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Original article

Patterns of plant diversity in seven temperate forest types of Western Himalaya, India

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A B S T R A C T

Plant biodiversity patterns were analyzed in seven temperate forest types [*Populus deltoides* (PD), *Juglans regia*, *Cedrus deodara*, *Pinus wallichiana*, mixed coniferous, *Abies pindrow* (AP) and *Betula utilis* (BU)] of Kashmir Himalaya. A total of 177 plant species (158 genera, 66 families) were recorded. Most of the species are herbs (82.5%), while shrubs account for 9.6% and trees represent 7.9%. Species richness ranged from 24 (PD) to 96 (AP). Shannon, Simpson, and Fisher α indices varied: 0.17–1.06, 0.46–1.22, and 2.01–2.82 for trees; 0.36–0.94, 0.43–0.75, and 0.08–0.35 for shrubs; and 0.35–1.41, 0.27–0.95, and 5.61–39.98 for herbs, respectively. A total of five species were endemic. The total stems and basal area of trees were 35,794 stems (stand mean 330 stems/ha) and 481.1 m^2 (stand mean 40.2 m^2/ha), respectively. The mean density and basal area ranged from 103 stems/ha (BU) to 1,201 stems/ha (PD), and from 19.4 m^2/ha (BU) to 51.9 m^2/ha (AP), respectively. Tree density decreased with increase in diameter class. A positive relationship was obtained between elevation and species richness and between elevation and evenness (R^2 = 0.37 and 0.19, respectively). Tree and shrub communities were homogenous in nature across the seven forest types, while herbs showed heterogeneous distribution pattern.

Introduction

The Himalayas are one of the youngest and richest ecosystems on earth with a variety of species and forest types due to the varying altitude, topographic, and climatic conditions (Mani 1978). The Himalayas cover about 12.84% of the total geographical area of India (Negi 2009). Himalayan forests are considered to be among the world's most depleted forests (Schickhoff 1995). Himalaya is recognized as one of the hotspots of biodiversity and harbors nearly 8,000 species of flowering plants, of which 25.3% are endemic (Singh and Hajra 1996). In the past 3 decades, there has been 23% loss of forest cover in western Himalayas (Anonymous 2005). Himalayas are complex and dynamic ecosystems that provide different ecosystem services (Khan et al 2012).

Species composition, community structure, and function are the most important ecological attributes of forest ecosystems, which show variations in response to environmental, as well as anthropogenic variables (Gairola et al 2008; Shaheen et al 2012; Bisht and Bhat 2013). A complex of factors viz. vegetation type, slope, aspect, edaphic factors, and altitude (Sharma et al 2009, 2010a; Gairola et al 2011a) determines the community composition, structure, and distribution pattern of diversity in mountain vegetation (Kessler 2001; Schmidt et al 2006). One important factor in mountain ecosystems is elevation (McVicar and Korner 2012), which has a strong influence on the structure of the vegetation in most mountains in the world (Zhang et al 2006). Changes in species diversity along elevational gradient have been the subject of numerous studies (Lomolino 2001; Fetene et al 2006), most of them found a *hump* shaped distribution, showing peak species diversity near the middle of the gradient (Austrheim 2002; Zhang and Ru 2010). The plant community structure and distribution pattern of Himalayan forests are poorly understood (Peer et al 2007). Western Himalaya not only supports huge floristic diversity (Sharma et al 2010b), but also stores large carbon stocks (Sharma et al 2010b; Dar and Sundarapandian 2015a, 2015b).

Kashmir Himalaya is located in the extreme northwest of the Himalayan biodiversity hotspot, and harbors a rich floristic diversity of immense scientific interest and supports about 12% of the country's total angiosperm flora and 3% of its endemics, while the

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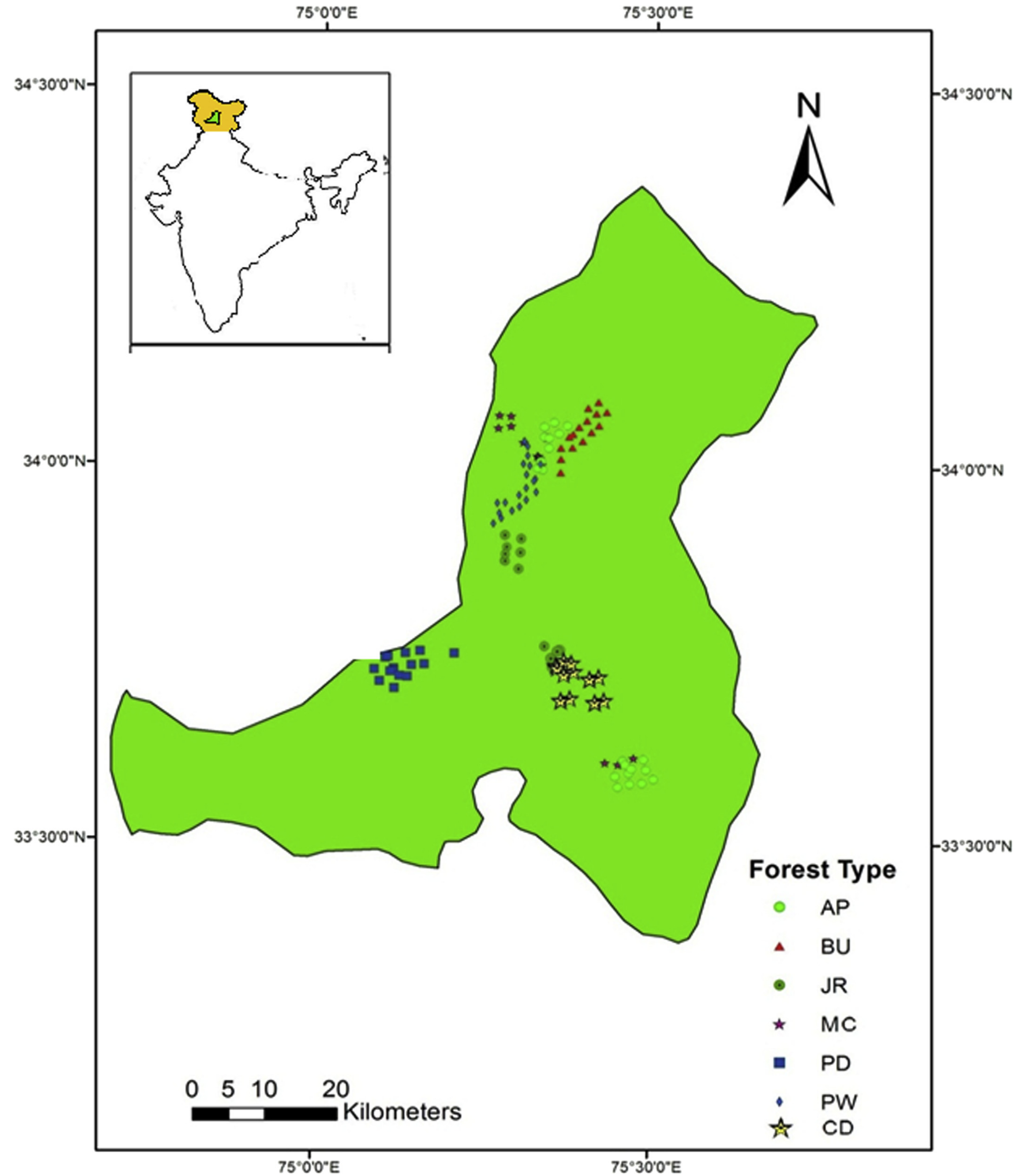

Figure 1. Location of the plots of seven temperate forest types of Kashmir Himalaya, India: AP = *Abies pindrow*; BU = *Betula utilis*; CD = *Cedrus deodara*; JR = *Juglans regia*; MC = mixed coniferous; PD = *Populus deltoides*; PW = *Pinus wallichiana*.

region represents only 0.4% of the total geographical area of India (Dar et al 2012). North-western Himalaya represents a unique bioregion owing primarily to its varied topography and habitat heterogeneity along a wide elevational range.

Several workers have also presented quantitative phytosociological work from different areas of Kashmir (Blatter 1928–1929; Dar and Kachroo 1982; Singh and Kachroo 1983; Ara et al 1995; Dar et al 1995, 2002; Khuroo et al 2004). However, there is a paucity of quantitative information on different forest types of temperate forests of Kashmir Himalaya. Hence the present study aimed to assess the variation in vegetation structure and floristic diversity of seven major forest types of temperate forests of Kashmir Himalaya, India, which are expected to provide current status and baseline data that can be used for biodiversity conservation and effective management of these fragile ecosystems.

Materials and methods

Study area

The present study was carried out in two forest divisions (Anantnag and Lidder) in seven temperate forest types of north-western Himalaya, along an elevational gradient of 1,550–3,250 m of Anantnag District, Jammu and Kashmir, India (Figure 1 and Table 1). The district constitutes the south-central part of Jammu and Kashmir State and is situated between 33° 22′ and 34° 27′ N latitudes, and 74° 30′ and 75° 35′ E longitudes. The district is surrounded by Pirpanjal range in the south and southeast and Zanskar range in the north and northeast and the elevational gradient of the area ranges from 1,500 m to 5,420 m. The highest peak in the area is Kolahoi (5,420 m). The type of vegetation varies along the elevational gradient. The lower valley harbors broad-leaved vegetation up to an altitude of 2,000 m. Coniferous natural forests occur between 2,000 and 2,800 m, beyond which there is high altitude broad-leaved *Betula utilis* forest mixed with *Abies pindrow* up to 3,250 m. Above 3,250 m elevation, the area is covered by alpine grassland vegetation. The soil types found in the region are of four orders: entisols, inceptisols, alfisols, and mollisols (Anonymous 1991). The climate of the area is sub-humid temperate and is influenced by monsoon conditions. The year is divisible into four distinct seasons: spring (March–May); summer (June–August); autumn (September–November); and winter (December–February). This temperate region receives moderate to high snowfall from December to February. Annual precipitation from 2000 to 2012 in this area ranged from 844 mm to 1,213 mm and the mean monthly temperatures range from −8.3°C to 26°C (Figure 2). July is the warmest month of the year, with temperatures rising to an average of 29.5°C; January is the coldest month, with temperature dropping to −8.3°C.

Field methods

Phytosociological analysis was carried out from March 2011 to October 2013. Seven forest types between 1,550 m and 3,250 m elevation were selected and named on the basis of their dominant tree species: *Populus deltoides* (PD); *Juglans regia* (JR); *Cedrus deodara* (CD); *Pinus wallichiana* (PW); mixed coniferous (MC); *A. pindrow* (AP); and *B. utilis* (BU). A total of 111 nested plots of 50 m × 50 m size were laid at random in the seven forest types (Table 1; Figure 1) and each plot was further subdivided into 25 quadrats of 10 m × 10 m to collect the quantitative data on the tree layer. In the same plots, 525 quadrats of 5 m × 5 m (75 in each forest type) and the same number of 1 m × 1 m quadrats were laid to study shrub and herbaceous layer respectively. All individuals ≥ 10 cm girth at breast height were considered as trees and enumerated. The collected specimens and photographs were identified at the Centre for Taxonomy, Department of Botany, University of Kashmir, Srinagar, India.

Table 1. Study site characteristics of seven temperate forest types of Kashmir Himalaya, India.

Forest type	Latitude (°)	Longitude (°)	Altitude (m)	Number of plots
Populus deltoides (PD)	75.08–75.20	33.72–33.78	1,550–1,800	15
Juglans regia (JR)	75.25–75.35	33.75–33.89	1,800–2,000	13
Cedrus deodara (CD)	75.31–75.40	33.73–33.99	2,050–2,300	14
Pinus wallichiana (PW)	75.27–75.35	33.93–34.03	2,000–2,300	20
Mixed coniferous (MC)	75.19–75.47	33.60–34.07	2,200–2,400	12
Abies pindrow (AP)	75.28–75.47	33.59–34.10	2,300–2,800	22
Betula utilis (BU)	75.36–75.50	33.59–33.99	2,800–3,250	15

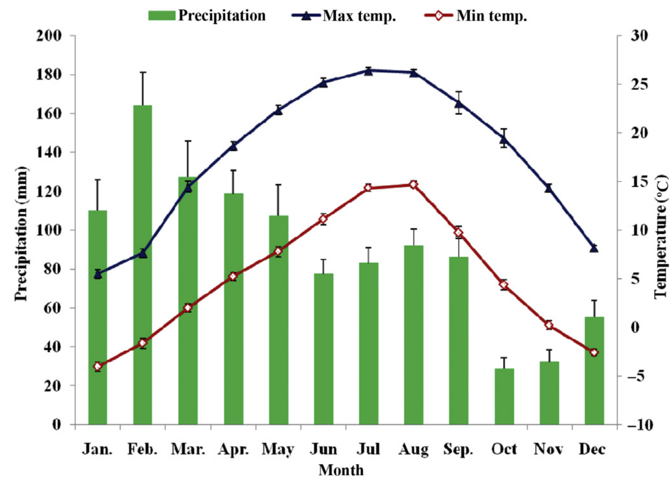

Figure 2. Mean monthly maximum and minimum temperature and precipitation pattern of 12 years of data (2002–2013) in the study area (Data from MeT Department, Srinagar, India which is nearest to the study area): Max. = maximum; Min. = minimum; temp = temperature.

Data analysis

Species diversity indices such as Shannon, Simpson, Fisher's α and Evenness were calculated using the Past 3.1 program (version 3.1; Øyvind Hammer, Natural History Museum, University of Oslo). Importance value index (IVI) was sum of the values of relative frequency, relative density, and relative basal area (Curtis and McIntosh 1950). The abundance to frequency (A/F) ratio for different species was determined by following Whitford (1949) and Gairola et al (2011a). The ratio indicates regular (< 0.025), random (0.025–0.050), and contagious (> 0.050) distribution pattern. Species heterogeneity was calculated by following Whittaker (1972). Regression analysis was used to study the relationship between elevation and species richness, and diversity indices. Regression analysis was used to study the relationship of elevation with species richness and evenness.

Results

Species richness and diversity

A total of 177 species (14 trees, 17 shrubs and 146 herbs including grasses) from 158 genera belonging to 66 families were recorded (Table 2), of which 82.5% of the species belonged to the herbaceous community, while shrubs accounted for 9.6%, and trees for 7.9%. Species richness varied among the forest types, ranging from 24 species in PD forest to 96 species in AP forest with an average of 73 species per forest type for conifers and 33 species for broad-leaved forest types, with an overall mean of 58 species. Thirty-one species (18%) were common to all the forest types, while 75 species (42%) are uncommon; occurring at only one site not in others and 25 species (14%) were found in more than two forest types.

Table 2. Phytosociological and diversity attributes of seven temperate forest types [*Populus deltoides* (PD), *Juglans regia* (JR), *Cedrus deodara* (CD), *Pinus wallichiana* (PW), mixed coniferous (MC), *Abies pindrow* (AP), and *Betula utilis* (BU)] of Kashmir Himalaya, India.

Parameter	PD	JR	CD	PW	MC	AP	BU	Total
No. of plots	15	13	14	20	12	22	15	111
Species richness	24	31	58	77	62	96	60	177
Genera	24	31	56	75	59	88	58	158
Families	16	22	30	40	30	40	32	66
Tree species richness	4	6	4	7	3	3	2	14
Shrub species richness	—	—	9	5	7	9	3	17
Herb species richness	20	25	45	65	52	84	55	146
Shannon index								
Tree	0.56	0.60	0.55	0.18	1.06	0.41	0.17	0.50
Shrub	—	—	1.22	0.53	0.73	0.76	0.46	0.74
Herb	2.68	2.54	2.18	2.49	2.01	2.82	2.83	2.50
Simpson index								
Tree	0.72	0.73	0.75	0.94	0.36	0.79	0.92	0.74
Shrub	—	—	0.43	0.75	0.66	0.68	0.75	0.65
Herb	0.08	0.14	0.25	0.20	0.35	0.20	0.11	0.19
Fisher α								
Tree	0.52	1.14	0.71	1.41	0.50	0.50	0.35	0.73
Shrub			0.95	0.45	0.70	0.87	0.27	0.64
Herb	5.61	6.83	13.62	23.14	20.80	39.98	25.43	19.34
Evenness								
Tree	0.33	0.32	0.40	0.17	0.96	0.47	0.60	0.46
Shrub			0.32	0.25	0.20	0.15	0.52	0.28
Herb	0.42	0.16	0.09	0.09	0.06	0.07	0.14	0.14
Species heterogeneity								
Trees	0.34	0.55	0.46	0.21	0.8	0.4	0.29	—
Shrubs	0	0	0.7	0.32	0.37	0.32	0.48	—
Herbs	0.9	0.8	0.79	0.81	0.63	0.77	0.87	—
Total tree density	18,008	2,856	2,731	3,978	2,353	4,324	1,544	35,794
Tree density (stems/ha)	1,201	220	195	199	196	197	103	322
Total tree basal area (m^2)	541.7	500.2	610.7	897.2	560.5	1,141.0	290.8	4,542.1
Tree basal area (m^2/ha)	36.1	38.5	43.6	44.9	46.7	51.9	19.4	40.92
Shrub density (No./ha)	—	—	12,392	32,616	15,280	26,240	17,888	20,883
Herb density (No./m^2)	192	259	357	361	233	287	196	279
Maximum tree dbh (cm)	51.9	94.6	103.8	150.4	129.3	119.1	93.9	106.14
Mean tree dbh (cm)	16.9	44.7	51.3	52.3	53.2	55.4	45.8	45.65

dbh = diameter at breast height.

The average number of species per stand in seven forests ranged from 20 to 36 (Table 2). Shannon's index ranged from 0.17 (BU) to 1.06 (MC), from 0.46 (BU) to 1.22 (CD) and from 2.01 (MC) to 2.83 (BU) for trees, shrubs, and herbs, respectively. The highest Simpson index values were observed in PW (0.94), PW/BU (0.75), and MC (0.35) for trees, shrubs, and herbs, respectively, and lowest values were in MC (0.36), CD (0.43), and PD (0.08). The highest values of Fisher's α were observed in PW (1.41), CD (0.95), and AP (39.98) for trees, shrubs, and herbs, respectively, and lowest values were in BU (0.35), PW (0.45), and PD (5.61). Species evenness index values ranged from 0.17 to 0.96 for trees, from 0.15 to 0.52 for shrubs, and from 0.06 to 0.42 for herbs and were highest in MC (0.96), BU (0.52), and PD (0.42) for trees, shrubs, and herbs, respectively. Species richness varied greatly across the forest types and was 2–7, 3–9, and 20–84 for trees, shrubs, and herbs, respectively.

Species area curves

The species area curves of understory vegetation for all the seven forest types reached an asymptote within 1,775 m^2 area (Figure 3). PD and JR forests reached an asymptote on 625 m^2 and 850 m^2, whereas AP forest type reached an asymptote on 1,775 m^2.

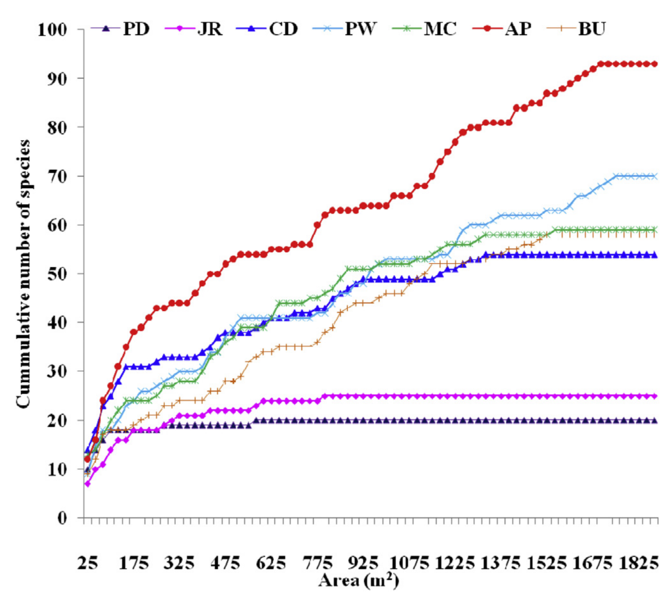

Figure 3. Species area curves for seven temperate forest types of Kashmir Himalaya, India: AP = *Abies pindrow*; BU = *Betula utilis*; CD = *Cedrus deodara*; JR = *Juglans regia*; MC = mixed coniferous; PD = *Populus deltoides*; PW = *Pinus wallichiana*.

Table 3. Importance value index (IVI) of seven temperate forest types [*Populus deltoides* (PD), *Juglans regia* (JR), *Cedrus deodara* (CD), *Pinus wallichiana* (PW), Mixed coniferous (MC), *Abies pindrow* (AP) and *Betula utilis* (BU)] of Kashmir Himalaya, India.

Species	Mean IVI						
	PD	JR	CD	PW	MC	AP	BU
Trees							
Abies pindrow (Royle ex D. Don) Royle			11.23	5.04	100.12	264.67	12.11
Acer caesium Wall. ex Brandis				0.39			
Aesculus indica (Wall. ex Camb.) Hook.f.				0.26			
Betula utilis D. Don							287.89
Cedrus deodara (Roxb. ex Lamb.) G. Don.			258.88	0.31			
Juglans regia L.		254.54					
Robinia pseudoacacia L.	2.26	0.69					
Morus alba L.		1.33					
Picea smithiana (Wall.) Boiss			12.95	3.30	67.19	30.94	
Pinus wallichiana A. B. Jackson			16.93	290.44	132.69	4.38	
Populus deltoides Marsh.	252.83	24.89					
Salix alba L.	16.61	6.05					
Taxus wallichiana Zucc				0.26			
Ulmus villosa Brandis ex Gamble	28.30	12.49					
Shrubs							
Astragalus zanskarensis L.			5.91				
Berberis lycium Royle			184.84	30.86	39.81	22.22	
Desmodium elegans DC.						1.11	
Euonymus hamiltonianus Wall. in Roxb.				3.88	3.30		
Indigofera heterantha Wall. ex Brandis			4.84				
Indigofera linifolia (Linn.f.) Retz.			4.44			1.85	
Juniperus semiglobosa Regel							3.34
Lespedeza elegans Camb.			3.20				
Lonicera japonica Thunb.			4.00	4.83	6.68	10.19	
Parrotiopsis jacquemontiana (Dcne.) Rehder			46.49		2.25		
Plectranthus rugosus Wall.						1.05	
Rhododendron anthopogon D. Don							255.88
Rosa macrophylla Lindl.			2.86			1.09	
Rosa webbiana Wall. ex Royle					6.16		
Rubus ellipticus Smith.				2.67	1.71	6.04	
Sida cordata (Burm.f.) Borss-Waalk.						10.21	
Viburnum grandiflorum Wall. ex DC.			43.41	257.75	240.09	246.23	40.78
Herbs							
Achillea millefolium L.			0.92	0.37	0.36	1.12	
Aconitum laeve Royle							0.55
Actaea spicata L.							8.25
Adiantum venustum D. Don			1.39	0.39	1.15	2.89	
Agrimonia eupatoria L.						0.16	0.47
Ainsliaea aptera DC.			0.21		0.23	0.50	
Ajuga bracteosa Wall ex. Benth		2.02	0.74	0.49	0.40	0.34	
Alchemilla mollis (Buser) Rothm.					0.68		
Allium consanguineum Kunth						2.74	
Anagallis arvensis L.		2.47					
Anaphalis royleana DC.							0.76
Androsace rotundifolia Hardw.			0.33			1.21	
Androsace sempervivoides Jacq. ex Duby				0.50	2.27		
Anemone tetrasepala Royle							0.80
Anthemis cotula L.	5.20	5.57		0.31		0.55	
Aquilegia fragrans Benth.							0.98
Aquilegia moorcroftiana Wall. ex Royle						0.47	
Arenaria orbiculata Royle ex Edgew. & Hook.f.						0.84	
Arisaema jacquemontii Blume				0.66			
Artemisia absinthium L.			0.57			0.36	3.13
Artemisia laciniata Willd.			0.41	0.36		0.30	1.99
Atropa acuminata Royle ex Lindl.						2.06	
Bellis perennis L.				0.17			0.34
Bergenia ciliata (Haw.) Sternb.			0.32			0.12	0.79
Bothriochloa ischaemum (L.) Keng				2.07		2.90	
Bupleurum himalayense Klutz				0.32			
Caltha alba Jacq. ex Camb.							3.28
Cannabis sativa L.	10.29	9.66					
Cardamine impatiens L.				1.59	2.42	1.11	0.71
Carduus edelbergii Rech. f.			1.09	1.42		0.24	
Carpesium cernuum L.						0.54	
Centaurea iberica Trev. ex Spreng.							0.66
Cephalanthera longifolia (L.) Fritsch						0.53	
Cerastium cerastoides (L.) Britt.				7.35	0.42	0.71	1.47
Chamaerhodiola asiatica (D. Don) Nakai							1.94
Chenopodium album L.				0.16			0.34
Cichorium intybus L.	1.00						
Circaea alpina L. var. *himalaica* C. B. Clarke					0.44	0.72	
Cirsium falconeri Petrak			0.22		0.66	1.57	0.47

Table 3 (*continued*)

Species	Mean IVI						
	PD	JR	CD	PW	MC	AP	BU
Clematis buchananiana DC.			0.60				
Clinopodium vulgare L.	27.31	18.24	4.40	9.87	11.51	4.57	
Commelina benghalensis L.					2.19	1.32	
Conium maculatum L.				0.24			
Conyza canadensis (L.) Cronquist	40.58	8.32		0.81	0.72		
Corydalis diphylla Wall.				0.34			0.74
Cucubalus baccifer L.					0.50	0.83	
Cynodon dactylon (L.) Pers.	16.45	5.33	40.78				
Cynoglossum glochidiatum Wall. ex Benth.				0.16			0.47
Cypripedium cordigerum D. Don				0.94			
Dactylis glomerata L.	32.33	52.51			3.70	5.02	12.29
Delphinium cashmerianum Royle				0.18		0.47	
Digitalis lutea L.				0.30	0.24	0.89	
Dioscorea deltoidea Wall. ex Kunth			0.20			0.12	
Diplazium esculentum (Retz.) Sw.			0.77	0.72	0.85	2.77	4.78
Elsholtzia densa Benth.				1.48		0.88	
Elsholtzia eriostachya Benth.						3.84	0.46
Epilobium laxum Royle					0.59	0.34	
Epimedium elatum Morr. & Decne.					0.43		
Epipactis helleborine (L.) Crantz.				0.89			
Epipactis royleana Lindl.				0.49	1.04	0.70	
Erigeron bonariensis L.			0.62				
Erodium cicutarium (L.) L'Hér.						0.34	
Erodium laciniatum (Cay.) Willd.				0.16			
Filipendula vestita (Wall. ex G. Don) Maxim.							2.76
Fragaria nubicola (Lindl. ex Hook.f.) Lacaita	25.53	4.07	28.98	32.16	19.98	19.76	0.94
Galinsoga parviflora Cav.	16.41			0.31			
Galium aparine L.			1.19	0.80	0.86	0.33	41.86
Galium asperuloides Edgew.						0.39	
Geranium pratense L.		1.31	4.60	9.68	3.20	3.44	3.90
Geum urbanum L.						1.02	
Gnaphalium indicum L.			0.41				
Heracleum candicans Wall. ex DC.					0.41		
Heracleum hirsutum Edgew.					0.37		1.13
Hypericum perforatum L.			1.26	0.50		0.69	
Impatiens brachycentra Kar. & Kir.		12.80			1.20	2.78	7.23
Indigofera linifolia (L.f.) Retz			0.40				
Lactuca dissecta D. Don			0.20	0.17			
Lamium album L.						0.71	1.35
Lancea tibetica HK. F. & T.			0.57				
Lapsana communis L.					0.25		
Lavatera cashmeriana Camb.				0.55			
Leontopodium himalayanum DC.							1.16
Lindelofia angustifolia (Schrenk) Brand.							0.71
Lychnis coronaria (L.) Desr.						0.38	
Malva neglecta Wall.							70.98
Marrubium vulgare L.				0.31			
Mentha longifolia (L.) Huds.				1.16	0.87	0.50	
Myosotis alpestris F.W. Schmidt						0.49	
Myosotis arvensis (L.) Hill.	4.56	2.62		0.36	0.44	0.98	
Myosoton aquaticum (L.) Moench.	10.47	19.68	1.54	0.33	1.65	5.04	
Myriactis wallichii Less.	1.82	2.78	3.11	6.25	2.19	4.12	0.87
Nepeta erecta (Royle ex Benth.) Benth.						0.47	
Nepeta nervosa Royle ex Benth.						0.29	0.55
Oenothera rosea Soland.							0.47
Oplismenus compositus (L.) P. Beauv.			3.04		0.44	1.59	
Orobanche alba Stephan ex Willd.						0.17	
Oxalis acetosella L.	31.23	6.24	10.29	22.54	11.59	9.53	18.04
Oxyria digyna (L.) Hill						0.43	
Paeonia emodi Wall. ex Hk. f.				1.41			
Pedicularis pectinata Wall. ex Benth.							2.26
Persicaria nepalensis (Meisn.) H. Gross						0.00	
Phlomis bracteosa Royle ex Benth.							5.33
Phytolacca latbenia (Moq) Hans Walter		0.99	2.11	5.82	3.92	4.21	
Plantago erosa Wall.				0.17	1.01	0.55	
Plantago himalaica Pilger						0.68	
Plantago lanceolata L.					0.73		
Plantago major L.	14.33	15.30	2.57	1.94	0.89	3.12	0.34
Pleurospermum candollei (DC.) C.B. Clarke in Hook. f.						4.78	
Poa annua L.				5.62	1.32	1.56	
Poa bulbosa L.		87.74					
Poa stewartiana Bor			5.53	5.68	3.05	2.20	
Podophyllum hexandrum Royle			1.10	1.15	1.30	1.27	

(*continued on next page*)

Table 3 (*continued*)

Species	Mean IVI						
	PD	JR	CD	PW	MC	AP	BU
Polemonium caeruleum L.							1.18
Polygonatum verticillatum (L.) All.							3.06
Polygonum affine D. Don							1.93
Polygonum amplexicaule D. Don			3.22	3.39		2.35	31.04
Potentilla atrosanguinea G. Lodd. ex D. Don.		8.64				1.41	18.10
Potentilla biflora Willd. ex Schlecht.						0.29	
Primula macrophylla D. Don						0.13	
Prunella vulgaris L.	29.86	4.99	6.86	3.00	2.99	5.01	
Pteracanthus alatus (Wall. ex Nees) Bremek.				0.15			
Pyrola rotundifolia L.				0.18			
Ranunculus hirtellus Royle			0.43	0.67	0.44	1.01	0.39
Ranunculus laetus Wall. ex Royle						1.08	
Ribes orientale Desf.							25.36
Rorippa islandica (Oeder) Borbás							1.46
Rumex nepalensis Spreng			4.27	7.64	3.50	7.82	
Sambucus nigra L.	1.25		3.94	6.65	5.39	5.36	
Sedum ewersii Ledeb.			0.38				0.50
Silene vulgaris (Moench) Garcke				0.18	0.38	0.33	0.44
Solanum nigrum L.	3.82	6.43		0.16			
Stellaria media (L.) Cry.				0.31			0.43
Stipa sibirica (L.) Lam.			138.33	123.31	172.75	128.48	6.53
Swertia ciliata (D. Don ex G. Don) B. L. Burtt							0.91
Taraxacum officinale G.H. Weber ex Wiggers.	8.62	7.29	3.00	2.61	2.90	3.95	
Thymus linearis Benth.			0.47				1.26
Trifolium repens L.		3.69	3.31	0.31	1.24	3.27	
Trillium govanianum Wall. ex Royle						0.31	0.40
Tussilago farfara L.					0.24	0.97	
Juncus inflexus L.						1.19	
Urtica dioica L.	10.78	6.93	0.22	0.19	1.06	1.99	
Valeriana jatamansi Jones ex Roxb.						0.53	1.45
Verbascum thapsus L.	8.16	4.39	1.33	0.55	1.98	1.20	
Veronica biloba schreb. ex L.				1.72	20.68		
Vincetoxicum hirundinaria Medik.				0.18			
Viola canescens Wall. ex Roxb.			13.78	19.17		17.73	

Density and stand basal area

There were 35,794 individuals of trees and the mean stand density in seven forest types ranged from 103 trees/ha in the BU forest to 1,201 trees/ha in the PD forest (Table 2). The total basal area was 4,542.1 m^2 and the mean stand basal area ranged from 19.4 m^2/ha to 51.9 m^2/ha in BU and AP forests, respectively. The highest shrub density (32,616 individuals/ha) and basal area (2.9 m^2/ha) was observed in PW forest, whereas the least density (12,392 individuals/ha) and basal area (0.96 m^2/ha) was in CD and MC forests, respectively. In PD and JR forests, no shrub species was found. In case of herbaceous community, the highest density (361 individuals/m^2) and basal area (13.07 cm^2/m^2) were observed in PW and AP forests, respectively, while the least density (192 individuals/m^2) and basal area (4.45 cm^2/m^2) were found in PD and BU forests, respectively.

Population density

The population density of the enumerated 14 tree species varied considerably across the seven forest types. In PD forest type, *P. deltoides* was the most abundant species (94%, 1125 stems) in terms of density and IVI (Table 3). Similarly, *J. regia* (82%, 181 stems), *C. deodara* (88%, 172 stems), *P. wallichiana* (97%, 193 stems), *A. pindrow* (90%, 178 stems), and *B. utilis* (95%, 98 stems) were dominant species in JR, CD, PW, AP, and BU forest types, respectively. In MC forest, *A. pindrow* (33.41%, 65 stems), *P. wallichiana* (21.89%, 43 stems), and *Pinus wallichiana* (44.7%, 88 stems) were dominant.

Viburnum grandiflorum was the most abundant shrub species in terms of both density and IVI in coniferous forests [PW (94%, 32,616 individuals), MC (92%, 15,280 individuals), and AP (94%, 26,240 individuals)], except CD forest where *Berberis lyceum* (68%, 8,448 individuals) was the most abundant species. However, in BU forest, *Rhododendron anthopogon* (86%, 17,888 individuals) was the dominant species.

Stipa sibirica was the dominant species in the herbaceous community in coniferous forests [CD (50.5%, 180.1 individuals/m^2), PW (55%, 198.4 individuals/m^2), MC (76.7%, 178.5 individuals/m^2), and AP (61.7%, 177.1 individuals/m^2)], while in low-elevation broad-leaved forests (PD/JR), *Dactylis glomerata* (33.9%, 65.22 individuals/m^2) and *Poa bulbosa* (45.7%, 118.4 individuals/m^2) were dominant species in terms of density, whereas *Conyza canadensis* was dominant in PD forest in terms of IVI. However, in BU forest type *Malva neglecta* (41.7%, 81.64 individuals/m^2) was the abundant species.

A total of five species belonging to five families were found to be endemic to Himalaya: *Anaphalis royleana*; *Delphinium cashmerianum*; *Geum urbanum*; *Lespedeza elegans*; and *Sedum ewersii*. Among them, four are herbs and one is a shrub. *Acer caesium* (vulnerable), *Cypripedium cordigerum* (rare), *Dioscorea deltoidea* (vulnerable), *J. regia* (near threatened), and *Taxus wallichiana* (endangered) are recognized as threatened species by the International Union for Conservation of Nature.

Size class distribution

Tree density decreased with increasing diameter class (Figure 4). In total, the highest density of 21.7% was contributed by 10.1–20 cm diameter class and lowest density of 0.3% was contributed by > 100.1 cm diameter class in all forest types. Tree density in the lower diameter class (3.1–10 cm) was greater in PD (27.1%), compared to all other forest types, while the higher

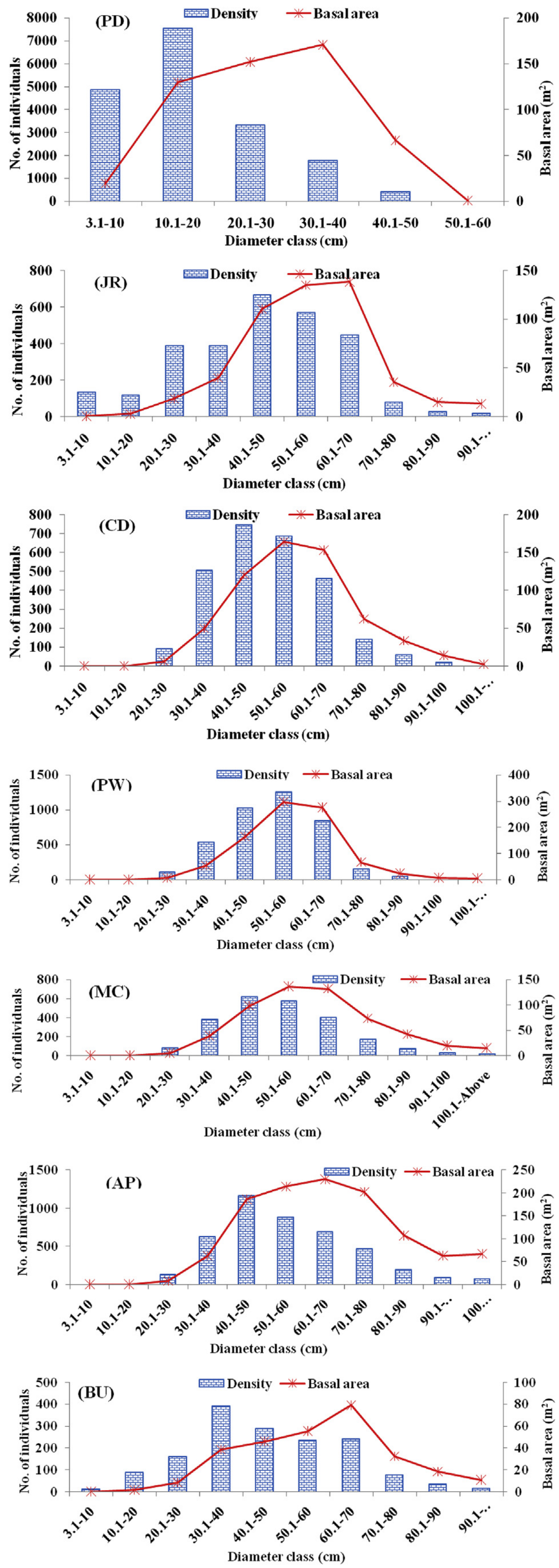

Figure 4. Size class distribution of tree density and basal area (m^2) in seven temperate forest types of Kashmir Himalaya, India: AP = *Abies pindrow*; BU = *Betula utilis*; CD = *Cedrus deodara*; JR = *Juglans regia*; MC = mixed coniferous; PD = *Populus deltoides*; PW = *Pinus wallichiana*.

diameter ($\geq$ 100 cm) was greater in AP (1.8%) and MC (0.7%) forests. Among all the forest types, the first five diameter classes (3.1–60 cm) contributed 86.3% of the density whereas the other five diameter classes (> 60.1 cm) contributed 13.7% of the density.

Family composition

The number of species in a family varied from 1 to 22 (Table 4). Of the total 66 families, 31.81% (21) families were represented by single genus and species and 19.7% (13) families were represented by two species. Asteraceae (represented by 21 genera and 22 species, 12.4%) and Lamiaceae (represented by 10 genera and 13 species, 7.3%) were taxonomically the most speciose families. Seven families were common among all the seven forest types.

Species distribution pattern

Abundance to frequency ratio for the tree stratum indicated that 11.5%, 26.8%, and 61.7% of the species exhibited regular, random, and contagious distribution patterns, respectively (Table 5). In the shrub layer, all the species (100%) showed a contagious pattern, whereas, in the case of the herb layer, 0.7%, 10.2%, and 89.1% of the species showed regular, random, and contagious distribution patterns, respectively.

Species heterogeneity

In the tree layer, species heterogeneity ranged from 0.21 (PW) to 0.8 (MC; Table 2), in the shrub layer, it ranged from 0.32 (PW/AP) to 0.7 (CD), however in the herb layer it ranged from 0.63 (MC) to 0.9 (PD).

Discussion

There are large variations in species richness, basal area, and density in temperate forest ecosystems due to their varying climatic conditions, topography, and elevation gradients (Table 6) as well as forest types, lack of uniform plot dimensions, and standard girth or diameter class (Sundarapandian and Pascal 2013). The species richness in seven temperate forests of Western Kashmir Himalaya ranged between 24 and 96 (2–7 trees, 3–9 shrubs, and 20–84 herbs), which is well within the range (19–105 species in 70 plots of 0.03 ha each) reported in alpine forests of Hengduan Mountains, northwest Yunnan, China (Sherman et al 2008). Species richness reported in the present study are higher than the results reported (66 species: trees, 12; shrubs, 19; and herbs, 34) from nearby temperate forests of Garhwal Himalaya of Uttarakhand (Gairola et al 2011b), in temperate forests of Shimla (55 species: 6 trees, 14 shrubs, and 35 herbs in 36 plots of 0.1 ha each), Himachal Pradesh (Singh and Gupta 2009). The species richness value of the present study is lower than the temperate forests in Arunachal Pradesh (128 species: 41 trees, 22 shrubs, and 65 herbs in 60 plots of 0.01 ha each; Rana and Gairola 2009), in Kedernath Wildlife Sanctuary (116 species: 16 trees, 35 shrubs and 65 herbs in 60 plots of 0.01 ha each), Central Himalaya (Semwal et al 2010) and western Himalayan (122 species in 180 stands of 30 m × 30 m each) moist temperate forests in Kashmir, Pakistan (Shaheen et al 2012). Greater species richness was observed in mid-elevation (2,300–2,800 m) coniferous forest types compared to low elevation broad-

Table 4. Contribution of families to genera (G), species richness (S), and density (D; No./ha) in seven temperate forest types [*Populus deltoides* (PD), *Juglans regia* (JR), *Cedrus deodara* (CD), *Pinus wallichiana* (PW), mixed coniferous (MC), *Abies pindrow* (AP), and *Betula utilis* (BU)] of Kashmir Himalaya, India.

Family	PD			JR			CD			PW			MT			AP			BU		
	G	S	D	G	S	D	G	S	D	G	S	D	G	S	D	G	S	D	G	S	D
Acanthaceae	0		0			0			0	1	1	133			0			0			0
Adoxaceae	1	1	600			0	1	1	2,400	1	1	6,400	1	1	2,253	1	1	3,867			0
Amaryllidaceae			0			0			0			0			0	1	1	2,933			0
Apiaceae	1	1	54,600	1	1	43,600	1	1	5,867	3	3	8,933	2	3	6,667	1	1	16,800	2	2	4,400
Apocynaceae			0			0			0	1	1	133			0			0			0
Araceae			0			0			0	1	1	533			0			0			0
Asparagaceae			0			0			0			0			0			0	1	1	15,400
Asteraceae	6	6	299,000	4	4	42,600	10	11	13,333	10	10	41,333	8	8	10,175	10	11	3,6400	7	8	34,800
Athyriaceae			0			0	1	1	800	1	1	1,867	1	1	2,133	1	1	11,200	1	1	11,200
Balsaminaceae			0	1	1	44,800			0			0	1	1	2,000	1	1	11,467	1	1	39,400
Berberidaceae							2	2	9,248	2	2	3,107	3	3	2,267	2	2	2,264			
Betulaceae																			1	1	98
Boraginaceae	1	1	6,800	1	1	3,200				2	2	4,000	1	1	800	1	2	4,400	2	2	1,000
Brassicaceae										1	1	12,267	1	1	815	1	1	7,467	2	2	3,000
Cannabaceae	1	1	8,400	1	1	8,400			0			0			0			0			0
Caprifoliaceae							2	2	2,136	2	2	30,896	2	2	14,288	3	3	26,163	2	2	3,016
Caryophyllaceae	1	1	28,400	1	1	128,400	1	1	5,867	4	4	55,200	4	4	13,226	6	6	53,200	3	3	2,600
Celastraceae										1	1	40	1	1	24						
Chenopodiaceae			0			0			0	1	1	133			0			0	1	1	400
Commelinaceae			0			0			0			0	1	1	3,613	1	1	6,267			0
Crassulaceae							1	1	267										2	2	1,400
Cupressaceae																			1	1	224
Dioscoreaceae			0			0	1	1	267			0			0	1	1	267			0
Ericaceae																			1	1	15,448
Fabaceae				1	1	8,400	5	6	18,056	1	1	533	1	1	8,133	2	3	20,989			
Gentianaceae			0			0			0			0			0			0	1	1	600
Geraniaceae				1	1	1,600	1	1	16,933	2	2	60,533	1	1	8,821	2	2	13,333	1	1	6,800
Grossulariaceae			0			0			0			0			0			0	1	1	17,400
Hamamelidaceae							1	1	912				1	1	32						
Hippocastanaceae										1	1	0									
Hypericaceae			0			0	1	1	1,333	1	1	800			0	1	1	1,600			0
Juglandaceae				1	1	182															
Juncaceae			0			0			0			0			0	1	1	1,200			0
Lamiaceae	2	2	388,600	3	3	48,800	4	4	33,467	6	6	153,467	4	4	36,733	9	11	99,507	4	4	7,600
Malvaceae										1	1	7,200				1	1	184	1	1	816,400
Melanthiaceae			0			0			0			0			0	1	1	267	1	1	400
Mimmocaceae	1	1	3	1	1	1															
Moraceae				1	1	1															
Onagraceae													2	2	1,733	2	2	4,933	1	1	400
Orchidaceae										2	3	9,067	1	1	1,867	2	2	2,667			
Orobanchaceae										1	1	2,667				1	1	400			
Oxalidaceae	1	1	252,600	1	1	16,600	1	1	89,333	1	1	349,467	1	1	90,049	1	1	94,667	1	1	114,800
Paeoniaceae			0			0			0			0			0	1	1	267			0
Papaveraceae			0			0			0	1	1	400			0			0	1	1	800
Phrymaceae			0			0	1	1	400			0			0			0			0
Phytolaccaceae			0			0			0			0			0			0	1	1	4,600
Pinaceae							4	4	195	4	4	198	3	3	196	3	3	197	1	1	5
Plantaginaceae				1	1	600	1	1	1,067	4	4	12,533	4	5	101,642	4	4	14,533			
Poaceae	2	2	729,000	3	3	2,188,000	4	4	2,999,300	3	4	2,105,067	4	5	1,839,081	6	7	1,885,867	2	2	114,800
Poleminiaceae			0			0			0			0			0			0	1	1	1,200
Polygonaceae							2	2	14,267	2	2	36,800	1	1	3,571	2	2	22,267	2	3	184,600
Primulaceae				1	1	2,000	1	1	400	1	1	667	1	1	25,600	2	2	23,733			
Pteridaceae			0			0	1	1	3,867	1	1	2,667	1	1	2,667	1	1	36,800			0
Pyrolaceae			0			0			0	1	1	267			0			0			0
Ranunculaceae							2	2	1,333	2	2	1,067	1	1	533	3	4	27,600	6	6	69,400
Rosaceae	1	1	130,600	2	2	40,400	2	2	281,507	2	2	509,640	4	4	156,832	6	7	213,133	4	4	101,200
Rubiaceae							1	1	5,333	1	1	1,333	1	1	2,400	1	2	2,533	1	1	400,400
Salicaceae	2	2	1,157	2	2	25															
Sapindaceae										1	1	0									
Saxifragaceae			0			0	1	1	267			0			0	1	1	133	1	1	600
Scrophulariaceae	1	1	12,000	1	1	2,400	1	1	2,000	1	1	400	1	1	3,067	1	1	6,800			0
Solanaceae	1	1	5,200	1	1	6,200				1	1	133				1	1	800			
Taxaceae										1	1	0									
Ulmaceae	1	1	40	1	1	11															
Urticaceae	1	1	8,800	1	1	4,400	1	1	267	1	1	267	1	1	782	1	1	4,000			0
Violaceae			0			0	1	1	71,467	1	1	221,333			0	1	1	23,3867			0

leaved forests and high elevation broad-leaved forest. This may be due to the fact that mid-elevation ranges are less disturbed than the low elevation ranges. Low elevation broad-leaved forests are managed plantations; where shrub community is completely absent. This could also be one of the reasons for low species richness in managed plantations. Occasional removal of understory vegetation in these plantations could be another reason for low diversity. Highly variable climatic conditions across these forest

Table 5. Distribution pattern (%) of trees, shrubs and herbs in seven temperate forest types of Kashmir Himalaya, India.

Forest/vegetation type		Regular	Random	Contagious
Populus deltoides (PD)	Trees	7	29	64
	Shrubs	0	0	100
	Herbs	1	18	81
Juglans regia (JR)	Trees	5	30	65
	Shrubs	0	0	100
	Herbs	4	8	88
Cedrus deodara (CD)	Trees	0	33	67
	Shrubs	0	0	100
	Herbs	0	15	85
Pinus wallichiana (PW)	Trees	0	14	86
	Shrubs	0	0	100
	Herbs	0	2	98
Mixed coniferous (MC)	Trees	25	47	28
	Shrubs	0	0	100
	Herbs	0	3	97
Abies pindrow (AP)	Trees	3	30	67
	Shrubs	0	0	100
	Herbs	0	4	96
Betula utilis (BU)	Trees	40	3	57
	Shrubs	0	0	100
	Herbs	0	21	79

types also have a strong influence on vegetation patterns. Tree density and grazing intensity alter the understory community, which causes lower species richness values of ground flora at low elevation than at mid- and high-elevation forests. The increase in species richness in mid-altitude may be due to lower density and basal area (Mandal and Joshi 2014). Zhang and Mi (2007) also reported the increasing trend in species richness with increasing altitude between 2,100 m and 3,050 m in northern China and stated that this trend may have been the result of differences in grazing intensity. Nogues-Bravo et al (2008) reported that areas at higher altitudes are more likely to be a refuge for large numbers of species, because human activities decrease with increased altitude. Although altitude is the main factor in controlling the species distribution, some cofactors such as topography, aspect, slope, and exposure can also alter the structure and species composition (Shanks and Norris 1950). A gradual monotonic decrease in species richness with increasing altitude is considered as a general pattern (Francis and Currie 1998). However, species richness does not show this pattern in our study. It showed a hump-shaped pattern with altitude (c.f. Figure 5), which is consistent with overall interpolated species richness patterns in Himalayas (Bhattarai et al 2004;

Table 6. Comparison of phytosociological attributes and species richness of different temperate forests of the present and previous studies.

Forest type	Region/Locality	Elevation (m. asl)	Total area sampled	Density (D)	Basal area (BA)	Species richness	Source
Temperate forests	Kashmir Himalaya, India	1,550–3,250	111 (0.25 ha)	103–1,201	19.4–51.9	$177 = 14^T + 17^S + 146^H$	Present study
Temperate forests	Changbai Mountain, China	750–2,100	68 (0.04 ha)	—	—	$213 = 37^T + 32^S + 144^H$	Bai et al (2011)
Sub-alpine region	Garhwal Himalaya, India	2,200–3,000	20 (50 × 50 cm)	—	—	90	Bisht and Bhat (2013)
Temperate deciduous forests	Denmark	—	50 ha	770	30.7	165	Borchsenius et al (2004)
Sub-tropical to warm temperate	Central Himalaya	1,300–1,750	40 (0.01 ha)	540–1,630	25–47.2	—	Chaturvedi and Singh (1987)
Tropical semi-evergreen	Manipur, northeast India	—	20 (0.01 ha each)	10–675	—	$123 = 17^T + 36^S + 70^H$	Devi and Yadava (2006)
Abies pindrow	Pithoragarh, Kumaun Himalaya,	3,100	3 (0.5 ha)	660	78.90	—	Dhar et al (1997)
Moist temperate forest	Mandal-Chopta, Garhwal Himalaya, Uttarakhand	1,500–3,000	NA	—	—	338	Gairola et al (2010)
Moist temperate forests	Western Himalaya, Garhwal Uttarakhand, India	2,400–2,850	NA	380–1,180	41.25–86.56	65	Gairola et al (2011a)
Moist temperate forests	Western Himalaya, India	1,500–2,500	NA	990–1,470	35.08–84.25	129	Gairola et al (2011b)
Temperate forests	Mandal-Chopta Garhwal Himalaya, India	1,500–2,850	NA	380–1,390	32.77–86.56	—	Gairola et al (2012)
Temperate forests	Northeast, Spain	1,500–2,200	329 (2,632 m)	—	—	9	Gracia et al (2007)
Dry forests	Miombo, Zambia	1,292–1,300	24 (0.25 ha)	308–736	5.6–27.5	83	Kalaba et al (2013)
Temperate forests	Naran valley, Pakistan	2,450–4,100	144 (0.25 ha)	—	—	$198 = 12^T + 20^S + 166^H$	Khan et al (2011)
Community temperate forests	Dolpha, Mid-west Nepal	1,900–2,700	20 (0.01 ha)	2,090–2,100	90.07–151.98	16	Kunwar and Sharma (2004)
Temperate forests	Manang, central Nepal	3,000–4,000	80 (0.01 ha)	—	—	168	Panthi et al (2007)
Temperate forests	Arunachal Pradesh, India	350–700	60 (0.01 ha)	550–860	19.61–78.32	$128 = 41^T + 22^S + 65^H$	Rana and Gairola (2009)
Temperate forests	Garhwal Himalaya, India	500–6,940	20 (0.01 ha)	1,090–1,980	20.97–40.19	8–19	Raturi (2012)
Wet temperate forest	Abbottabad, Pakistan	800–2,500	NA	—	—	167	Saima et al (2010)
Temperate forests	Kumaun Himalaya	1,280–2,227	48 (0.01 ha)	—	—	7–21	Saxena and Singh (1984)
Temperate forests	Central himalaya, India	1,400–2,700	60 (0.01 ha)	20–170		$116 = 16^T + 35^S + 65^H$	Semwal et al (2010)
Temperate forests	Western Himalaya, northern Pakistan	>3,300	30 (0.01 ha)	—	—	83	Shaheen et al (2011a)
Temperate alpine pastures	Western Himalaya, Pakistan	2,600–3,500	20.5 ha	—	—	69	Shaheen et al (2011b)
Sub-tropical	Bagh western Himalaya, Pakistan	1,000–2,200	20 (900 m^2)	344	69.31	72	Shaheen et al (2011c)
Moist temperate forests	Western Himalaya, Kashmir	1,700–2,600	180 (900 m^2 each)	90–227	42.32–105.29	122	Shaheen et al (2012)
Sub-tropical	Northwestern Himalaya, Jammu & Kashmir, India	580–3,500	750 (0.04 ha)	—	—	2–28	Sharma and Raina (2013)
Moist temperate forest	Dudhatoli, Garhwal Himalaya	1,800–3,000	NA	—	—	268	Sharma et al (2013)

(continued on next page)

Table 6 (*continued*)

Forest type	Region/Locality	Elevation (m. asl)	Total area sampled	Density (D)	Basal area (BA)	Species richness	Source
Alpine zone	Northwest Yunnan, China	3,800–5,200	70 (0.036)	—	—	369	Sherman et al (2008)
Temperate forests	Shimla, Himachal Pradesh	1,650–2,295	36 (0.1 ha)	4,217–7,765	18.49–52.54	$55 = 6^T + 14^S + 35^H$	Singh and Gupta (2009)
Temperate: evergreen, deciduous & coniferous	Mt. Emei, Sichuen, China	660–3,099	10 (0.02–0.04 ha)	—	—	122	Tang and Ohsawa (1997)
Temperate forests	Azad Kashmir, Pakistan	—	70 (0.01 ha)	—	—	200	Tanvir et al (2014)
Tropical moist deciduous	Uttar Pradesh, India	—	18 (300 m^2)	57–148	24.84–45.55	166	Tripathi and Singh (2009)
Temperate forests	Baihua mountain, China	750–2,043	61 (0.02 ha)	—	—	171	Zhang et al (2013)

asl = above sea level; H = herbs; NA = not available; S = shrubs; T = trees.

Shaheen et al 2012). Similarly, Sanchez-Gonzalez and Lopez-Mata (2005) reported that intermediate elevation forests (2,950–3,200 m) have higher values of species richness and diversity compared to low (< 2,950 m), and high (3,200–3,500 m) elevations, and very low at elevations above 3,500 m in temperate forests of Sierra Nevada, Mexico. In the Himalayan region, few variations have been recorded in species richness values in the 1,500–2,000 m altitudinal range (Grytnes and Vetaas 2002). However, species richness can also be influenced by the microclimate of the area with variations in edaphic factors (Ferrer-Castan and Vetaas 2003).

The diversity values recorded in the present study are lower than the reported range of 1.16–3.40 for Himalayas (Kunwar and Sharma 2004; Shah et al 2009; Shaheen et al 2012). A positive correlation was observed between species richness and elevation ($R^2 = 0.37$) and evenness of trees with altitude ($R^2 = 0.19$; Figure 5).

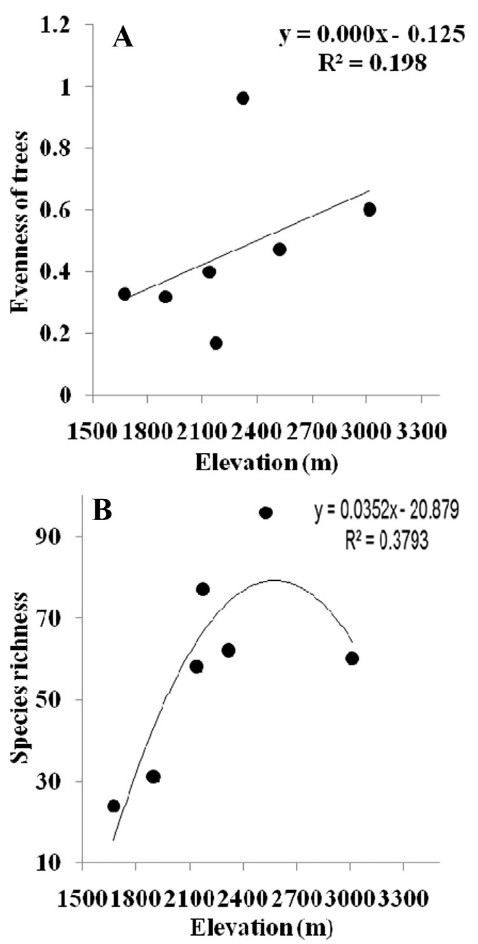

Figure 5. Relationship between species evenness (A) and richness (B) with elevation in seven temperate forest types of Kashmir Himalaya, India.

Tree density recorded in the coniferous forests are higher than the value (90/ha in 180 stands of 30 m × 30 m each) reported in western moist temperate forests of Kashmir Himalaya, Pakistan by Shaheen et al (2012) and lower than the values (540/ha) reported from Nainital, Indian Himalayas by Saxena and Singh (1982), in moist temperate forests of Garhwal Himalayas (493–1,180 stems/ha), Uttarakhand by Gairola et al (2011a), in Kumaun Himalayas (420–680 stems/ha) by Singh et al (1994), and in Pauri Garhwal Himalayas (220–640 stems/ha) by Sharma et al (2001). The lower density in coniferous forests of the present study may be due to illegal cutting of trees by the local communities. The harsh environmental condition (snowfall) lead to falling of trees. In high elevation (BU forest), these extreme climatic conditions might have reduced the tree density. Coniferous forests are old growth forests with large-sized mature trees, which may also be the reason for low density. The higher tree density in PD forest may be because these are managed plantations and prevalence of young trees, which are smaller in size.

The averaged basal area for all the forest types i.e. 40.16 m^2/ha (19.4–51.9 m^2/ha) is lower than the other Himalayan regions such as 42.3–100.8 m^2/ha in moist temperate forests of Kashmir, Pakistan (Shaheen et al 2012); 90.1–151.9 m^2/ha in trans-Himalayan forests of Nepal (Kunwar and Sharma 2004); 41.25–86.56 m^2/ha in moist temperate forests of Garhwal Himalaya, Uttarakhand (Gairola et al 2011b) and 5–114 m^2/ha in temperate forests of central Himalayas, Kumaun (Singh et al 1994), while it is closer to the values (31.50–57.33 m^2/ha) reported in temperate forests of Pauri Garhwal, Uttarakhand (Baduni and Sharma 1996), in the *A. pindrow* forest in moist temperate forests of Garhwal Himalayas (Gairola et al 2011a) and in temperate forests of Garhwal (15–60 m^2/ha, Bhandari et al 1997). However, the results obtained are higher than the results reported by Ghildiyal et al (1998, 24–29 m^2/ha) in oak forests in Garhwal Himalaya and Baduni and Sharma (1999, 18.45–38.25 m^2/ha) in *Quercus floribunda* forest of Garhwal Himalaya. The lower basal area of the study area may be due to lesser density of trees in coniferous forests (CD, PW, MC, and AP) and BU forest. Similarly, low basal area in PD and JR forests could be attributed to very young and dense plantations.

In temperate forests of Kashmir Himalaya, six prominent species, including *P. deltoides*, *J. regia*, *C. deodara*, *P. wallichiana*, *A. pindrow*, and *B. utilis* contribute largely to the total density (84%) and IVI of the trees in respective forest types. The high Simpson index value in the studied temperate forest when compared to several other temperate and tropical forest types, could be attributed as monospecific forest.

Diameter class-wise distribution is one of the important aspects of forest structural heterogeneity, dynamics and functioning of many forest ecosystems (Lutz et al 2013). All the forest types showed greater density in mid-diameter class (30.1–80 cm), except PD forest type. The diameter class distribution of the present study indicates that these forests are mature forests except PD forest type, which has > 90% of the trees from lower diameter class (3.1–30 cm diameter at breast height).

Asteraceae, Lamiaceae, Ranunculaceae, Rosaceae, Poaceae, Caryophyllaceae, and Fabaceae were the more speciose families in temperate forests of Kashmir Himalaya. Similarly, Asteraceae and Lamiaceae have been reported as dominant families in temperate forests of India and elsewhere (Gairola et al 2010; Saima et al 2010; Khan et al 2012; Sharma et al 2013). Shaheen et al (2011a) also reported that Asteraceae (19%), Poaceae (13%), Ranunculaceae (11%), Rosaceae (8%), and Saxifragaceae (8%) were dominant families in western Himalayas, northern Pakistan. Dar et al (2012) found that the Asteraceae (260 species), Poaceae (160 species), Brassicaceae (115 species), Rosaceae (98 species), and Lamiaceae (88 species) were the first five large families of the total flora of Kashmir. Hooker (1906) stated Orchidaceae, Fabaceae, Poaceae, Rubiaceae, Euphorbiaceae, Acanthaceae, Asteraceae, Cyperaceae, Lamiaceae, and Utricaceae as the diverse families of India. It is clear that across various temperate forests, a great similarity is evident at the family level.

Most of the species in all the three vegetation strata (trees, herbs, and shrubs) showed a contagious distribution pattern. Several workers have also reported the contagious distribution pattern as a common phenomenon in temperate forests (Kershaw 1973; Gairola et al 2011b). Odum (1971) reported that contagious distribution pattern is the most common pattern in nature. Variation in distribution pattern across the vegetation layers seems to be associated with a large number of factors, especially the microenvironment and biotic nature (Joshi and Tiwari 1990).

Tree and shrub layers showed a homogenous pattern, while the herb layer was heterogeneous. This is because each forest type is dominated by different species of herbs. A similar observation was reported by several other workers in central Himalayan forests (Saxena and Singh 1982; Kumar et al 2004; Gairola et al 2011b).

The present study reveals that the temperate forests in Western Himalaya contain more species richness in mid-elevation coniferous forests than that of broad-leaved forests at both higher and lower elevations. The variation in species composition and richness may be due to the age structure of forest types, level of anthropogenic pressure, and difference in climatic conditions.

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