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Impacts of roads and trails on floral diversity and structure of Ganga-Choti forest in Kashmir Himalayas

Impactos de caminos y senderos en la diversidad de flora y la estructura del bosque de Ganga-Choti en Cachemira, Himalaya

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SUMMARY

Roads and trails bring deteriorating changes in the structure and composition of forests. The present study investigated the impact of roads and trails on floral diversity and structure of Ganga Choti forest, Kashmir. Phytosociological attributes using systematic quadrate sampling were recorded and analyzed using multivariate ordination techniques including Principal Component Analysis and Cluster Analysis. The total number of species found in the area was 101 belonging to 47 plant families. The dominant family was Poaceae followed by Labiateae, Asteraceae and Rosaceae. The dominant species of the area included *Pinus wallichiana, Abies pindrow, Viburnum grandiflorum, Sarcococca saligna, Poa alpina, Fragaria nubicola, Onychium japonicum* and *Poa pratensis*. The dominant life form was Hemicryptophyte (31.68 %), whereas leaf spectra class was Microphyll (30.69 %). The average diversity value was 3.39 with a maximum of 3.71 at the control site and 3.08 at the disturbed site. Average tree density was 505/ha with a maximum of 680/ha at the control site and a minimum of 330/ha at the disturbed site. Intense deforestation was indicated by a stump density value of 330/ha. Results revealed that roads and trails have adversely affected the composition and structure of vegetation with high pressure on keystone tree species. Disturbed sites showed lower values of diversity indices, species richness and regeneration synchronized with high deforestation, overgrazing, erosion and increased frequency of invasive species. The study area needs immediate attention of the management for conservation of local forests by minimizing the impacts of roads and trails.

Key words: deforestation, Himalayas, species diversity, overgrazing.

RESUMEN

Los caminos y senderos deterioran la estructura y composición de los bosques. El presente estudio investigó el impacto de los caminos y senderos en la diversidad de flora y la estructura del bosque de Ganga Choti, Cachemira. Los atributos fitosociológicos se registraron mediante muestreo cuadrado sistemático. Los atributos fitosociológicos se registraron utilizando un muestreo cuadrado sistemático y se analizaron mediante técnicas de ordenación multivariante, que incluyeron análisis de componentes principales y análisis de conglomerados. Se encontraron 101 especies plantas en el área, pertenencias a 47 familias. La familia dominante fue Poaceae seguida de Labiateae, Asteraceae y Rosaceae. Las especies dominantes del área incluyeron *Pinus wallichiana*, *Abies pindrow*, *Viburnum grandiflorum*, *Sarcococca saligna*, *Poa alpina*, *Fragaria nubicola*, *Onychium japonicum* y *Poa pratensis*. La forma de vida dominante fue hemicriptófita (31,68 %), mientras que la clase de espectros de hojas fue microfila (30,69 %). El valor de diversidad promedio fue 3,39 con un máximo de 3,71 en el sitio de control y 3,08 en el sitio alterado. La densidad promedio de árboles por hectárea fue de 505 con un máximo de 680 en el sitio de control y un mínimo de 330 en el sitio alterado. La deforestación intensa fue indicada por un valor de densidad de tocones por hectárea de 330. Los resultados revelaron que los caminos y senderos han afectado adversamente la composición y la estructura de la vegetación con alta presión sobre especies clave de árboles. Los sitios alterados mostraron valores menores de índices de diversidad, riqueza de especies y regeneración, sincronizados con alta deforestación, pastoreo excesivo, erosión y mayor frecuencia de especies invasoras. El área de estudio necesita una atención inmediata de la administración para la conservación de los bosques locales para minimizar los impactos de los caminos y senderos.

Palabras clave: deforestación, Himalaya, diversidad de especies, sobrepastoreo.

INTRODUCTION

Forest paths and trails strongly influence plant species composition in natural forests (Godefroid and Koedam 2004). Road infrastructure, and the access that it provides, degrades forest ecosystem by increasing edge habitats, reducing forest cover, increasing agricultural expansion, promoting migration and forestland encroachment (Verburg *et al*. 2004). Roads affect forest ecosystem by altering the level of available light, water, drainage patterns, soil structure and soil nutrients, and act as a barrier to migration and dispersal (van-Wyk and Smith 2001). Major impact on forest ecosystem regarding function is due to alteration of microclimate and the isolation of ecosystem patches by causing fragmentation and creating edges (Hill and Pickering 2006).

Road constructions also affect the impact on conservation potential of the area with secondary impacts such as people influx, economic development and construction activities. The invasion of alien weeds and invasive plants is another major issue associated with road development (Hua *et al.* 2013). Roads are the major source of landslides and sediment loss as well (Pietikainen 2006). Flow of surface and ground water and nutrients is affected by trails changing the geomorphic processes and sediment loads. Roads provide an easy passageway to nomads as livestock rearing has been the main source of livelihood in Himalayas for centuries (Kumar *et al.* 2001). Effects of trampling may exceed up to one meter from the trail edge by causing compaction of leaf litter and soil, reducing the abundance of woody and herbaceous plants (Nilsson 2001).

Population rise has resulted in exceeding forest use beyond the carrying capacity of the forest ecosystem in Kashmir Himalayas. Roads and trails are the easy passageways for the population to access the forest area for their needs, resulting into forest degradation (Shameem *et al.* 2010). The study area has four link roads and numerous trails used for the movement of locals and their livestock. The current study is based on the hypothesis that roads and trails have significant deteriorating consequences on forest structure and species diversity in the study area. Furthermore, roads and trails are associated with increased anthropogenic forest disturbances such as logging, overgrazing and erosion affecting floral diversity and forest structure. The specific objective of the study is to investigate the effects of roads and trails on floral diversity, species composition, richness, community maturity and evenness of forest stands. It was further aimed at analyzing the impact of anthropogenic pressure regarding deforestation, overgrazing and soil degradation on the phytosociological attributes of forest vegetation.

METHODS

The study area lies in Azad Jammu and Kashmir in Pir Panjal Sub range of western Himalayas. Sudhan Galli is located at an elevation of 2300 m at 34º04'34.92" N latitude and 73º44'54.52" E Longitude (figure 1). Topographically the entire area is mountainous, generally sloping from northeast to southwest covered with moist temperate forest vegetation. Annual precipitation is about 1,500 millimeter. May and June are the hottest months with average temperature of 20-25 ºC, while December and January are the coldest months with heavy snowfall and freezing temperature (Pak-Met 2014). The study was carried out during May-August 2016. Four forest sites were selected for the study including two disturbed and two control sites. The altitude, latitude and longitude of all study sites were recorded. The effect of roads and trails on vegetation distribution was investigated by placing quadrates along trails and roads. The quadrats were laid 5-20 m away from the trails and 5-50 m away from the roads. The quadrate size of 1 m × 1 m was used for the herbs, whereas for trees and shrubs quadrats size was 20 m × 20 m and 5 m × 5 m respectively. Vegetation attributes were recorded including density, frequency and cover. Phytosociological attributes

Figure 1. Map of the study area (Right) and satellite imagery of study sites (Left).

Mapa del área de estudio (derecha) e imágenes satelitales de los sitios de estudio (izquierda).

including Importance Value Index, Diversity, Evenness, Richness and maturity were calculated following standard protocols (Cox 1967, Ahmed and Shaukat 2012). Visual indicators such as hoof marks, animal excreta, browsed vegetation, eroded area and signs of trampling were used to determine grazing intensity. Deforestation rate was recorded by counting the number of stumps, whereas regeneration rate was calculated by counting the number of seedlings (Shaheen *et al*. 2011). Results were statistically analyzed by using Multivariate ordination techniques including Principal Component Analysis and Cluster Analysis (ter-Braak and Smilaur 1998).

RESULTS

A total of 101 plants were recorded from the study area belonging to 46 families. The dominant family was Poaceae with 11 species followed by Lamiaceae or Labiateae, Asteraceae and Rosaceae with nine members each. Pteridaceae displayed five species, whereas Pinaceae and Polygonaceae showed four species each. The dominant species of the area included *Pinus wallichiana* and *Abies pindrow* with IVI values of 79.44 and 67.9, respectively, followed by *Viburnum grandiflorum* (36.83), *Sarcococca saligna* (19.8), *Poa alpina, Fragaria nubicola, Onychium japonicum, Poa pratensis* and *Oxalis corniculata*. Hemicryptophytes was the dominated life form class having a percentage of 31.68 followed by Phanerophytes (18.8 %) and Geophytes (16.8 %). Microphylls were the dominant leaf spectrum class with a percentage of 30.69 followed by Mesophyll (28.7 %) and Nanophylls (26.7 %) (table 1).

The number of species was higher (65) in the control sites range as compared to disturbed sites (43). Density, frequency and cover values recorded for the disturbed sites were also lower than those of control sites (table 2). The Average Shannon diversity value in the area was 3.39 with a maximum of 3.89 recorded at control site 2, whereas a minimum of 2.93 at disturbed site 1. The disturbed sites showed lower values (0.97) as compared with the control sites (3.71). Simpson diversity was calculated to be 0.97. Average evenness was 0.86 with a maximum of 0.94 at control site 2, whereas a minimum of 0.78 at dis-

Table 1. Floristic composition, importance values, life form and leaf spectra of studied sites.
Composición florística, valores de importancia, forma de vida y espectros foliares en los sitios estudiados.

	Species Name	Family	Life form	Leaf spectrum	Importance value
1	*Abies pindrow* Royle	Pinaceae	MP	L	44.88
2	*Achillea millefolium* L.	Asteraceae	H	L	0.70
3	*Adiantum venustum* D. Don	Adiantaceae	G	L	1.47
4	*Aesculus indica* Wall. Ex Camb.	Hippocastinaceae	MP	Me	1.98
5	*Ajuga bracteosa* Wall. ex Benth.	Lamiaceae	TH	Mi	0.50
6	*Arisaema flavum* (Forsk.) Schott.	Araceae	G	Me	2.10
7	*Arisaema jacquemontii* Blume	Araceae	G	Me	1.25
8	*Aristolochia punjabensis* Lace	Aristolochiaceae	L	Mi	0.96
9	*Artemisia dubia* Wall. ex Besser	Asteraceae	H	N	0.10
10	*Arthroxon prinodes* (Steud.)	Poaceae	H	N	2.92
11	*Asplenium adiantum–nigrum* L.	Adiantaceae	G	L	1.28
12	*Aster himalaicus* C.B. Clarke	Asteraceae	H	Mi	0.30
13	*Berberis lycium* Royle.	Berberidaceae	NP	N	2.54
14	*Bergenia ciliata* (Haw.) Sternb.	Saxifragaceae	H	Me	0.73
15	*Bistorta amplexicaulis* (D. Don)	Polygonaceae	H	Mi	3.45
16	*Bupleurum falcatum* Linn.	Umbelliferae	TH	N	0.66
17	*Calamintha umbrosa* Fisch. *et* Meyer	Lamiaceae	H	Mi	1.46
18	*Caltha alba* Jacq.ex.Camb.	Ranunculaceae	CH	Me	0.15
19	*Caltha palustris* L.	Ranunculaceae	CH	Me	1.21
20	*Cedrus deodara* (Roxb. ex D. Don)	Pinaceae	MP	L	0.35

Continue

Table 1 Continued

21	*Chrysopogon echinulatus* (Nees)	Poaceae	H	N	0.20
22	*Cichorium intybus* L.	Asteraceae	CH	Me	0.25
23	*Cirsium vulgare* (Savi) Ten.	Asteraceae	TH	Ma	4.79
24	*Convolvulus arvensis* L.	Convolvulaceae	L	Me	0.18
25	*Conyza bonariensis* L.	Asteraceae	TH	Mi	0.92
26	*Cotoneaster rosea* Edgew.	Rosaceae	NP	L	0.32
27	*Cynodon dactylon* L.	Poaceae	H	N	1.28
28	*Cynoglossum glochidiatum* Wall. ex. Benth.	Boraginaceae	TH	Mi	1.21
29	*Cyperus compressus* L.	Cyperaceae	G	N	0.23
30	*Dactylis glomerata* L.	Poaceae	H	N	2.79
31	*Desmodium elegans* DC.	Papilionaceae	NP	Me	1.20
32	*Digitaria sanguinalis* (Linn.)	Poaceae	H	N	0.84
33	*Dryopteris juxtaposita* Christ.	Pteridaceae	H	N	0.23
34	*Dryopteris stewartii* More	Pteridaceae	G	Me	4.48
35	*Duchesnea indica* (Andrews)	Rosaceae	H	Mi	3.53
36	*Elaeagnus umbellata* Thunb.	Elaeagnaceae	NP	Mi	0.47
37	*Equisetum arvense* L.	Equisetaceae	TH	N	0.47
38	*Erigeron multiradiatus* Benth. ex C. B. Clarke	Asteraceae	TH	Mi	0.40
39	*Euphorbia helioscopia* L.	Euphorbiaceae	CH	Mi	0.19
40	*Fragaria nubicola* Lindl.	Rosaceae	H	Mi	9.46
41	*Galium aparine* L.	Rubiaceae	TH	N	3.72
42	*Gentiana kurroo* Royle	Gentianaceae	TH	N	0.89
43	*Geranium wallichianum* D. Don. ex. Sweet.	Geraniaceae	H	Mi	3.61
44	*Hedera helix* auct.	Araliaceae	L	Me	1.58
45	*Hedera himalaica* Tobler	Araliaceae	L	Me	0.58
46	*Impatiens bicolor* L.	Balsaminaceae	G	Me	4.11
47	*Impatiens edgeworthii* Hook. f., Fl. Brit. Ind.	Balsaminaceae	G	Me	1.58
48	*Indigofera heterantha* Wall.ex Brandi	Papilionaceae	NP	N	1.91
49	*Isodon rugosus* Wall. ex Benth.	Lamiaceae	MC	Me	2.88
50	*Jasminum humile* L.	Oleaceae	H	N	2.29
51	*Lilium polyphyllum* D. Don	Liliaceae	G	Mi	0.38
52	*Lonicera quinquelocularis* Hardwicke	Caprifoliaceae	MC	Me	1.80
53	*Machilus odoratissima* Wall. ex Nees	Lauraceae	MP	Me	2.34
54	*Micromeria biflora* Benth	Lamiaceae	TH	L	1.00
55	*Nepeta erecta* Boyle ex Benth.	Lamiaceae	CH	Mi	4.89
56	*Oenothera rosea* L Her. Ex Ait	Onagraceae	CH	Mi	0.86
57	*Onychium japonicum* Thunb.	Pteridaceae	G	L	5.83
58	*Origanum vulgare* L.	Lamiaceae	H	Mi	0.77
59	*Oxalis corniculata* L.	Oxalidaceae	H	N	4.32
60	*Phalaris paradoxa* Lion.	Poaceae	TH	N	1.30
61	*Picea smithiana* (Wall.) Boiss	Pinaceae	MP	L	2.77

Continue

Table 1 Continued

62	*Pinus wallichiana* A B. Jackson	Pinaceae	MP	L	45.66
63	*Plantago lanceolata* L.	Plantaginaceae	H	Mi	1.43
64	*Plantago major* L.	Plantaginaceae	H	Me	3.88
65	*Poa alpina* L.	Poaceae	H	N	7.55
66	*Poa pratensis* L.	Poaceae	H	N	3.48
67	*Polygonum aviculare* L.	Polygonaceae	H	L	3.73
68	*Polygonum nepalense* Meisner.	Polygonaceae	G	Me	0.87
69	*Potentilla anserina* L.	Rosaceae	H	N	0.85
70	*Prunella vulgaris* L.	Lamiaceae	TH	Mi	2.61
71	*Prunus padus* L.	Rosaceae	MP	Me	2.31
72	*Pteris cretica* L.	Pteridaceae	G	Mi	2.29
73	*Pteris vittata* L.	Pteridaceae	G	Mi	1.40
74	*Quercus incana* Roxb.	Fagaceae	MP	Me	2.81
75	*Ranunculus muricatus* L.	Ranunculaceae	CH	Me	2.62
76	*Rosa macrophylla* Lindl.	Rosaceae	L	Mi	0.57
77	*Rubus arcticus* L.	Rosaceae	Np	Mi	0.20
78	*Rubus fruticosus* L.	Rosaceae	Np	Mi	2.06
79	*Rumex nepalensis* Spreng.	Polygonaceae	CH	Mi	4.95
80	*Salvia lanata* Roxb.	Lamiaceae	CH	Me	0.41
81	*Sambucus wightiana* Wall.ex Wight *et* Arn.	Sambucaceae	CH	Me	0.65
82	*Sarcococca saligna* (D.Don) Muell. Arg.	Buxaceae	NP	Me	7.46
83	*Sauromatum venosum* (Ait.) Schott.	Araceae	G	Me	0.31
84	*Sedum ewersii* Ledeb.	Crassulaceae	G	Mi	0.15
85	*Sibbaldia cunneata* O.kunz	Rosaceae	H	N	0.68
86	*Sisymbrium irio* L.	Brassicaceae	TH	Mi	0.44
87	*Skimmia laureola* DC	Rutaceae	NP	Me	2.67
88	*Solanum nigrum* L.	Solanaceae	CH	Ma	0.56
89	*Stellaria media* L.	Caryophyllaceae	H	N	2.13
90	*Tagetes minuta* L.	Asteraceae	TH	N	0.19
91	*Taraxacum officinale* Weber	Asteraceae	H	Mi	2.29
92	*Themeda anathera* (Nees) Hack.	Poaceae	H	N	0.19
93	*Thymus linearis* Benth.	Lamiaceae	CH	Mi	1.36
94	*Trifolium repens* L.	Poaceae	H	N	8.67
95	*Urtica dioica* L.	Urticaceae	H	Me	2.46
96	*Valeriana pyrolifolia* Decne.	Valerianaceae	G	Mi	0.20
97	*Verbascum thapsus* L.	Scrophulariaceae	TH	Ma	0.63
98	*Viburnum grandiflorum* Wall. ex DC	Caprifoliaceae	NP	Me	19.74
99	*Viola canescens* Wall. ex.Roxb.	Violaceae	G	Mi	5.76
100	*Viola odorata* L.	Violaceae	H	Mi	0.96
101	*Vulfia myrosus* L.	Poaceae	H	N	0.88

Life form. MP: Megaphanerophytes= 7.69 %. MC: Microphanerophytes= 1.92 %. NP: Nanophanerophytes= 10.57 %. CH: Chamaephytes = 12.5 %. TH: Therophytes = 14.42 %. G: Geophytes = 17.30 %. L: Liana = 4.807 %. H: Hemicryptophytes = 30.7 %.

Leaf spectra. Ma: Macrophyll = 2.88 %. Me: Mesophyll = 28.84 %. Mi: Microphyll = 30.76 %. L: Leptophyll = 11.53 %. N: Nanophyll = 25.96 %.

turbed site 1. Average richness recorded for the area was 1.81 with a maximum richness value of 2.23 at disturbed site 1, whereas a minimum value of 1.48 at disturbed site 2. The disturbed sites showed lower values of maturity index (25.75) when compared with 34.6 at control sites. The average maturity value recorded from the area was 30.17 with a minimum of 23.13 at disturbed site 1, whereas a maximum of 42.22 at control site 2. None of the forest sites was found to be mature (> 60 %) as the average maturity index values for the investigated area was 30.18. Relatively higher values were reported at control sites (34.6) than those reported for disturbed sites (25.75) revealing the negative impact of roads and trails on the forest (table 2).

Forest stands showed tree density of 505/ha with a maximum of 760/ha at control site 1, whereas a minimum of 200/ha at disturbed site 2. The disturbed sites showed lower density values (330/ha) as compared with 680/ha at control sites. Intense deforestation and logging were indicated at the disturbed sites with a stump density value of 520/ha as compared with the 150/ha at control sites. Average stump density recorded from the area was 335/ha with maximum stump density of 600/ha at disturbed site 2, whereas a minimum of 100/ha at control site 2. Average stem/stump value recorded from the area was 2.78 with a maximum value of 6 at control site 2, whereas a minimum value of 0.3 at disturbed site 2. Regeneration value in the area was 290 seedling/ha with a maximum of 500/ha at control site 2, whereas a minimum of 0/ha at disturbed site 2. The disturbed sites showed lower regeneration rate (130/ha), compared with 430/ha at control sites (table 3).

Disturbed sites showed higher grazing intensity placed in grazing classes 2 and 3 showing maximum hoof marks, animal excreta and browsed vegetation. Control sites showed relatively lower grazing pressure. Disturbed site 1 was highly eroded and placed in class 3, while disturbed site 2 was moderately eroded and placed in class 2, within erosion classes. No visible effect of erosion was observed at the control sites.

PCA axis explained 94 % variance in the data indicating the statistical strength of the test. PCA Biplot showed dominant species of the area separated away along the X-axis; *i.e., Pinus wallichiana and Abies pindrow* representing their ultra-dominance. *Viburnum grandiflorum, Poa*

Table 2. Phytosociological parameters of forest communities from the study area.
Parámetros fitosociológicos de las comunidades forestales del área de estudio.

Study Site	Specie number	Simpson diversity	Shannon diversity	Richness	Evenness	Maturity Index
Control 1	68	0.94	3.53	1.86	0.84	26.98
Control 2	63	0.98	3.89	1.66	0.94	42.22
Average control	65.5	0.96	3.71	1.76	0.89	34.60
Disturbed 1	43	0.99	2.93	2.23	0.78	23.13
Disturbed 2	40	0.97	3.22	1.48	0.87	28.37
Average disturbed	41.5	0.98	3.08	1.86	0.83	25.75
Overall average	53.5	0.97	3.39	1.81	0.86	30.17

Table 3. Structural attributes and disturbance indicators of studied forest stands.
Atributos estructurales e indicadores de perturbación de rodales forestales estudiados.

Study site	Tree density/ha	Stump density/ha	Stem/ stumps value	Seedlings/ha	Erosion class	Grazing class
Control 1	760	200	3.8	400	class 1	class 1
Control 2	600	100	6.0	500	class 1	class 1
Average control	680	150	4.9	450	un-eroded	ungrazed
Disturbed 1	460	440	1.04	260	class 3	class 2
Disturbed 2	200	600	0.3	0	class 2	class 3
Average disturbed	330	520	0.67	130	eroded	grazed
Overall average	505	335	2.78	290		

alpina and *Trifolium repens* were significantly correlated with the disturbed sites. *Cirsium vulgare, Nepeta erecta, Polygonum aviculare, Rumex nepalensis, Poa pratensis, Urtica dioica, Onychium japonicum, Skimmia laureola, Bistorta amplexicaulis* were also found clumped near the disturbed sites. On the other hand, *Fragaria nubicola, Sarcococca saligna, Dactylis glomerata* and *Stellaria media* showed strong correlation with the control site (figure 2). The cluster analysis dendrogram revealed 104 species arranged in five major associations grouped based on correlation and dominance in communities. *Abies pindrow, Pinus wallichiana* and *Viburnum grandiflorum* were branched out at the1st cut level, having maximum relative abundance at all sites. The 2nd association comprised 9 co-dominant species, whereas the 3rd association had 24 species abundantly found at disturbed sites. The species of control sites were clustered in the 4th and 5th groups with 24 and 15 species respectively (figure 3).

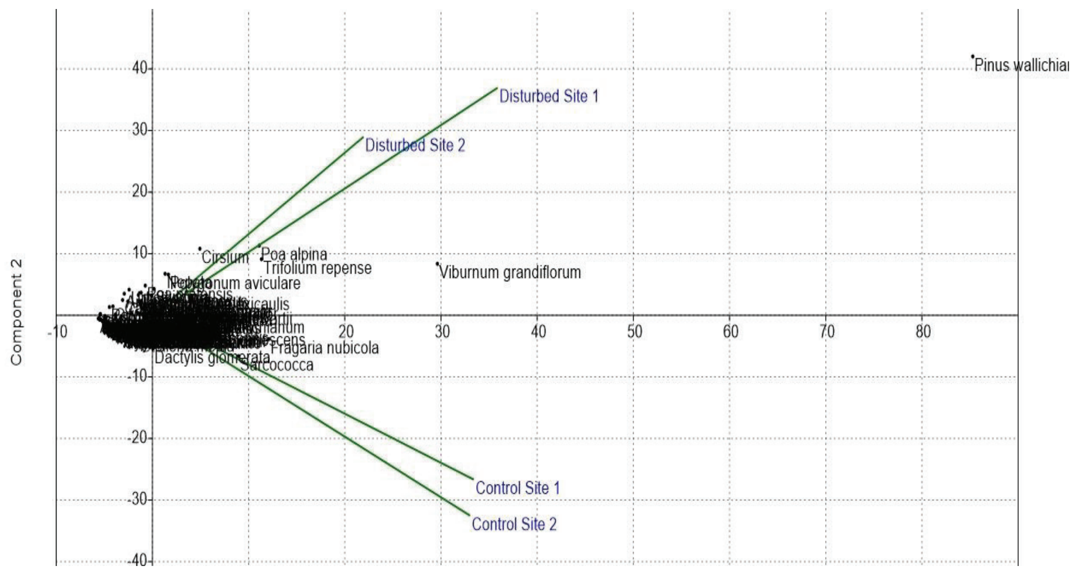

Figure 2. Principal Component Analysis Biplot of the species and study sites.

Gráfico del análisis de componentes principales de las especies y sitios de estudio.

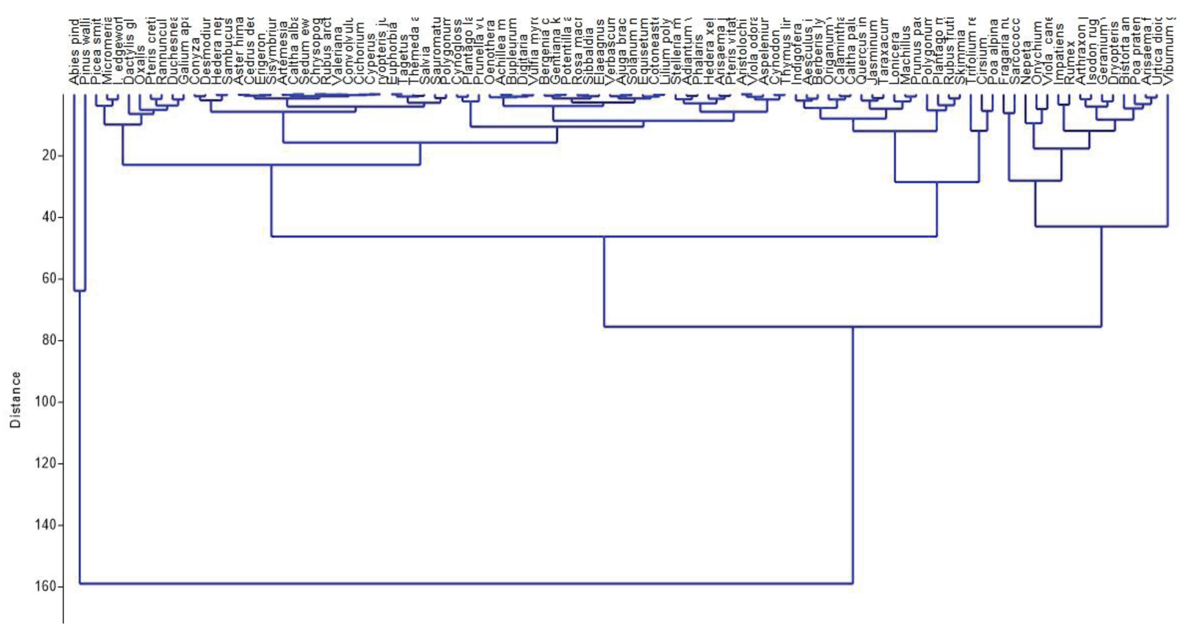

Figure 3. Cluster Analysis Dendrogram of the species data based on Euclidean distance.

Dendrograma del análisis de conglomerados de los datos de especies basado en la distancia euclidiana.

DISCUSSION

The current study was based on the assessment of impact of roads and trails on the vegetation of the Ganga Choti forests. The forest structure and composition of the investigated area showed important influence of the impacts of roads and trails. Vegetation parameters fluctuated significantly correlated with the intensity of road and trail disturbance.

Average tree density of the forest stands was calculated to be 505/ha. This value is less than 1828/ha calculated in the temperate forest of Garhwal Himalaya (Devlal and Sharma 2008), 610/ha in Subtropical Zone of Garhwal Himalaya, India (Tiwari *et al.* 2010), 1028/ha in the temperate forest of Garhwal Himalaya (Kumar *et al.* 2001), 963/ha in the temperate forest of Arunachal Pradesh, India (Bharali *et al.* 2011), 820/ha in Gangotri valley, India (Dhaulkhandi *et al.* 2008) and 602/ha in Himalayas of Pakistan (Ahmed *et al.* 2006). Low tree density indicates high disturbance due to fuelwood and timber extraction at disturbed areas (Sagar *et al.* 2003). This is synchronized with high stump density (520/ha) at disturbed sites indicating severe deforestation and pressure. Presence of roads and trails are as low as 1 % of the land area and can degrade the vegetation of an area up to 20 % (Nepstad *et al.* 2001). Locals access the forest for fuel wood, timber, fodder and non-timber products leading to forest degradation.

Natural regeneration was as poorly represented as 130 seedlings/ha at disturbed sites. Average regeneration rate calculated for the studied area was 290 seedlings/ha, which is less than 5,474/ha in the Sikkim Himalaya (Sundriyal *et al.* 1994), 5,200/ha in Gangotri, India (Dhaulkhandi *et al.* 2008) and 2681/ha in Garhwal Himalaya, India (Tiwari *et al.* 2010). High disturbance prevents the vegetation from reaching the climax community. Simpson's diversity value of 0.98 showed the instability of vegetation communities at the investigated sites due to high intensity of anthropogenic pressure, microclimatic variations and edaphic factors correlated with roads and trails disturbance (Sen *et al.* 2008).

Average value of specie richness was high at the disturbed site (1.86) as compared with 1.76 at control sites, which showed the invasion of non-native flora at the site. The new land use type favors the non-native species and non-managed alien vegetation (Cardoso *et al.* 2013). Mild disturbances and high moisture level increase the species richness allowing increased light, water and nutrients in open trail sections as compared with closed tree canopies of control plots (Atik *et al.* 2011). The percentage of climbers/lianas was very low (4.9 %) in the area, indirectly indicating the lower trees diversity and density (Dhaulkhandi *et al.* 2008).

Results revealed high soil erosion at disturbed sites due to road cuttings, exposing the soil to slides and erosion. The forest areas with roads are reported to have fivefold increase in landslide intensity, which is also reflected in our study area (Ovando 2008). Slope is also a key factor influencing potential for impacts to soil and vegetation. Exposed trail slopes are subjected to surface erosion, evident from diminished vegetation cover and reduced plant heights along the trail (White *et al.* 2006). Roads and trails associated activities cause loss of herbaceous understory and compaction of soil resulting in decreased forest productivity and sediment loss leading to loss of freshwater habitats and altered stream hydrology (Pietikainen 2006).

CONCLUSIONS

The investigated forest showed significant deteriorating impacts on forest structure and composition associated with the presence of roads and trails. The disturbed sites with roads and trails were characterized by lower floral diversity, species richness and immature communities. High grazing pressure, deforestation intensity and soil degradation were observed at the disturbed sites correlated with roads and trails presence. There is an immediate need for sustainable management of local forests by minimizing the impacts of roads and trails. It is recommended to incorporate biodiversity conservation into the design and implementation of road projects along with Sound road engineering and design work, minimizing forest fragmentation, maintaining partial tree canopy cover and controlling erosion and runoff.

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