canopy openness on lichen species richness and composition. We found a considerable variation in lichen species richness among the four selected land-use types, with decline of species richness from forest to cultivated land. These findings are in accordance with other studies like Stofer et al. (2006), who also observed decreasing lichen species richness from natural forest landscape to open agricultural landscape in a large-scale study covering several European biogeographic zones.

Our study revealed a monotonic decrease in total lichen species richness with increasing canopy openness. In the present study, low canopy openness of about 10% still supported a high number of lichen species. In the steep Himalayan mixed forests, canopy openness of 10% and more is likely to provide sufficient light into the forest stand and, in general, light limitation does not seem to be a major limiting factor for lichen species richness in the mountain forests of KCA.

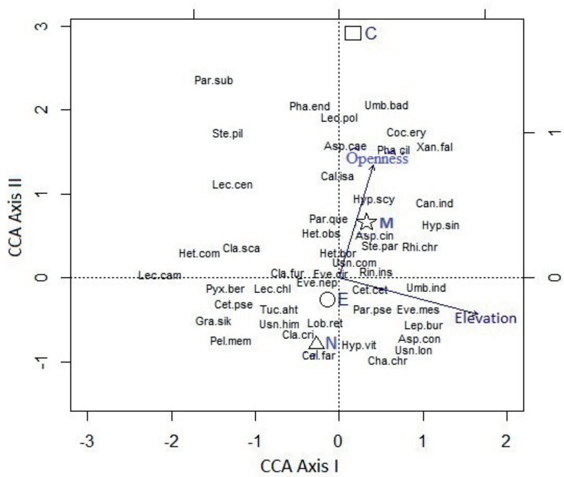

Figure 4 – Canonical Correspondence Analysis (CCA) of lichen composition constraint by elevation, canopy openness and land-use types; C = Cultivated, M = Meadow, E = Exploited, and N = Natural. Arrow indicates the direction of increasing values and their length is proportional to the correlation between the variable and the plot scores (not shown) on the two ordination axes. Land-use types are shown as centroids. For full names of species see Appendix 1.

As trees are an important factor explaining lichen species composition and richness (Mežaka et al. 2008; Odor et al. 2013), meadows and natural forests seemed to provide lichen-rich habitats because of a high diversity and abundance of trees. The exploited forest type with varying disturbance intensity still maintained a reasonable diversity of microhabitats for epiphytic lichens, but some species that depend on semi-shaded habitats and high moisture in natural forests, such as corticolous lichens, are declining in exploited forests. Pinokiyo et al. (2008) also found the maximum number of corticolous lichens in dense forest. In the present study, we found high saxicolous lichen richness in meadows, because a high abundance of rocks and boulders are exposed on meadows, where litter does not continuously cover their surface. Exposed rock surfaces can support more saxicolous lichens than in closed forests, where slightly inclined rock surfaces are often covered with litter. On cultivated lands, slightly inclined rock surfaces are often disturbed by human influence to remove them or to use them for various activities related to farming. Frequent and intense disturbance of rock surfaces in agricultural land is a significant difference to European land-use gradients, where Wolseley et al. (2006) recorded high saxicolous richness in farmland including cultivated land.

The saxicolous species richness revealed a gradual increase of species richness with increasing canopy openness and reached an average of 7.4 species per transect at 85% openness, which corresponds to meadows and open cultivated land. Rocks and boulders inside forest landscapes are primarily covered by litter or mosses and also have a low exposition to solar radiation. However, corticolous species richness showed a decline with increasing openness and reached an average of 19.8 species at 10% openness. Because corticolous lichens in the studied land-use gradients form a more species-rich species pool than saxicolous species, the observed decline of saxicolous species richness is overcompensated by a stronger increase of epiphytic lichens. As the lichen diversity is related to tree diversity, density (Baniya et al. 1999; Li et al. 2011; Li et al. 2013b, 2013a) and humidity (Pinokiyo et al. 2008), cultivated landscapes bear a limited number of trees, shrubs and fewer rocks and boulders as well as less humidity. The resulting lower epiphytic lichen species richness cannot be compensated by an increased density of boulders and bare rocks, which are generally covered with lichen vegetation under an open sky receiving direct solar radiation.

The lichen richness pattern is also closely related to the management practices of the particular landscape, e. g. the protected area. The traditional shifting cultivation practice common to this area (Aryal et al. 2010) is significantly explained after finding of declining lichen richness pattern with open canopy. The shifting cultivation practice opens up a landscape which seems not to support lichen richness and its diversity pattern. Further, the shifting cultivation practice is also common to Makalu-Barun areas of East Nepal. Thus, future diversity of lichen seems in a difficult situation. Conservation of lichen will automatically conserve the landscape.

In addition to the differences between land-use types, our study clearly indicated a distinct variation in species richness along the elevational gradient studied. We found a linear relationship with increasing elevation. Cobanoglu and Sevgi (2009) reported a similar pattern for epiphytic lichens with elevations from 1300 m to 1900 m in Turkey. However, a majority of former studies reported an unimodal relationship (Bruun et al. 2006; Grytnes et al. 2006; Baniya et al. 2010, 2012). Unlike these studies, which generally covered long elevational gradients, our study was more closely confined to a local scale, with an elevational gradient covering temperate to subalpine forests, but not reaching areas above the timberline. Therefore our linear relationship can be interpreted as part of an unimodal relationship on larger scales.

Lichen species composition showed a strong species turnover along CCA axis I (elevation) and CCA axis II (land use-types). Natural and exploited forests supported diverse lichen vegetation which decreased towards meadows and cultivated land. These results confirm findings from European land-use gradients from forest to agricultural land-use types (Stofer et al. 2006).

Conclusion

We conclude that besides elevation as a general climate proxy, differences in land use, which directly affect canopy openness, are the two main general factors of both lichen species richness and composition in this area of the Himalayas in Nepal. Forests with diverse habitats and relatively low canopy openness harbour more lichen species than meadows and cultivated land. However, elevation and canopy openness are not direct drivers. Canopy openness influences light intensity and relative moisture on the forest floor and tree trunks, which directly affect lichen diversity. In addition, elevation serves as a general climate proxy for temperature or precipitation, which more directly influences both species richness and composition of lichen communities. Highest species richness of lichens was reached at the highest altitudinal level of our survey, indicating that the maximum total species richness of lichens as well as the richness of most of the studied species groups is at or above 3800 m in this part of the Himalayas.

Acknowledgement

We thank the Swiss National Science Foundation (JRP IZ70Z0_131338 to CS, MN and K. K. Shrestha) for financial support. We are also grateful to all members of the CDB-WSL Project, Prof. Dr. Krishna Kumar Shrestha, Prof. Dr. Khadga Basnet, Dr. Jyoti Pd. Gajurel, Mr. Shiva Devkota, Mr. Sanjeev Kumar

Rai, Mr. Hem Bdr. Katuwal, Mr. Yam Aryal and Mr. Rajesh Tamang for their kind support. We thank all local people of Ghunsa, KCA, and Utra Kumar Rai for his help with collecting lichens in the field.

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Appendices

Appendix 1 – List of lichens, their family, growth forms, substrate groups, photobiont partner and frequency of occurrence along land use types in the study area. Cru – crustose, Fol – foliose, Fru – fruticose, Lep – leprose, Cort – corticolous, Musc – muscicolous, Saxi – saxicolous, Terr – terricolous, BGA – blue green alga, GA – green alga, C – cultivated land, M – meadow, E – exploited forest, F – natural forest.

S.N.	Name of Lichen species	Short form	Family	Growth form	Substrate group	Photobiont partner	Frequency (Number)	Land use types
1	*Amandinea punctata* (Hoffm.) Coppins & Scheid.	Ama pun	Caliciaceae	Cru	Cort	GA	2	F
2	*Aspicilia caesiocinerea* (Nyl.ex Malbr.) Arnold	Asp cae	Megasporaceae	Cru	Saxi	GA	12	C, E, M, F
3	*Aspicilia cinerea* (L.) Körb.	Asp cin		Cru	Saxi	GA	4	C, E, F, M
4	*Aspicilia contorta* (Hoffm.) Körb.	Asp con		Cru	Saxi	GA	2	E, F
5	*Aspicilia griseocinerea* Räsänen	Asp gri		Cru	Cort	GA	1	C
6	*Bacidia laurocerasi* (Delise ex Duby) Zahlbr.	Bac lau	Ramalinaceae	Cru	Cort	GA	1	F
7	*Bacidia rubella* (Hoffm.) A. Massal.	Bac rub		Cru	Cort	GA	2	F, E
8	*Bryoria himalayensis* (Motyka) Brodo & D. Hawksw.	Bry him	Parmeliaceae	Fru	Cort	GA	1	F
9	*Bryoria lactinea* (Nyl.) Brodo & D. Hawksw.	Bry lac		Fru	Cort	GA	1	E
10	*Bryoria smithii* (Du Rietz) Brodo & D. Hawksw.	Bry smi		Fru	Cort	GA	3	M, F, E
11	*Bryoria tenuis* (Dahl) Brodo & D. Hawksw.	Bry ten		Fru	Cort	GA	5	E, M, F
12	*Buellia aethalea* (Ach.) Th. Fr.	Bue aet	Caliciaceae	Cru	Saxi	GA	1	F
13	*Buellia inornata* Zahlbr.	Bue ino		Cru	Cort	GA	1	E
14	*Buellia montana* H. Magn.	Bue mon		Cru	Cort	GA	2	M
15	*Calicium subquercinum* Asah.	Cal sub		Cru	Cort	GA	4	F, E
16	*Caloplaca chlorina* (Flot.) Sandst.	Cal chl	Teloschistaceae	Cru	Cort	GA	1	M
17	*Caloplaca citrina* (Hoffm.) Th. Fr.	Cal cit		Cru	Cort	GA	1	F
18	*Caloplaca encephalarti* (Kremp.) Zahlbr.	Cal enc		Cru	Cort	GA	1	E
19	*Caloplaca farinosa* Poelt & Hinter.	Cal far		Cru	Cort	GA	3	F
20	*Caloplaca holocarpa* (Hoffm.) Wade	Cal hol		Cru	Cort	GA	1	F
21	*Caloplaca holochracea* (Nyl.) Zahlbr.	Cal hol		Cru	Saxi	GA	1	M
22	*Caloplaca isabellina* Poelt & Hinter.	Cal isa		Cru	Saxi	GA	5	M, C, E
23	*Candelaria indica* (Hue) Vain.	Can ind	Candelariaceae	Fol	Saxi	GA	3	C, E, M
24	*Candelariella vitellina* (Hoffm.) Müll. Arg.	Can vit		Cru	Saxi	GA	1	M
25	*Candelariella xanthostigma* (Pers. ex Ach.) Lettau	Can xan		Cru	Cort	GA	2	E, M
26	*Cetrelia braunsiana* (Müll.) W. Culb. & C. Culb.	Cet bra	Parmeliaceae	Fol	Cort	GA	4	E, F, M
27	*Cetrelia cetrarioides* (Delise) W. Culb. & C. Culb.	Cet cet		Fol	Cort	GA	10	E, F, M
28	*Cetrelia olivetorum* (Nyl.) W. Culb. & C. Culb.	Cet oli		Fol	Cort	GA	1	E
29	*Cetrelia pseudolivetorum* (Asahina) W. Culb. & C. Culb.	Cet pse		Fol	Cort	GA	2	E, F
30	*Chaenotheca chrysocephala* (Ach.) Th. Fr.	Cha chr	Coniocybaceae	Cru	Cort	GA	3	F
31	*Chaenotheca phaeocephala* (Turner) Th. Fr.	Cha pha		Cru	Cort	GA	1	E
32	*Chaenotheca trichialis* (Ach.) Hellb.	Cha tri		Cru	Cort	GA	1	F
33	*Chrysothrix candelaris* (L.) Laundon	Chr can	Chrysotricaceae	Lep	Saxi	GA	1	M
34	*Chrysothrix chlorina* (Ach.) Laundon	Chr chl		Lep	Cort	GA	1	E
35	*Chrysothrix xanthina* (Vain.) Kalb	Chr xan		Lep	Cort	GA	1	F
36	*Cladoina chlorophaea* (Flörke ex Sommerf.) Spreng.	Cla chl	Cladoniaceae	Fru	Musc	GA	1	F
37	*Cladoina corniculata* Ahti & Kashiw.	Cla cor		Fru	Musc	GA	1	C
38	*Cladonia coccifera* (L.) Willd.	Cla coc		Fru	Musc	GA	6	E, M
39	*Cladonia coniocraea* (Flörke) Spreng.	Cla con		Fru	Musc	GA	4	E, F
40	*Cladonia corymbescens* Nyl. ex Leight.	Cla cor		Fru	Musc	GA	4	M, E
41	*Cladonia crispata var. cetrariiformis* (Delise) Vain.	Cla cri		Fru	Cort	GA	3	E, F
42	*Cladonia fimbriata* (L.) Fr.	Cla fim		Fru	Musc	GA	1	E
43	*Cladonia furcata* (Huds.) Schrad.	Cla fur		Fru	Cort	GA	4	E, F, M
44	*Cladonia macilenta* Hoffm.	Cla mac		Fru	Terr	GA	1	M
45	*Cladonia macroptera* Räsänen	Cla mac		Fru	Saxi	GA	1	E
46	*Cladonia ramulosa* (With.) Laundon	Cla ram		Fru	Musc	GA	1	M
47	*Cladonia scabriuscula* (Delise) Nyl.	Cla sca		Fru	Saxi	GA	2	E, M
48	*Cladonia stellaris* (Opiz) Pouzar & Vězda	Cla ste		Fru	Terr	GA	1	E
49	*Cladonia subconistea* Asahina	Cla sub		Fru	Cort	GA	2	E
50	*Cladonia subsquamosa* Kremp.	Cla sub		Fru	Cort	GA	1	E
51	*Cladonia subulata* (L.) F.H. Wigg.	Cla sub		Fru	Cort	GA	1	M
52	*Cladonia verticillata* (Hoffm.) Schaer.	Cla ver		Fru	Musc	GA	1	C
53	*Coccocarpia erythroxyli* (Spreng.) Swinsc. & Krog	Coc ery	Coccocarpiaceae	Fol	Saxi	BGA	2	M, C
54	*Collema subconveniens* Nyl.	Col sub	Collemataceae	Fol	Cort	BGA	2	F
55	*Dibaeis baeomyces* (L. f.) Rambold & Hertel	Dib bae	Icmadophilaceae	Cru	Saxi	GA	1	E
56	*Coenogonium luteum* (Dicks.) Kalb & Lücking	Coe lut	Coenogoniaceae	Cru	Cort	GA	3	F, E
57	*Diploschistes scruposus* (Schreb.) Norman	Dip scr	Ghraphidaceae	Cru	Saxi	GA	1	M
58	*Diplotomma alboatrum* (Hoffm.) Flot.	Dip alb	Caliciaceae	Cru	Cort	GA	1	E
59	*Diplotomma himalayense* S. Singh & D.D. Awasthi	Dip him		Cru	Cort	GA	3	E, M
60	*Diplotomma proximatum* (Magn.) S. Singh & D.D. Awasthi	Dip pro		Cru	Cort	GA	3	E, F
61	*Erioderma meiocarpum* Nyl.	Eri mei	Pannariaceae	Fol	Cort	BGA	3	F, M
62	*Evernia mesomorpha* Nyl.	Eve mes	Parmeliaceae	Fru	Cort	GA	5	F, M, E
63	*Hypotrachyna cirrhata* (Fr.) Divakar, A. Crespo, Sipman, Elix & Lumbsch	Hyp cir		Fol	Cort	GA	5	E, M, F
64	*Hypotrachyna nepalensis* (Taylor) Divakar, A. Crespo, Sipman, Elix & Lumbsch	Hyp nep		Fol	Cort	GA	6	F, E, M
65	*Flavoparmelia caperata* (L.) Hale	Fla cap		Fol	Saxi	GA	1	M

S.N.	Name of Lichen species	Short form	Family	Growth form	Substrate group	Photobiont partner	Frequency (Number)	Land use types
66	*Glyphis cicatricosa* Ach.	Gly cic	Graphidaceae	Cru	Cort	GA	1	F
67	*Graphis nigroglauca* Leight.	Gra nig		Cru	Cort	GA	1	F
68	*Graphis pyrrhocheiloides* Zahlbr.	Gra pyr		Cru	Cort	GA	3	E, F
69	*Graphis rimulosa* (Mont.) Trevis.	Gra rim		Cru	Cort	GA	1	F
70	*Graphis scripta* (L.) Ach.	Gra scr		Cru	Cort	GA	4	E, F
71	*Graphis sikkimensis* Nagarkar & Patw.	Gra sik		Cru	Cort	GA	5	F, E
72	*Graphis sorediosa* Nagarkar & Patw.	Gra sor		Cru	Cort	GA	1	F
73	*Haematomma puniceum* (Sm. ex Ach.) Massal.	Hae pun	Haematommataceae	Cru	Cort	GA	6	F, M, E
74	*Heterodermia angustiloba* (Müll. Arg.) D.D. Awasthi	Het ang	Physciaceae	Fol	Cort	GA	3	E, F
75	*Heterodermia boryi* (Fée) Kr.P. Singh & S.R. Singh	Het bor		Fol	Cort	GA	6	E, M, C, F
76	*Heterodermia comosa* (Eschw.) Follman & Redon	Het com		Fol	Cort	GA	2	M, E
77	*Heterodermia diademata* (Taylor) D.D. Awasthi	Het dia		Fol	Cort	GA	1	F
78	*Heterodermia firmula* (Nyl.) Trevis.	Het fir		Fol	Cort	GA	1	E
79	*Heterodermia incana* (Stirt.) D.D. Awasthi	Het inc		Fol	Cort	GA	1	E
80	*Heterodermia obscurata* (Nyl.) Trevis.	Het obs		Fol	Saxi	GA	3	M, E
81	*Heterodermia pellucida* (D.D. Awasthi) D.D. Awasthi	Het pel		Fol	Cort	GA	1	E
82	*Heterodermia pseudospeciosa* (Kurok.) W. Culb.	Het pse		Fol	Cort	GA	1	E
83	*Heterodermia rubescens* (Räsänen) D.D. Awasthi	Het rub		Fol	Cort	GA	2	E, F
84	*Heterodermia speciosa* (Wulf.) Trevis.	Het spe		Fol	Cort	GA	3	E
85	*Heterodermia togashii* (Kurok.) D.D. Awasthi	Het tog		Fol	Cort	GA	6	E, M, F
86	*Heterodermia tremulans* (Müll. Arg.) W. Culb.	Het tre		Fol	Cort	GA	1	M
87	*Heterodermia verrucifera* (Kurok.) W.A. Weber	Het ver		Fol	Cort	GA	1	F
88	*Hypogymnia hypotrypa* (Nyl.) Rass.	Hyp hyp	Parmeliaceae	Fol	Cort	GA	4	F, E
89	*Hypogymnia vittata* (Ach.) Gasil.	Hyp vit		Fol	Cort	GA	2	F, E
90	*Hypotrachyna crenata* (Kurok.) Hale	Hyp cre		Fol	Saxi	GA	1	E
91	*Hypotrachyna exsecta* (Taylor) Hale	Hyp exs		Fol	Cort	GA	1	E
92	*Hypotrachyna infirma* (kurok.) Hale	Hyp inf		Fol	Cort	GA	1	F
93	*Hypotrachyna majoris* (Vain.) Hale	Hyp maj		Fol	Cort	GA	1	M
94	*Hypotrachyna revoluta* (Flörke) Hale	Hyp rev		Fol	Cort	GA	1	M
95	*Hypotrachyna scytophylla* (Kurok.) Hale	Hyp scy		Fol	Saxi	GA	4	M, C, E
96	*Hypotrachyna sinuosa* (Sm.) Hale	Hyp sin		Fol	Saxi	GA	4	C, M, E
97	*Hypotrachyna sublaevigata* (Nyl.) Hale	Hyp sub		Fol	Cort	GA	1	C
98	*Lasallia freyana* D.D. Awasthi	Las fre	Umbilicariaceae	Fol	Saxi	GA	1	M
99	*Lecanora frustulosa* (Dicks.) Ach.	Lec fru	Lecanoraceae	Cru	Saxi	GA	1	C
100	*Lecanora albella* (Pers.) Ach.	Lec alb		Cru	Cort	GA	3	M, E
101	*Lecanora allophana* (Ach.) Nyl.	Lec all		Cru	Cort	GA	1	E
102	*Lecanora campestris* (Schaer.) Hue	Lec cam		Cru	Saxi	GA	2	E, F
103	*Lecanora cenisia* Ach.	Lec cen		Cru	Saxi	GA	4	M, F, C
104	*Lecanora chlarotera* Nyl.	Lec chl		Cru	Cort	GA	8	F, E ,M
105	*Lecanora intricata* (Ach.) Ach.	Lec int		Cru	Saxi	GA	1	M
106	*Lecanora polytropa* (Ehrh.) Rabenh.	Lec pol		Cru	Saxi	GA	2	C, M
107	*Lecanora rugosella* Zahlbr.	Lec rug		Cru	Cort	GA	4	F, E
108	*Lecanora saligna* (Schrad.) Zahlbr.	Lec sal		Cru	Cort	GA	1	F
109	*Lecanora strobilina* Ach.	Lec str		Cru	Cort	GA	1	M
110	*Lecanora varia* (Hoffm.) Ach.	Lec var		Cru	Cort	GA	1	M
111	*Lecidea betulicola* (Kullh.) H. Magn.	Lec bet	Lecideaceae	Cru	Cort	GA	1	F
112	*Lecidea erythrophaea* Flörke ex Sommerf	Lec ery		Cru	Cort	GA	1	F
113	*Lecidea fuscoatra* (L.) Ach.	Lec fus		Cru	Saxi	GA	1	M
114	*Lecidea vorticosa* (Flörke) Körb.	Lec vor		Cru	Saxi	GA	1	M
115	*Lecidella elaeochroma* (Ach.) M. Choisy	Lec ela	Lecanoraceae	Cru	Cort	GA	1	M
116	*Lepraria crassissima* (Hue) Lettau	Lep cra	Stereocaulaceae	Cru	Saxi	GA	1	M
117	*Lepraria ecorticata* (J.R. Laundon) Kukwa	Lep eco		Cru	Saxi	GA	1	M
118	*Lepraria membranacea* (Dicks.) Vain.	Lep mem		Cru	Cort	GA	2	M, E
119	*Leptogium askotense* D.D. Awasthi	Lep ask	Collemataceae	Fol	Cort	BGA	1	E
120	*Leptogium burnetiae* Dodge	Lep bur		Fol	Cort	BGA	3	F, E, M
121	*Leptogium chloromelum* (Sw.) Nyl.	Lep chl		Fol	Cort	BGA	1	F
122	*Leptogium cyanescens* (Rabenh.) Körb.	Lep cya		Fol	Cort	BGA	1	F
123	*Leptogium pedicellatum* P.M. Jørg.	Lep ped		Fol	Cort	BGA	7	E, F, M
124	*Leptogium saturninum* (Dicks.) Nyl.	Lep sat		Fol	Cort	BGA	1	M
125	*Lethariella cladonioides* (Nyl.) krog	Let cla	Parmeliaceae	Fru	Cort	GA	1	M
126	*Lobaria isidiosa* (Müll. Arg.) Vain.	Lob isi	Lobariaceae	Fol	Cort	BGA	1	F
127	*Lobaria pindarensis* Räsänen	Lob pin		Fol	Cort	BGA	3	F
128	*Lobaria retigera* (Bory) Trev.	Lob ret		Fol	Cort	BGA	5	E, F
129	*Melanelia panniformis* (Nyl.) Essl.	Mel pan	Parmeliaceae	Fol	Cort	GA	1	M
130	*Melanelia tominii* (Oxner) Essl.	Mel tom		Fol	Saxi	GA	2	M
131	*Menegazzia terebrata* (Hoffm.) A. Massal.	Men ter		Fol	Cort	GA	6	E, F
132	*Mycobilimbia hunana* (Zahlbr.) D.D. Awasthi	Myc hum	Lecideaceae	Cru	Terr	GA	1	C
133	*Mycoblastus affinis* (Schaer.) T. Schauer	Myc aff	Tephromelatacae	Cru	Cort	GA	2	F
134	*Myelochroa subaurulenta* (Nyl.) Elix & Hale	Mye sub	Parmeliaceae	Fol	Cort	GA	1	F
135	*Nephroma isidiosum* (Nyl.) Gyeln.	Nep isi	Nephromataceae	Fol	Musc	BGA	1	M
136	*Nephroma nakaoi* Asahina	Nep nak		Fol	Cort	BGA	4	F, E, M
137	*Nephromopsis nephromoides* (Nyl.) Ahti & Randl.	Nep nep	Parmeliaceae	Fol	Cort	GA	1	E
138	*Ochrolechia androgyna* (Hoffm.) Arnold	Och and	Ochrolechiaceae	Cru	Saxi	GA	1	F
139	*Ochrolechia parellula* (Müll. Arg.) Zahlbr.	Och par		Cru	Saxi	GA	1	F
140	*Ochrolechia rosella* (Müll. Arg.) Vers.	Och ros		Cru	Cort	GA	8	E, F, M

S.N.	Name of Lichen species	Short form	Family	Growth form	Substrate group	Photobiont partner	Frequency (Number)	Land use types
141	*Parmotrema thomsonii* (Stirt.) A. Crespo, Divakar & Elix	Par tho	Parmeliaceae	Fol	Cort	GA	1	E
142	*Parmelia squarrosa* Hale	Par squ		Fol	Cort	GA	2	M
143	*Parmeliella cinerata* Zahlbr.) P.M. Jørg.	Par cin		Fol	Cort	BGA	1	E
144	*Parmelina quercina* (Willd.) Hale	Par que		Fol	Cort	GA	4	F, C, E, M
145	*Parmotrema cetratum* (Ach.) Hale	Par cet		Fol	Cort	GA	2	E, F
146	*Parmotrema latissimum* (Fée) Hale	Par lat		Fol	Cort	GA	1	F
147	*Parmotrema nilgherrense* (Nyl.) Hale	Par nil		Fol	Cort	GA	5	E, F, M
148	*Parmotrema praesorediosum* (Nyl.) Hale	Par pra		Fol	Cort	GA	1	M
149	*Parmotrema pseudocrinitum* (Abbayes) Hale	Par pse		Fol	Cort	GA	1	M
150	*Parmotrema pseudonilgherrense* (Asahina) Hale	Par pse		Fol	Cort	GA	8	E, M, F
151	*Parmotrema reticulatum* (Taylor) M. Choisy	Par ret		Fol	Saxi	GA	2	C, E
152	*Parmotrema saccatilobum* (Taylor) Hale	Par sac		Fol	Cort	GA	1	E
153	*Parmotrema sancti-angelii* (Lynge) Hale	Par san		Fol	Saxi	GA	1	M
154	*Parmotrema subarnoldii* (Abbayes) Hale	Par sub		Fol	Saxi	GA	2	C, M
155	*Parmotrema tinctorum* (Despr. ex Nyl.) Hale	Par tin		Fol	Cort	GA	1	E
156	*Parmotrema ultralucens* (Krog) Hale	Par ult		Fol	Saxi	GA	1	M
157	*Peltigera didactyla* (With.) J.R. Laundon	Pel did	Peltigeraceae	Fol	Musc	BGA	1	E
158	*Peltigera dolichorrhiza* (Nyl.) Nyl.	Pel dol		Fol	Cort	BGA	3	F, E
159	*Peltigera dolichospora* (D.A. Lu) Vitik.	Pel dol		Fol	Cort	BGA	2	E, F
160	*Peltigera malacea* (Ach.) Funck	Pel mal		Fol	Musc	BGA	1	F
161	*Peltigera membranacea* (Ach.) Nyl.	Pel mem		Fol	Musc	BGA	2	F
162	*Peltigera polydactylon* (Neck.) Hoffm.	Pel pol		Fol	Musc	BGA	3	E, F
163	*Peltigera praetextata* (Flörke) Zopf	Pel pra		Fol	Musc	BGA	1	C
164	*Pertusaria albescens* (Huds.) M. Choisy & Wern.	Per alb	Pertusariaceae	Cru	Cort	GA	1	E
165	*Pertusaria amara* (Ach.) Nyl.	Per ama		Cru	Cort	GA	1	F
166	*Pertusaria amarescens* Nyl.	Per ama		Cru	Saxi	GA	2	M, E
167	*Pertusaria commutata* Müll. Arg.	Per com		Cru	Saxi	GA	1	E
168	*Pertusaria composita* Zahlbr.	Per com		Cru	Cort	GA	1	M
169	*Pertusaria hemisphaerica* (Flörke) Erichsen	Per hem		Cru	Cort	GA	1	F
170	*Pertusaria krogiae* A.W. Archer, Elix, Eb. Fisch., Killmann & Sérus	Per kro		Cru	Cort	GA	1	E
171	*Pertusaria lactea* (L.) Arnold	Per lac		Cru	Cort	GA	1	F
172	*Pertusaria ophthalmiza* (Nyl) Nyl.	Per oph		Cru	Cort	GA	1	F
173	*Pertusaria pertusa* (Weigel) Tuck.	Per per		Cru	Cort	GA	2	E, F
174	*Pertusaria psoromica* A.W. Archer & Elix	Per pso		Cru	Cort	GA	2	M, F
175	*Pertusaria umbricola* A.W.Archer & Elix	Per umb		Cru	Cort	GA	2	E
176	*Pertusaria velata* (Turner) Nyl.	Per vel		Cru	Cort	GA	1	F
177	*Pertusaria xanthoplaca* Müll. Arg.	Per xan		Cru	Cort	GA	1	E
178	*Phaeophyscia ciliata* (Hoffm.) Moberg	Pha cil	Physciaceae	Fol	Cort	GA	4	C, E
179	*Phaeophyscia endococcina* (Körb.) Moberg	Pha end		Fol	Saxi	GA	2	M, C
180	*Phaeophyscia hispidula* (Ach.) Moberg	Pha his		Fol	Cort	GA	1	M
181	*Phaeophyscia hispidula* var. *exornatula* (Zahlbr.) Moberg	Pha his		Fol	Cort	GA	2	F
182	*Phaeophyscia primaria* (Poelt) Trass	Pha pri		Fol	Saxi	GA	1	C
183	*Phaeographis extrusa* (Stirt.) Zahlbr.	Phe ext	Graphidaceae	Cru	Cort	GA	1	F
184	*Phlyctis argena* (Ach.) Flot.	Phl arg	Phlyctidaceae	Cru	Cort	GA	1	F
185	*Physcia caesia* (Hoffm.) Fürnr.	Phy cae	Physciaceae	Fol	Saxi	GA	3	M, C
186	*Physcia dilatata* Nyl.	Phy dil		Fol	Cort	GA	1	E
187	*Physcia semipinnata* (Gmelin) Moberg	Phy sem		Fol	Cort	GA	1	E
188	*Physcia tenella* (Scop.) DC.	Phy ten		Fol	Saxi	GA	1	M
189	*Platismatia erosa* W. Culb. & C. Culb.	Pla ero	Parmeliaceae	Fol	Cort	GA	3	E, F, M
190	*Polychidium stipitatum* Vězda & W.A. Weber	Pol sti	Massalongiaceae	Fru	Cort	BGA	1	F
191	*Porina chlorotica* (Ach.) Müll.Arg.	Por chl	Porinaceae	Cru	Saxi	GA	1	F
192	*Porpidia albocoerulescens* (Wulfen) Hertel & Knoph	Por alb	Lecideaceae	Cru	Saxi	GA	1	F
193	*Pyxine berteriana* (Fée) Imsh.	Pyx ber	Caliciaceae	Fol	Cort	GA	2	F, E
194	*Ramalina conduplicans* Vain.	Ram con	Ramalinaceae	Fru	Cort	GA	8	F, E, M
195	*Ramalina hossei* Vain.	Ram hos		Fru	Cort	GA	4	E, F, M
196	*Ramalina roesleri* (Hochst) Hue	Ram roe		Fru	Cort	GA	3	M, F
197	*Ramalina sinensis* Jatta	Ram sin		Fru	Cort	GA	1	F
198	*Rhizocarpon badioatrum* (Flörke ex Spreng.) Th. Fr.	Rhi bad	Rhizocarpaceae	Cru	Saxi	GA	2	E, M
199	*Rhizocarpon obscuratum* (Ach.) A. Massal.	Rhi obs		Cru	Saxi	GA	1	M
200	*Rhizoplaca chrysoleuca* (Sm.) Zopf	Rhi chr	Lecanoraceae	Fol	Saxi	GA	2	M
201	*Rinodina efflorescens* Malme	Rin eff	Physciaceae	Cru	Cort	GA	1	M
202	*Rinodina instrusa* (Krempelh. in Nyl.) Mamle	Rin ins		Cru	Cort	GA	2	M, E
203	*Rinodina lecideina* H. Mayrhofer & Poelt	Rin lec		Cru	Saxi	GA	1	C
204	*Rinodina sophodes* (Ach.) A. Massal.	Rin spo		Cru	Saxi	GA	1	M
205	*Sclerophora amabilis* (Tibell) Tibell	Scl ama	Coniocybaceae	Fru	Cort	GA	1	F
206	*Stereocaulon paradoxum* I.M. Lamb	Ste par	Stereocaulaceae	Fru	Saxi	GA	7	M, E, C
207	*Stereocaulon piluliferum* Th.Fr.	Ste pil		Fru	Saxi	GA	2	C, E
208	*Sticta nylanderiana* Zahlbr.	Sti nyl	Lobariaceae	Fru	Cort	GA	2	F
209	*Sticta praetextata* (Räsänen) D.D. Awasthi	Sti pra		Fru	Cort	GA	2	F, E
210	*Sticta weigelii* (Ach.) Vain.	Sti wei		Fru	Cort	BGA	1	F
211	*Sulcaria sulcata* (Lév.) Bystr. ex Brodo & D. Hawksw.	Sul sul	Parmeliaceae	Fru	Cort	GA	2	F, E
212	*Nephromopsis ahtii* (Randl. & Saag) Randl. & Saag	Nep aht		Fol	Cort	GA	7	E, F
213	*Nephromopsis laureri* (Kremp.) Kurok.	Nep lau		Fol	Cort	GA	5	F, E, M

S.N.	Name of Lichen species	Short form	Family	Growth form	Substrate group	Photobiont partner	Frequency (Number)	Land use types
214	*Umbilicaria badia* Frey	Umb bad	Umbilicariaceae	Fol	Saxi	GA	4	C, E,
215	*Umbilicaria indica var. indica* Frey	Umb ind		Fol	Saxi	GA	8	F, M, E
216	*Umbilicaria vellea* (L.) Ach. em. Frey	Umb vel		Fol	Saxi	GA	3	M, F
217	*Usnea bailey* (Stirt.) Zahlbr.	Usn bai	Parmeliaceae	Fru	Cort	GA	1	E
218	*Usnea cirrosa* Motyka	Usn cir		Fru	Cort	GA	8	E, F, M
219	*Usnea compressa* Taylor	Usn com		Fru	Cort	GA	5	F, M, E
220	*Usnea cornuta* Körb.	Usn cor		Fru	Cort	GA	4	E, M, F
221	*Usnea himalayana* Bab.	Usn him		Fru	Cort	GA	2	E, F
222	*Usnea longissima* Ach.	Usn lon		Fru	Cort	GA	3	F, E
223	*Usnea pygmoidea* (Asahina) Y. Ohmura	Usn pyg		Fru	Cort	GA	1	M
224	*Usnea* sp1 Dill. ex Adans.	Usn sp1		Fru	Cort	GA	3	M, E
225	*Usnea* sp2 Dill. ex Adans.	Usn sp2		Fru	Cort	GA	2	F, M
226	*Verrucaria nigrescens* Pers.	Ver nig	Verrucariaceae	Cru	Saxi	GA	1	C
227	*Xanthoparmelia tinctina* (Maheu & A. Gillet) Hale	Xan tin	Parmeliaceae	Fol	Cort	GA	1	M
228	*Xanthoria fallax* (Hepp) Arnold	Xan fal	Teloschistaceae	Fol	Cort	GA	2	M, C
229	*Xanthoria parietina* (L.) Th. Fr.	Xan par		Fol	Cort	GA	1	F

Appendix 2 – TukeyHSD test for multiple comparisons of mean species richness of lichens between land-use types and b. Biplot CCA scores.

a) TukeyHSD test for multiple comparisons of mean species richness of lichens between land-use types.

Variables	Difference	Lower	Upper	p adjusted
Exploited-Cultivated	14.46	3.93	24.99	0.00
Natural-Cultivated	12.33	2.05	22.60	0.01
Meadow-Cultivated	9.90	−0.62	20.43	0.07
Natural-Exploited	−2.13	−12.09	7.82	0.94
Meadow-Exploited	−4.56	−14.77	5.66	0.63
Meadow-Natural	−2.42	−12.38	7.53	0.91

b) Pearson correlations between environmental variables and CCA axes.

Variables	CCA1	CCA2
Elevation	0.964	−0.184
Exploited forest	−0.005	−0.178
Natural forest	−0.187	−0.573
Meadow	0.161	0.355
Canopy openness	0.193	0.755

*Appendix 3 – Regression analysis results modelled for lichen species richness, growth forms, substrate types and photobiont types as response variables and canopy openness and elevation as predictor variables. The Quasi-Poisson family error fitted in GLM (Generalized Linear Model). p-values refer to linear (linear model) or quadratic (linear & quadratic model) coefficient. p-value codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1. ns (non-significant) for p>|0.1| which means marginal significance.*

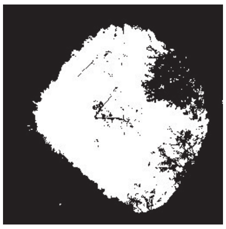
Predictor variables	Response variables	Model	Degrees of freedom	Residual deviance	Deviance explained	ΔD^2	p(>|t value|)
Canopy openness	Total lichen richness	Intercept	35	222.23		0	***
		Linear	**34**	**199.19**	**23.04**	**0.104**	*****
		Linear & quadratic	33	192.35	6.85	0.134	ns
	Crustose species richness	Intercept	35	65.36		0	***
		Linear	**34**	**58.56**	**6.80**	**0.104**	**.**
		Linear & quadratic	**33**	57.96	**0.60**	0.113	ns
	Fruticose species richness	Intercept	35	111.10		0	***
		Linear	**34**	**99.39**	**11.71**	**0.105**	*
		Linear & quadratic	33	90.94	8.45	0.18	0.09
	Corticolous species richness	Intercept	35	289.78		0	***
		Linear	**34**	**218.15**	**71.63**	**0.247**	******
		Linear & quadratic	33	204.48	13.67	0.294	ns
	Saxicolous species richness	Intercept	35	104.63		0	***
		Linear	**34**	**79.87**	**24.76**	**0.23**	******
		Linear & quadratic	33	75.72	4.15	0.27	ns
	Cyanolichen species richness	Intercept	35	68.57		0	0.37
		Linear	34	55.61	12.96	0.189	*
		Linear & quadratic	33	54.72	0.89	0.202	ns
	Green algal lichen species richness	Intercept	35	189.80		0	***
		Linear	**34**	**174.93**	**14.87**	**0.078**	**.**
		Linear & quadratic	33	168.55	6.38	0.112	ns
Elevation	Total species richness	Intercept	35	222.23		0	***
		Linear	**34**	**163.35**	**53.88**	**0.26**	******
		Linear & quadratic	33	160.42	2.93	0.28	ns
	Crustose species richness	Intercept	35	65.36		0	***
		Linear	**34**	**56.24**	**9.12**	**0.14**	*****
		Linear & quadratic	33	55.97	0.27	0.14	ns

Predictor variables	Response variables	Model	Degrees of freedom	Residual deviance	Deviance explained	ΔD²	p(>|t value|)
Elevation	Foliose species richness	Intercept	35	137.8		0	***
		Linear	**34**	**104.81**	**32.99**	**0.24**	**
		Linear & quadratic	33	102.2	2.61	0.26	ns
	Fruticose species richness	Intercept	35	111.10		0	***
		Linear	**34**	**92.02**	**19.08**	**0.172**	*
		Linear & quadratic	33	91.65	0.37	0.152	ns
	Corticolous species richness	Intercept	35	289.78		0	***
		Linear	**34**	**235.08**	**54.7**	**0.189**	**
		Linear & quadratic	33	227.09	7.99	0.216	ns
	Cyanolichen species richness	Intercept	35	68.57		0	0.23
		Linear	**34**	**59.13**	**9.44**	**0.138**	*
		Linear & quadratic	33	58.38	0.75	0.149	ns
	Green algal lichen species richness	Intercept	35	189.80		0	***
		Linear	**34**	**140.67**	49.13	**0.259**	**
		Linear & quadratic	33	138.19	2.48	0.272	ns

Appendix 4 – Representative hemispherical photographs chosen from the analysed images characterizing transects in Ghunsa Valley, Kanchenjunga. (1 = 2 000 m, 2 = 2 600 m, 3 = 3 000 m, 4 = 3 400 m and 5 = 3 800 m; E = eastern slope, W = western slope; c = cultivated land, e = exploited forest, m = meadows and f = natural forest).


1Ecb
openness = 70.5%


1Emb
openness = 62.4%

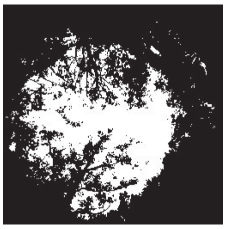

1Eea
openness = 55.75%


1Efb
openness = 9.98%


1Wcb
openness = 84.76%


1Wmb
openness = 82.81%


1Web
openness = 37.05%


1Wfb2
openness = 38.46%

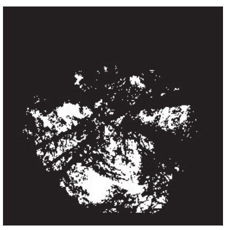

2Ecb1
openness = 62.35%

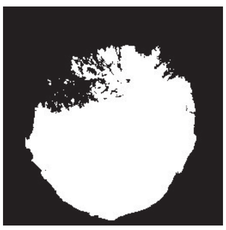

2Efb
openness = 31.48%


2Wcb
openness = 65.46%


2Wmb
openness = 58.33%


2Web
openness = 20.42%


2Wfb
openness = 16.48%

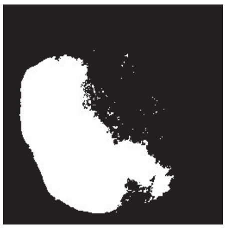

3Emc
openness = 55.92%


3Eeb
openness = 24.23%

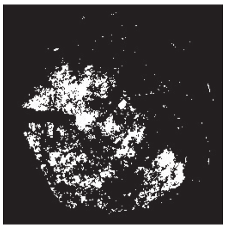
3Efb
openness = 14.06%

3Wcb
openness = 69.39%

3Wmb
openness = 61.24%



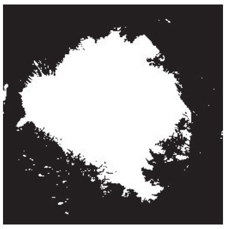
3Web
openness = 36.53%



3Wfb
openness = 17.19%

4Ecb
openness = 55.98%

4Emb
openness = 7.16%

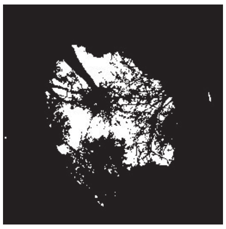


4Eeb
openness = 50.71%

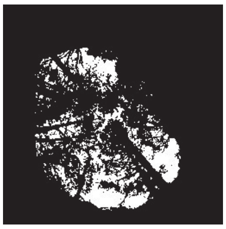
4Efb
openness = 21.51%

4Wcb
openness = 61.36%

4Wmb
openness = 61.04%



4Wee
openness = 18.34%



4Wfb1
openness = 17.51%

5Emb
openness = 47.72%

5Eeb
openness = 21.05%

5Efb
openness = 19.78%

5Wcb
openness = 47.85%

5Wmb
openness = 62.88%

5Wec
openness = 35.16%

5Wfc
openness = 31.24%