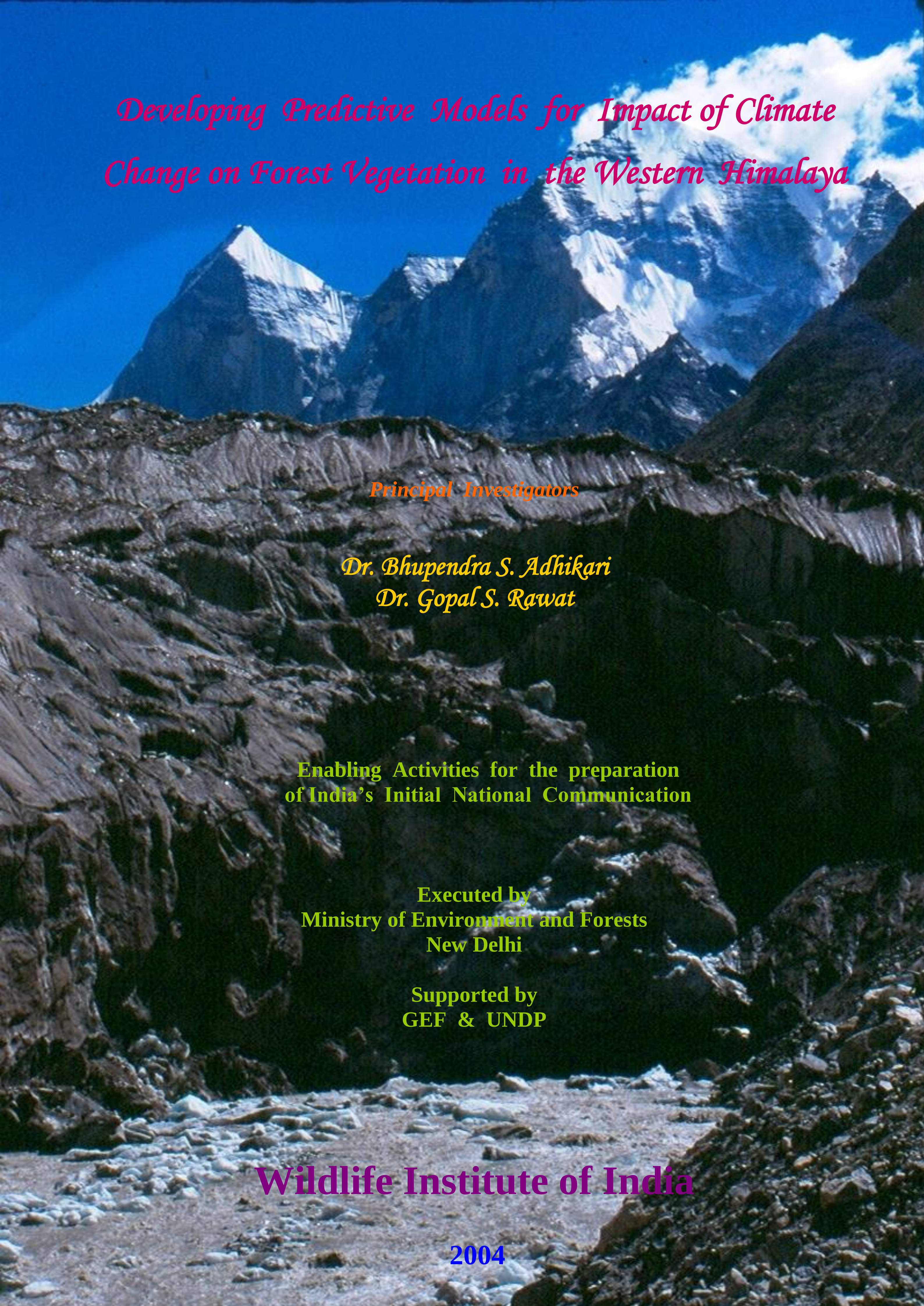

Developing Predictive Models for Impact of Climate Change on Forest Vegetation in the Western Himalaya

Principal Investigators

Dr. Bhupendra S. Adhikari
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Enabling Activities for the preparation of India's Initial National Communication

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Contents

Executive Summary

The present study deals with the impact of climate change on the structural and functional attributes (biomass and productivity) of the vegetation along an altitudinal gradient (1600-3700m asl), within watersheds and among different forest types in Garhwal Himalaya. The study provides an insight on the vegetation of Garhwal Himalaya with special reference to temperature and comparison with Kumaun Himalayan forests. Among all watersheds (Dharamganga, Dogadda, Asiganga, Bhatwari and Gangotri), 18 major forest types were identified. Out of 81 sites, most of the sites were dominated by kharsu oak (Quercus semecarpifolia) forest (# 25) followed by banj oak (Quercus leucotrichophora) forest (#8) and mixed-broadleaved, conifer-broadleaved and oak-conifer forests (each #7). The species richness and density were highest (8 and 510 trees ha^{-1}) for horse chestnut, while the total basal area was highest for banj oak forest (74.5 m^{2} ha^{-1}). The total biomass was highest for horse chestnut forests (487.0 t ha^{-1}), productivity for oak-conifer forest (20.0 t ha^{-1} yr^{-1}) followed by deciduous broadleaved forest (19.6 t ha^{-1} yr^{-1}), while the litter fall for deciduous broadleaved forest (6.6 t ha^{-1} yr^{-1}).

The carbon allocation in biomass was highest in horse chestnut forests (243.5 t C ha^{-1}), oak-conifer forest (10.0 t ha^{-1} yr^{-1}) in productivity and deciduous-broadleaved forest (3.3 t ha^{-1} yr^{-1}) in litter fall. The total carbon storage was high (196-344 t ha^{-1}) for horse chestnut, oak-conifer, tilonj oak (Quercus floribunda), deciduous-broadleaved, silver fir and kharsu oak forests, intermediate (125-195 t ha^{-1}) for chir pine (Pinus roxburghii), toon (Cedrella toona), mixed-broadleaved, tilonj oak-mixed, conifer-broadleaved, mixed oak and deciduous-conifer forests and low (<125 t ha^{-1}) for alder(Alnus nepalensis), banj oak, deodar(Cedrus deodara), kai (Pinus wallichiana)l and birch (Betula utilis) forests. The carbon accumulation was extremely high (11.4-13.1 t ha^{-1} yr^{-1}) in deciduous-broadleaved, oak-conifer and horse chestnut forests. Along altitudinal gradient the species richness was highest at 1800, 2300, 2400 and 2500m; density at transition place (1700m) and between 2100-2800m and total basal area at 2700 and 2800m. However, biomass between 2400-3200m, productivity between 2700-3100m and litter fall between 2700-3200m was highest. The allocation of carbon was highest for all the parameters (biomass, productivity and litter fall) was highest at 2800m (kharsu oak/oak-conifer forest) followed by altitude 2700m (kharsu oak/silverfir (Abies pindrow)/oak-conifer forests). Among watersheds, Dogadda having the highest biomass, productivity and litter fall followed by Dharamganga, while Gangotri have the least values for biomass, productivity and litter fall and allocation of carbon was following the same pattern.

At a regional scale (both Kumaun and Garhwal, the relationships between temperature and structural and functional attributes are: i) the density declines at 2750m and at 11.1 ℃ MAT, ii) the total basal area declines at 2650m and at 11.5 ℃ MAT, and iii) the biomass, productivity and litter fall decline at 3050m and at 9.7 ℃ MAT.

CHAPTER 1

1.0 INTRODUCTION

In forestry sector carbon sequestration and carbon sinks of forests are considered to be the most important functions. The global carbon cycle is well connected with the climate and the forests of the world. According to Steffen et al. (1998) the large amount of carbon exchange in the atmosphere is through global terrestrial ecosystems, while the net fluxes are much smaller. It is estimated that on worldwide basis that the gross primary production (GPP), is 120 Pg C yr^{-1}, short-term carbon uptake (STCU) as net primary production (NPP), medium-term carbon uptake (MTCU) as net ecosystem production (NEP) and long-term carbon uptake (LTCU) as net biome production (NBP) are 60 Pg C yr^{-1}, 10 Pg C yr^{-1} and 0-2 Pg C yr^{-1}, respectively. The forests of Europe constitute a sink of 0.09-0.12 Pg C yr^{-1}, while the forests of the world would be a source of 0.5-1.3 Pg C yr^{-1}, mainly because of deforestation in the tropics.

The information on future development in forestry sector, *viz*., resources and carbon budget as well as impact of climate change on these resources are the requirement of the International conventions, such as the United Nations Framework Convention on Climate Change (UNFCCC) and The Kyoto Protocol (1997).

The studies on the functioning of forest ecosystems and forest management have always taken climatic parameters into account as these interact in a complex manner at varying scales. Among pioneer studies on the impact of climate change on vegetation composition include Emanuel et al. (1985), Smith et al. (1992), Woodward (1992), Leemans & Vandenborn (1994), Cramer (1996). Solomon (1986), Pastor & Post (1988), Kienast (1991), Prentice et al. (1991), Bugmann (1997), Price et al. (1999) have studied the impact of climate change on forest succession. The impact of climate change on species diversity, plant distribution, vegetation zones, primary production and ecosystem processes have been studied by several other workers viz., Ketner (1990), Liljelund (1990), Holten (1990), Habjorg (1990), Dahl (1990), Skre (1990), Prentice (1986), Dukes & Mooney (1999), Ritchie (1986), Graumlich (1991), Bradfield & Scagel (1984), Paulsen et al. (2000) and Hasenauer (1999). The change in climate governs tree phenology (Kramer et al. 1996, Menzel & Fabian 1999, Linkosalo et al. 2000), forest productivity (McGuire et al. 1993, Joyce 1995, Aber et al. 2001, Coops & Waring 2001), growth and yield (Woodbury et al. 1998, Hasennauer et al. 1999).

The productivity of the forests depends on the rate of photosynthesis, which in turn is influenced by the availability of climatic factors, such as ambient temperature and carbon dioxide. Besides photosynthesis, respiration and transpiration rates also affect the plant growth which are dependent on climate. In boreal regions generally plant growth is very slow due to low temperature, while in lower latitudes it slows down the plant growth (Kirschbaum 2000). Various phenophases, such as bud bursting, leaf unfolding, flowering, seed setting and leaf fall are also governed by the climatic factors. Leaf phenology and seed production can be directly linked with climate change, as these features strongly steer forest development (Meer et al. 2002). Experimental studies on the effects of climate change on forest vegetation are extremely difficult to execute as forests are slow growing, long-lived and complex systems.

Over the period of 1990 to 2100 global average surface temperature is projected to increase by 1.4-5.8ºC. This has been shown by the incorporated new results of Third Assessment Report of IPCC (2001). This projected warming will be higher than the projected increase in the IPCC Second Assessment Report (1995), which was 1.0-3.5ºC. The ecosystem becomes more susceptible to climatic changes, which are so rapid leaving no time for ecosystem to accept these changes unaffected (Watson et al. 2001). Considering this problem, the United Nations Framework Convention on Climate change (UNFCC) targeted on the stabilization of CO_2 concentrations at a level, which will prevent the dangerous anthropogenic interference with the climate system, within a timeframe allowing ecosystem enough to adapt naturally to climatic changes.

Vegetation response to climate change can be studied at a regional scale using simulation models depicting vegetation parameters or communities across eco-climatic gradients and sampling the important parameters at frequent intervals. Such studies also require climate change scenario at a comparable scale (Lasch et al. 1999).

The range of projections by global circulation models (GCMs) includes temperature increases from +1.5 °C to as much as +4 °C for the year 2100 depending on the model used and on the underlying greenhouse gas emission scenario (Houghton et al. 1990, 1996).

1.1 Study area

Phytogeography of the Himalayan region generated much interest right from the beginning of this century or even before, when floristic studies were initiated. It is evident that the Himalayan ranges encompass various elements: Austro-Polynesian, Malayo- Burman, Sino-Tibetan, Euro-Mediterranean, and African. About 29% of the endemic taxa of the Indian dicotyledonous flora occur in these mountains. Approximately 3200 species, which account for about 30% of higher plant species documented from the Himalaya, are said to be endemic to the region (Singh et al. 2000). The West Himalayan region shows pronounced Euro-Mediterranean affinities. Some of the Mediterranean elements of the Western Himalayan region are found in drier areas, where the monsoon influence is negligible e.g., *Quercus ilex, Celtis australis*, and species of *Olea, Acer, Aesculus, Alnus, Fraxinus, Cupressus, Junipers, Populus, Prunus,* and *Pinus.* With increasing aridity in the western Himalaya some of the seral communities/species are likely to shift eastwards. Thus it has an important bearing in the study of climate change in the region.

The present work deals with the impact of climate change on the forest vegetation of west Himalaya, i.e. Uttaranchal state. Five major watersheds, viz. Dharamganga, Dogadda, Bhatwari, Asiganga and Gangotri forming a catchment of river Bhagirathi were selected (Fig. 1).

The work provides an insight in to the patterns of vegetation in Garhwal Himalaya with reference to temperature at a local scale and compared with Kumaun Himalayan forests.

1.2 Geology

Along the southern edge of the Himalaya, the mountains rise abruptly from the alluvial plains. The Siwaliks, the first mountains (10-50 km wide) stand 500-1200 m having numerous transverse valleys, the most recent mountains; the Lesser Himalaya (with elevation up to 5000 m), and the Greater Himalaya (with elevation >5000 m). The Siwaliks has primarily quartz, rock fragments, feldspar, mica and calcarious cement, however, the rocks of Lesser and Greater Himalaya made up of mainly sedimentry mixture, low-grade metamorphosed and igneous rocks (Valdiya 1980).

1.3 Soil

According to Murthy and Pandey (1980) the soils belong to the brown forest category known as Palehumults. The soil parent materials may be either residual or transported. Soils on sandstone are coarse loams, with clay loams formed on limestone (Singh & Singh 1992). As elevation increase the soil texture becomes finer, especially >2000m. Around timberline a weak podzolization may occur. Soil profile has no clear cut differentiation at higher elevation and there is no separate humus layer in alpine area. By weight soil organic content in surface soil ranges from 1-4%, and sometimes in shady areas it goes up to 9% in oak forest (Rikhari, Unpublished).

1.4 Climate

The monsoonal rhythm throughout the elevational gradient influences the climate of the region during mid-June to late-September, which accounts for 75-80% of the annual rainfall. Winters are more severe and snowfall is frequent above 2500 m elevation (Adhikari et al. 1991). Differences between mean temperature of the warmest and coldest month range between 10ºC and 19ºC. The summer-winter difference declines up to 1000 m, and then stabilizes at about 10ºC along the remaining elevational transect (Singh et al. 1994). With increase in cloudiness the sun shine duration decreases towards higher elevations. The precipitation effectiveness increases with elevation because of temperature and sunshine decline (Muller 1982). Corresponding with the upper forest limit of forest vegetation the absolute minimum temperatures at 3600m elevation are -15ºC and -20ºC, which are less severe than the temperatures reported for continental temperate mountains (Sakai & Malla 1981, Muller 1982).

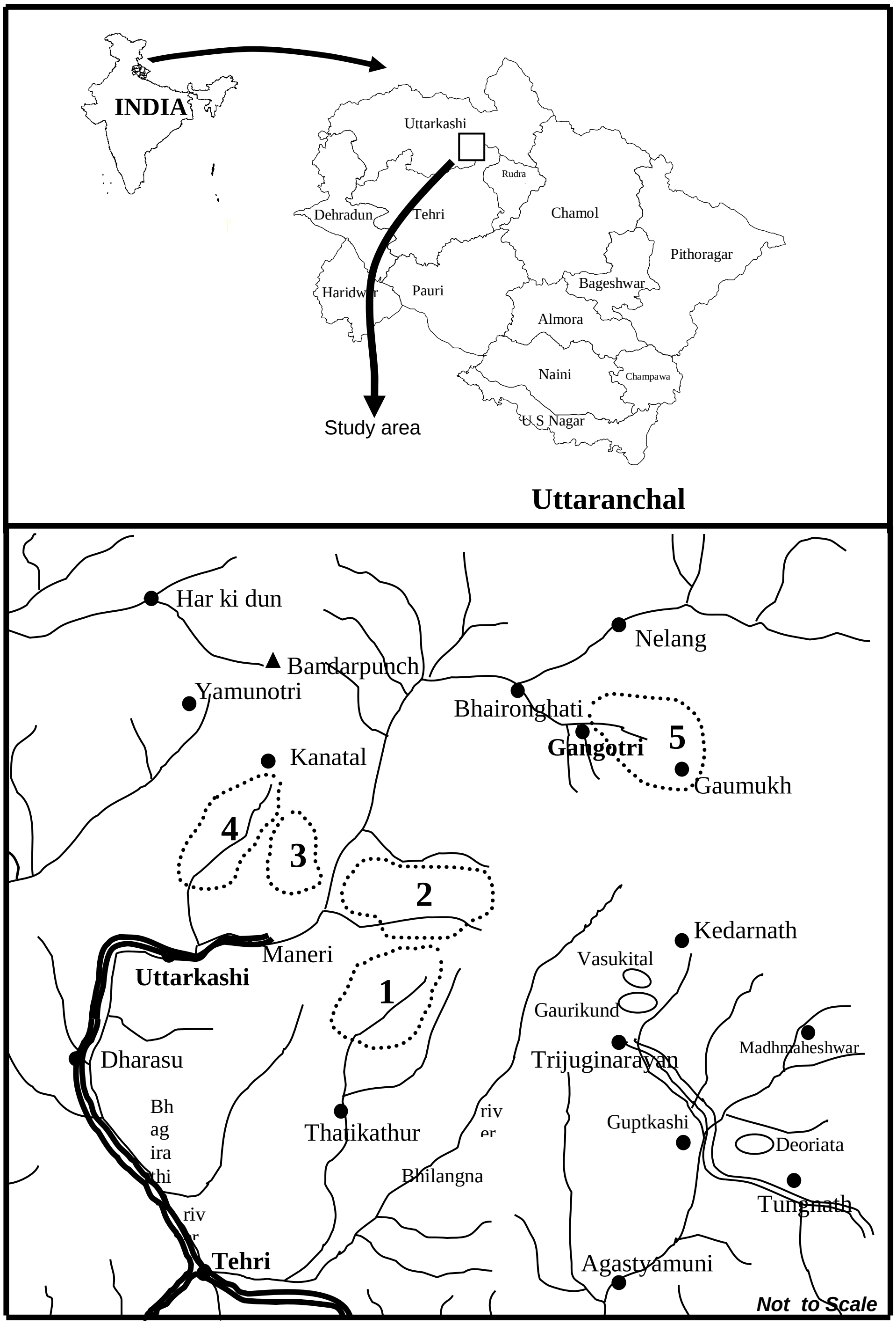


Fig.1: Map of the study area showing different watersheds in Garhwal Himalaya.

1. Dharamganga, 2. Dogadda, 3.Bhatwari, 4. Asiganga and 5. Gangotri.

1.5 Objectives

The following were the major objectives of the study:

1. To document structural changes in the forest vegetation along a wide altitudinal gradient

2. To study change in biomass, productivity and nutrient status all along the altitudinal gradient

3. Comparison of above parameters with the forests along altitudinal gradient as well as forest types in Kumaun Himalaya

4. Develop a status of each forest for above mentioned parameters

5. Prediction of shift in boundaries of forest formations in relation to climate change

2.0 METHODOLOGY

2.1 Site selection

Five watersheds were selected, four non-glaciated and one glaciated in Garhwal Himalaya for forest vegetation sampling. A trail in each watershed was selected as a base for transect. From the lowermost point of the trail, a series of one hectare plots were selected in each watershed at an interval of 100m rise in altitude up to timberline. The altitudinal range, length of trail and lowest and highest points are given in Table 1.

Table 1: Details of watersheds in Garhwal, western Himalaya.

Watershed	Altitudinal range (m)	Length of trail	Lowest point	Highest point
Dharamganga	1600-3400	22 km	Budakedar	Jorai Ridge top
Dogadda	1600-3400	19 km	Saura	Jorai ridge top
Asiganga	1600-3200	23 km	Sangamchatti	Dodital ridge top
Bhatwari	1800-3600	15 km	Barsu	Dyara ridge top
Gangotri (upper Bhagirathi)	3000-3700	18 km	Gangotri	Gaumukh

2.2 Soil sampling

The soil samples were collected from the hectare plots, atleast from five different places. At each place a monolith (10x10cm) was dug out down to 10cm and the soil was collected. After collecting soil from all the five monoliths, a composite sample of 300g was prepared and brought to the laboratory for organic carbon (%) and bulk density following Jackson (1958).

The volume of soil per hectare for a stratum down to 10cm would be 109cc, multiplying by the appropriate bulk density gave the weight of the soil. The weight of the soil was converted into percent of the soil carbon with the respective carbon percent in the soil.

2.3 Litter

For litter, five random quadarts ($1m^2$) were laid within each hectare plot. The litter was collected from each quadrat and weight. The litter was pooled from all the five quadrats and a composite sample was prepared and brought to the laboratory. In the laboratory the organic carbon of litter was analyzed. For a hectare plot the litter mass was calculated and it was multiplied by the organic carbon percent, which accounted for total amount of organic carbon in the litter.

2.4 Ecological parameters

2.4.1 Temperature

The rate of mineralization is strongly influenced by the temperature. In the event of global warming (increased temperature) this rate is likely to change and hence this parameter is considered very important to correlate with other traits of the forest ecosystem. Although, soil moisture also plays a major role in litter decomposition (Singh et al. 1994), this pattern could not been taken into consideration due to lack of reliable data.

2.4.2 Composition

In each hectare plot, 10 random quadrats (each 10x10 m) were laid for trees. In each quadrat all the individuals were measured species-wise at cbh (i.e., circumference at breast height, 1.37m). The data were analyzed for density, frequency and abundance (Curtis & McIntosh 1950) and Importance Value Index (IVI, Curtis 1959).

2.4.3 Biomass

To calculate biomass regression equations for different species were used, such as *Quercus semecarpifolia, Abies pindrow, Aesculus indica, Rhododendron arboreum, Symplocos chinensis, Quercus floribunda, Lyonia ovalifolia, Ilex dipyrena, Litsea umbrosa* and *Juglans regia* following Adhikari et al. (1995), *Acer cappadocicum* and interspecies following Singh et al. (1992), *Quercus floribunda, Quercus leucotrichophora, Rhododendron arboreum* and interspecies following Rawat and Singh (1988), *Cedrus deodara* following Adhikari et al. (1999) and *Pinus roxburghii* following Singh & Singh 1992).

Several new regression equations were developed viz., conifer (including *Abies pindrow, Cedrus deodara, Cupressus torulosa* and *Pinus roxburghii*), deciduous-I (*including Aesculus indica, Juglans regia* and *Acer cappadocicum*) and deciduous-II (including *Symplocos chinensis* and *Lyonia ovalifolia*).

The regression equation for Deciduous-I was used *for Ulmus wallichiana, Alnus nepalensis, Betula alnoides, Cornus macrophylla, Cedrella toona* and *Fraxinus micrantha*. The regression equation for Deciduous-II was used for *Buxus semepervirens, Salix wallichiana, Pyrus pashia, Sorbus foliolosa, Carpinus viminea, Viburnum erubescens* and *Syringa emodi*. For *Taxus baccata, Picea smithiana* and *Pinus wallichiana* the regression equation developed for conifer was used. The interspecies regression equations developed by Singh et al. (1992) were used for *Rhododendron campanulatum, Eunymous lacerus* and *Eurya acuminata*, while interspecies regression equations developed by Rawat & Singh (1988) *Machilus duthii* and *Machilus odoratissima.*

The regression equations for *Quercus floribunda* developed by Rawat & Singh were used up to 2500m asl, while regression equations for *Quercus floribunda* developed by Adhikari et al. (1995) were used for the stands at 2600m asl and more. Like-wise the regression equations for *Rhododendron arboreum* developed by Rawat & Singh were used up to 2400m asl, while regression equations for *Rhododendron arboreum* developed by Adhikari et al. (1995) were used for the stands at 2600m asl and more.

2.4.4 Production

The productivity of each forest type was calculated based on the data reported for the forests (Rawat & Singh 1988, Chaturvedi & Singh 1987, Singh et al. 1992, Adhikari et al. 1995) in Kumaun, western Himalaya. The biomass accumulation ratio (BAR) was calculated for major forest types, viz. Chir pine (*Pinus roxburghii*), mixed (low altitude), banj oak (*Quercus leucotrichophora*), tilonj oak (*Quercus floribunda*), mixed forest, horse chestnut (*Aesculus indica*), silver fir (*Abies pindrow*), kharsu oak (*Quercus semecarpifolia*), maple (*Acer cappadocicum*), birch (*Betula utilis*) and deodar (*Cedrus deodara*) forests.

For other forest types the BAR was calculated as the average value of BAR of selected forests, such as deciduous-broadleaved forest (horse chestnut, maple and birch forests), Kail (*Pinus wallichiana*) forest (chir pine, silver fir and deodar), mixed-broadleaved forest (banj oak, tilonj oak, horse chestnut and maple forests), oak forest (all oak forests), alder (*Alnus nepalensis*) forest (maple and birch forests), conifer-broadleaved forest (chir pine, silver fir, deodar, horse chestnut, maple and birch forests), mixed forest (banj oak, tilonj oak, horse chestnut, maple, chir pine, silver fir, deodar forests), toon (horse chestnut and maple forests) and for oak-conifer forest (banj oak, tilonj oak, kharsu oak, chir pine, silver fir and deodar forests).

2.4.5 Forest litter fall

The data on litter fall of different forests was collated from the studies conducted in Kumaun, western Himalaya (as mentioned for productivity). For other forest types similar data were obtained earlier as for productivity. The aboveground productivity to litter fall ratio was calculated to get the litter fall of the particular forest. However, for other forest types the similar combination was followed as for productivity.

2.4.6 Forest floor litter mass

For forest floor litter mass 10 random quadrats (50x50cm) were laid in each site. Only fresh litter and partially decomposed litter were collected from each quadrat. All the samples were pooled together and a sub-sample was brought to laboratory for further analysis.

2.4.7 Carbon content

The carbon content (percentage) for biomass, productivity and litter fall was calculated following Mc Brayer & Cromack (1980) as 50% of ash free dry weight.

At last, allocation of carbon in vegetation (tree layer), litter and soil was pooled to get the data for each site for carbon storage. However, carbon accumulation was calculated by summing up carbon allocation through productivity and litter fall for each site.

3.0 RESULTS

3.1 Ecological parameters (Species richness,Density and Total basal area)

Mainly three major parameters were taken in to consideration for forest composition, viz., density (trees ha^{-1}), total basal area (m^2 ha^{-1}) and Importance Value Index (IVI). Based on IVI values forests were identified and only the canopy forming species were considered (Table 2). The details of each watershed are given in Appendix I.

3.1.1 Watershed-wise

The watershed-wise ecological parameters are shown in Table 3.

3.1.1.1 Dharamganga watershed

In this watershed 6 forest types were identified. The average density was highest for tilonj oak-mixed and kharsu oak forests (362 & 363 trees ha^{-1}) and total basal area for tilonj oak forest (55.2 m^2 ha^{-1}), while average species richness was high in mid altitude forests.

3.1.1.2 Dogadda watershed

In this watershed 9 forest types were identified. The average density was highest for banj oak forest (595 trees ha^{-1}) followed by deciduous-broadleaved forest (510 trees ha^{-1}). The total basal area was highest for horse chestnut forest (74.5 m^2 ha^{-1}) followed by oak-conifer forest (71.5 m^2 ha^{-1}). The species richness 8, 9 and 8, respectively was highest for deciduous-broadleaved, mixed- broadleaved and tilonj oak forests.

Table 2: Forest types with major species (based on IVI values) along an altitudinal gradient in different watersheds in Garhwal, western Himalaya.

Altitude (m)	Watershed				
	Dharamganga	**Dogadda**	**Bhatwari**	**Asiganga**	**Gangotri**
1600	*P. roxburghii*	*P. roxburghii* *R. arboreum*	-	*P. roxburghii* *C. toona*	-
1700	*Q. leucotrichophora* *A. oblongum*	*P. roxburghii* *R. arboreum* *A. nepalensis* *C. toona*	-	*A. nepalensis*	-
1800	*P. roxburghii* *Q. leucotrichophora*	*R. arboreum* *A. nepalensis* *C. macrophyla* *Q. leucotrichophora* *P. roxburghii* *C. toona*	*Q. leucotrichophora*	*C. toona*	-
1900	*Q. leucotrichophora*	*P. ciliata* *A. nepalensis* *L. umbrosa*	*Q. leucotrichophora* *R. arboreum* *L. ovalifolia*	*A. nepalensis*	-
2000	*Q. leucotrichophora* *R. arboreum*	*Q. leucotrichophora* *P. roxburghii* *R. arboreum* *L. ovalifolia*	*Q. leucotrichophora* *R. arboreum* *S. chinensis*	**Village Agora**	-
2100	*Q. floribunda* *M. duthii*	*Q. leucotrichophora* *R. arboreum* *L. ovalifolia*	*Q. leucotrichophora* *Q. floribunda* *R. arboreum* *C. deodara* *L. ovalifolia* *I. dipyrena*	*Q. floribunda* *A. nepalensis* *B. alnoides*	-
2200	*Q. floribunda* *M. duthii*	*Q. leucotrichophora* *L. ovalifolia* *R. arboreum*	*Q. leucotrichophora* *Q. floribunda* *L. ovalifolia*	*A. nepalensis* *Q. floribunda* *B. alnoides*	-
2300	*Q. floribunda* *M. duthii*	*Q. leucotrichophora* *E. lacerus* *A. indica* *R. arboreum* *I. dipyrena*	*Q. leucotrichophora* *Q. floribunda* *L. ovalifolia*	*Q. floribunda* *M. duthii*	-
2400	*Q. floribunda*	*A. indica* *B. sempervirens*	*Q. floribunda* *A. indica*	*C. deodara* *Q. leucotrichophora*	-
2500	*Q. floribunda*	*A. pindrow* *Q. floribunda* *R. arboreum* *L. ovalifolia* *I. dipyrena*	*Q. floribunda* *Q. semecarpifolia* *R. arboreum*	*C. deodara* *P. wallichiana* *Q. semecarpifolia*	-
2600	*Q. semecarpifolia* *R. arboreum*	*Q. floribunda*	*Q. floribunda*	*Q. semecarpifolia* *R. arboreum*	-
2700	*Q. semecarpifolia*	*Q. floribunda* *A. pindrow* *Q. semecarpifolia* *A. indica* *R. arboreum*	*Q. semecarpifolia* *R. arboreum* *L. ovalifolia*	*A. pindrow*	-
2800	*Q. semecarpifolia* *R. arboreum*	*A. pindrow* *Q. semecarpifolia*	*Q. semecarpifolia* *R. arboreum*	*Q. semecarpifolia*	-

Altitude (m)	Watershed				
	Dharamganga	Dogadda	Bhatwari	Asiganga	Gangotri
		T. baccata *P. foliosa*	*A. caesium*		
2900	*Q. semecarpifolia* *R. arboreum*	*Q. semecarpifolia* *A. pindrow* *T. baccata*	*Q. semecarpifolia*	*A. pictum* *A. pindrow*	-
3000	*Q. semecarpifolia*	*Q. semecarpifolia* *T. baccata*	*Q. semecarpifolia* *R. arboreum* *A. pindrow*	*Q. semecarpifolia*	*C. deodara*
3100	*Q. semecarpifolia*	*Q. semecarpifolia* *T. baccata*	*Q. semecarpifolia* *A. pindrow* *T. baccata*	*Q. semecarpifolia*	*C. deodara* *P. wallichiana* *P. ciliata*
3200	*Q. semecarpifolia*	*Q. semecarpifolia*	*Q. semecarpifolia* *A. pindrow*	*Q. semecarpifolia*	*P. wallichiana*
3300	*Q. semecarpifolia*	*Q. semecarpifolia*	*Q. semecarpifolia* *A. pindrow*	-	*B. utilis* *P. wallichiana* *P. ciliata*
3400	*Q. semecarpifolia*	*Q. semecarpifolia*	*Q. semecarpifolia* *A. pindrow* *R. arboreum*	-	*B. utilis* *P. wallichiana*
3500	-	-	*Q. semecarpifolia*	-	*P. wallichiana*
3600	-	-	*Q. semecarpifolia*	-	*B. utilis*
3700	-	-	-	-	*B. utilis*

3.1.1.3 Asiganga watershed

In this watershed 7 forest types were identified. The average density was highest for alder forest (305 trees ha^{-1}), while the total basal area was lowest (13.4 m^2ha^{-1}). The maximum total basal area was recorded for deciduous-conifer forest (60.8 m^2 ha^{-1}), while average species richness was high for conifer-broadleaved (4) and mixed-broadleaved forests.

3.1.1.4 Bhatwari watershed

The watershed was mainly dominated by 6 forest types. The average density was highest for tilonj oak and oak-conifer forests (each 270 trees ha^{-1}) and total basal area was also highest for both forests (65.1 and 64.1 m^2 ha^{-1}, respectively). The average species richness was more towards lower altitude forests.

3.1.1.5 Gangotri (upper Bhagirathi) watershed

The watershed was mainly dominated by 5 major forest types. The average species richness was maximum (3) for conifer-broadleaved and deciduous-conifer forests. The average density was highest for deodar forest (37. 0 trees ha^{-1}) followed by conifer-broadleaved forest (330 trees ha^{-1}). The total basal area was highest for conifer-broadleaved forest (58.4 m^2 ha^{-1}), while the lowest was recorded for birch forest (5.2 m^2 ha^{-1}).

3.1.2 Forest-wise

In the Garhwal, western Himalaya overall 18 major forest types were identified (Table 4). Most of the watersheds were dominated by kharsu oak forest (# 25) followed by banj oak (8) and mixed-broadleaved, conifer-broadleaved and oak-conifer forests (each #7). There were few forests with single site (toon, deciduous-broadleaved, horse chestnut, silver fir and deodar forests).

The average species richness was highest for horse chestnut (8) followed by silver fir forests (7). The average density ranged from 120 (kail forest) to 510 trees ha^{-}

^{1} (horse chestnut forest). The total basal area was highest for banj oak forest (74.5 m^2 ha^{-1}) and lowest for conifer-broadleaved forest (5.2 m^2 ha^{-1}).

3.1.3 Altitudinal Gradient

The forest types, species richness, density and total basal area along an altitudinal gradient (1600-3700m) for Garhwal, western Himalaya are given in Table 5.

The average species richness is similar in all the forest above 3000m, however, it is maximum in mid altitudinal zone (1800-2600m). The average density peak at 2100m (banj oak, tilonj oak-mixed, oak and mixed broadleaved forests) and total basal area at 2800m (kharsu oak and oak-conifer forests). The lowest values for average density and total basal area were 170 trees ha^{-1} and 7.2 m2 ha^{-1} for birch forest.

Table 3: Species richness, density and total basal area of different forest types along an altitudinal gradient (1600-3700m) in Garhwal Himalaya.

Forest type	Altitude (m)	Species richness	Density (trees ha^{-1})	Total basal area (m^2 ha^{-1})
Dharamganga				
Chir pine	1600	1	230	41.4
Conifer-broadleaved	1800	3	170	21.3
Banj oak	1867	4	250	31.4
Tilonj oak-mixed	2200	4	363	33.6
Tilonj oak	2450	5	275	55.2
Kharsu oak	3000	2	362	40.1
Bhatwari				
Banj oak	1900	4	140	11.2
Oak-mixed	2250	5	175	17.0
Oak	2333	4	177	25.1
Tilonj oak	2600	4	270	65.1
Kharsu oak	3083	3	223	41.3
Oak-Conifer	3250	3	270	64.1
Asiganga				
Alder	1800	2	305	13.4
Toon	1800	2	120	21.4
Conifer-broadleaved	2167	4	280	29.6
Mixed broadleaved	2200	5	240	35.5
Silver fir	2700	3	260	30.4
Deciduous-conifer	2900	3	260	60.8
Kharsu oak	2940	2	230	36.3
Dogadda				
Chir pine	1600	4	440	51.2
Deciduous broadleaved	1900	8	510	50.0
Mixed broadleaved	1933	9	423	33.2
Banj oak	2150	4	595	30.3
Conifer-broadleaved	2250	6	405	46.6
Horse chestnut	2400	5	330	74.5
Tilonj oak	2600	8	370	49.2
Oak-Conifer	2800	5	383	71.5
Kharsu oak	3200	2	372	36.1
Gangotri				
Deodar	3000	1	370	24.8
Conifer-broadleaved	3100	3	330	58.4
Deciduous-conifer	3350	3	250	15.0
Kail	3350	2	215	8.8
Birch	3650	2	205	5.2

Table 4: Species richness, density and total basal area (TBA) of different forest types.

Forest type	Stands (#)	Species richness (#)	Density (trees ha^{-1})	Total basal area (m^2 ha^{-1})
Chir pine	2	3	335	46.3
Alder	2	4	295	23.5
Toon	1	6	298	56.2
Deciduous broadleaved	1	5	318	27.5
Banj oak	8	5	330	74.5
Mixed-broadleaved	7	3	260	30.4
Tilonj oak-mixed	4	2	304	38.8
Conifer-broadleaved	7	2	205	5.2
Mixed oak	3	1	370	24.8
Horse chestnut	1	8	510	50.0
Tilonj oak	4	2	215	8.8
Silver fir	1	7	309	33.0
Deodar	1	4	177	25.1
Kharsu oak	25	2	305	13.4
Oak-conifer	7	4	307	37.4
Deciduous-conifer	3	3	253	30.3
Kail	2	2	120	21.4
Birch	2	4	319	67.3

Table 5: Species richness, density and TBA of different forest types along an altitudinal gradient.

Altitude (m)	Forest type	Species richness (#)	Density (trees ha^{-1})	Total basal area (m^2 ha^{-1})
1600	Chir pine/Conifer-broadleaved	2	283	41.2
1700	Mixed broadleaved/Banj oak/Alder	4	337	22.0
1800	Mixed broadleaved/Banj oak/Conifer-broadleaved/Toon	6	258	27.6
1900	Deciduous broadleaved/Banj oak/Alder	5	245	25.8
2000	Conifer-broadleaved/Banj oak	4	243	26.1
2100	Banj oak/Tilonj oak-mixed/Oak/Mixed broadleaved	5	350	26.1
2200	Banj oak/Tilonj oak-mixed/Oak/Mixed broadleaved	4	303	31.4
2300	Mixed broadleaved/Tilonj oak-mixed/Oak	6	323	26.6
2400	Tilonj oak/Mixed oak/Conifer-broadleaved/Horse chestnut	5	263	48.0
2500	Conifer-broadleaved/Tilonj oak/Mixed oak	5	345	43.6
2600	Tilonj oak/Kharsu oak	5	323	48.9
2700	Kharsu oak/Silver fir/Oak-Conifer	4	315	55.1
2800	Kharsu oak/Oak-Conifer	3	315	62.8
2900	Kharsu oak/Oak-Conifer/Deciduous-conifer	3	298	41.9
3000	Kharsu oak/Deodar	2	335	45.1
3100	Kharsu oak/Conifer-broadleaved/Oak-Conifer	2	278	49.4
3200	Kharsu oak/Kail/Oak-Conifer	2	308	33.2
3300	Kharsu oak/Oak-Conifer/Deciduous-conifer	2	250	31.5
3400	Kharsu oak/Oak-Conifer/Deciduous-conifer	2	275	26.4
3500	Kharsu oak/Kail	2	275	23.1
3600	Kharsu oak/Birch	2	210	19.4
3700	Birch	1	170	7.2

3.2 *Biomass, productivity and litter fall*

The component-wise (bole, bole bark, branch, twig, foliage for aboveground biomass and stump root, lateral root and fine root for belowground biomass) biomass of tree layer for each forest type is given in Appendix II.

3.2.4 Watershed-wise

The watershed-wise biomass, productivity and litter fall is given in Table 6.

3.2.4.1 Dharamganga watershed

The average total biomass was maximum for tilonj oak forest (402.9 t ha^{-1}) and the minimum was for conifer-broadleaved forest (154.4 t ha^{-1}). Of the total biomass the aboveground biomass ranged from 77 (kharsu oak forest) to 89% (banj oak forest). The average total productivity was maximum for chir pine forest (20.0 t ha^{-1} yr^{-1}) and the minimum was for banj oak forest (5.6 t ha^{-1} yr^{-1}). Of the average total productivity the average aboveground productivity ranged from 51 (kharsu oak forest) to 74% (banj oak forest). The litter fall was ranged between 2.2 (banj oak forest) and 5.5 t ha^{-1} yr^{-1} (chir pine forest).

3.2.4.2 Dogadda watershed

The total biomass ranged from 150.5 (chir pine forest) to 486.7 t ha^{-1} (horse chestnut forest). Of the total biomass the aboveground biomass ranged from 77 (chir pine and kharsu oak forests) to 88% (banj oak forest). The average total productivity was maximum for oak-conifer forest (21.3 t ha^{-1} yr^{-1}) and the minimum was for mixed-broadleaved and banj oak forests (each 7.4 t ha^{-1} yr^{-1}). Of the average total productivity the average aboveground productivity ranged from 50 (kharsu oak forest) to 73% (banj oak forest). The litter fall was ranged between 2.3 (mixed-broadleaved forest) and 6.9 t ha^{-1} yr^{-1} (oak-conifer forest).

3.2.4.3 Asiganga watershed

The total biomass was maximum for deciduous-conifer forest (361.8 t ha^{-1}) and the minimum was for alder forest (137.6 t ha^{-1}). The aboveground biomass was accounting 77 to 82% in alder and mixed-broadleaved forests, respectively of the total biomass. The average total productivity was maximum for deciduous-conifer forest (17.2 t ha^{-1} yr^{-1}) and the minimum was for silver fir forest (7.5 t ha^{-1} yr^{-1}). Of the average total productivity the average aboveground productivity ranged from 51 (kharsu oak forest) to 61% (mixed-broadleaved forest). The litter fall was ranged between 2.3 (silver fir forest) and 6.9 t ha^{-1} yr^{-1} (deciduous-conifer forest).

3.2.4.4 Bhatwari watershed

The total biomass ranged between 71.5 (banj oak forest) and 439.9 t ha^{-1} (tilonj oak forest). Of the total biomass the aboveground biomass ranged from 78 (kharsu oak forests) to 90% (banj oak forest). The average total productivity was maximum for oak-conifer forest (19.0 t ha^{-1} yr^{-1}) and the minimum was for banj oak forest (2.4 t ha^{-1} yr^{-1}). Of the average total productivity the average aboveground productivity ranged from 51 (kharsu oak forest) to 75% (banj oak forest). The litter fall was ranged between 1.0 (banj oak forest) and 6.1 t ha^{-1} yr^{-1} (oak-conifer forest).

3.2.4.5 Gangotri (upper Bhagirathi) watershed

The total biomass ranged between 4.9 (birch forest) and 273.2 t ha^{-1} (conifer-broadleaved forest). Of the total biomass the aboveground biomass ranged from 75 (birch forests) to 85% (conifer-broadleaved forest). The average total productivity was maximum for conifer-broadleaved forest (14.7 t ha^{-1} yr^{-1}) and the minimum was for birch forest (0.3 t ha^{-1} yr^{-1}). Of the average total productivity the average aboveground productivity ranged from 55 (birch forest) to 68% (deodar forest). The litter fall was ranged between 0.1 (birch forest) and 4.7 t ha^{-1} yr^{-1} (conifer-broadleaved forest).

3.2.5 Forest-wise

Among 18 forest types (Table 7), the total biomass was high for horse chestnut, oak-conifer and tilonj oak forests (487.0, 432.6 and 401.9 t ha^{-1}, respectively) and it was quite low for deodar (97.5 t ha^{-1}), kail (63.2 t ha^{-1}) and birch (4.9 t ha^{-1}) forests. The aboveground biomass ranged from 3.7 (birch forest) to 386.7 t ha^{-1} (horse chestnut forest). However, the average productivity was high for oak-conifer forest (20.0 t ha^{-1} yr^{-1}) and deciduous broadleaved forest (19.6 t ha^{-1} yr^{-1}), while for most of the forest types (# 12) it was <12 t ha^{-1} yr^{-1}. The average aboveground productivity was high (74%) for banj oak forest and low (51%) for kharsu oak forest. The litter fall ranged between 0.1 (birch forest) and 6.6 t ha^{-1} yr^{-1} (deciduous broadleaved forest).

3.2.6 Altitudinal Gradient

Along altitudinal gradient the maximum average total biomass was at 2700 (Kharsu oak/Silver fir/oak-conifer forests) and 2800m (2700 (Kharsu oak/oak-conifer forests) altitude followed by altitude 2900-3200m (Table 8). However, the average aboveground biomass was highest at 2000m (87%, conifer-broadleaved and banj oak forests) and lowest at 3700m (72%, birch forest). In most of the forest types at mid altitude zone the average productivity values were high (12.2-17.4 t ha^{-1} yr^{-1}), while in lower and higher side of the altitudinal range it was low (<10 t ha^{-1} yr^{-1}), except at 1600m (14.5 t ha^{-1} yr^{-1}, Table 8). The litter fall values were high at 2700 and 2800m (5.2 and 5.5 t ha^{-1} yr^{-1}, respectively) altitude and low for 3700m (0.1 t ha^{-1} yr^{-1}, Table 8).

The pattern of aboveground, belowground and total biomass along an altitudinal gradient in each watershed is shown in Figs. 2a & b, 3a & b and 4.

Table 6: Stands (#), average altitude (m), biomass (aboveground and total, t ha^{-1}), production (aboveground and total, t ha^{-1} yr^{-1}) and litter fall (t ha^{-1} yr^{-1}) in different watersheds of Garhwal, western Himalaya.

Forest type	#	Altitude (m)	Biomass		Production		Litter fall
			Abgd	Total	Abgd	Total	
Asiganga							
Alder	2	1800	105.98	137.55	4.52	8.27	2.66
Toon	1	1800	127.03	163.33	4.59	8.45	2.77
Conifer-broadleaved	3	2167	160.45	196.12	6.46	10.53	3.26
Mixed broadleaved	3	2200	213.15	259.84	6.00	9.76	3.22
Silver fir	1	2700	192.44	242.26	3.99	7.50	2.28
Deciduous-conifer	1	2900	286.89	361.75	9.31	17.20	4.33
Kharsu oak	5	2940	237.98	306.33	6.17	12.15	3.79
Bhatwari							
Banj oak	3	1900	64.41	71.49	1.83	2.43	0.96
Oak-mixed	2	2250	124.04	149.97	3.49	5.63	1.88
Oak	3	2333	141.99	166.62	4.16	6.12	2.08
Tilonj oak	1	2600	360.39	439.92	10.31	14.78	3.66
Kharsu oak	6	3083	237.51	303.64	6.16	12.04	3.78
Oak-Conifer	4	3250	323.19	411.13	11.90	18.99	6.08
Dharamganga							
Chir pine	1	1600	224.42	271.87	13.53	19.99	5.52
Conifer-broadleaved	1	1800	132.85	154.42	5.35	8.29	2.70
Banj oak	3	1867	146.58	165.14	4.16	5.62	2.19
Tilonj oak-mixed	3	2200	256.68	299.29	7.22	11.24	4.62
Tilonj oak	2	2450	345.88	402.91	9.89	13.54	3.51
Kharsu oak	9	3000	283.95	367.47	7.36	14.57	4.52
Dogadda							
Chir pine	1	1600	115.62	150.49	6.97	11.06	2.84
Deciduous broadleaved	1	1900	301.78	378.87	10.91	19.61	6.56
Mixed broadleaved	3	1933	157.06	196.71	4.42	7.39	2.31
Banj oak	2	2150	190.86	217.84	5.41	7.41	2.85
Conifer-broadleaved	2	2250	217.27	263.58	8.75	14.16	4.41
Horse chestnut	1	2400	386.69	486.97	8.94	17.07	5.62
Tilonj oak	1	2600	302.19	362.03	8.64	12.16	3.07
Oak-Conifer	3	2800	367.64	461.14	13.54	21.30	6.91
Kharsu oak	5	3200	294.10	381.44	7.63	15.13	4.69
Gangotri							
Deodar	1	3000	80.05	97.52	4.17	6.10	1.01
Conifer-broadleaved	1	3100	230.96	273.15	9.30	14.67	4.69
Deciduous-conifer	2	3350	50.36	62.40	1.83	2.91	1.05
Kail	2	3350	51.11	63.20	2.27	3.52	1.07
Birch	2	3650	3.69	4.92	0.20	0.36	0.12

Table 7: Stands (#), altitude, biomass (aboveground, abgd; and total), production (aboveground, abgd; and total) and litter fall in different forest types in Garhwal, western Himalaya.

Forest type	Stands (#)	Altitude (m)	Biomass ($t\ ha^{-1}$)		Production ($t\ ha^{-1}\ yr^{-1}$)		Litter fall ($t\ ha^{-1}\ yr^{-1}$)
			Abgd	Total	Abgd	Total	
Chir pine	2	1600	170.0	211.2	10.2	15.5	4.2
Alder	2	1800	106.0	137.6	4.5	8.3	2.7
Toon	1	1800	127.0	163.3	4.6	8.5	2.8
Deciduous broadleaved	1	1900	301.8	378.9	10.9	19.6	6.6
Banj oak	8	1950	126.8	143.2	3.6	4.9	1.9
Mixed-broadleaved	7	2114	185.3	228.1	5.2	8.6	2.7
Tilonj oak-mixed	4	2175	208.0	242.7	5.9	9.1	3.7
Conifer-broadleaved	7	2271	182.8	220.4	7.4	11.8	3.7
Mixed oak	3	2333	142.0	166.6	4.2	6.1	2.1
Horse chestnut	1	2400	386.7	487.0	8.9	17.1	5.6
Tilonj oak	4	2525	338.6	401.9	9.7	13.5	3.4
Silver fir	1	2700	192.4	242.3	4.0	7.5	2.3
Deodar	1	3000	80.1	97.5	4.2	6.1	1.0
Kharsu oak	25	3048	265.6	342.7	6.9	13.6	4.2
Oak-conifer	7	3057	342.2	432.6	12.6	20.0	6.4
Deciduous-conifer	3	3200	129.2	162.2	4.3	7.7	2.1
Kail	2	3350	51.1	63.2	2.3	3.5	1.1
Birch	2	3650	3.7	4.9	0.2	0.4	0.1

Table 8: Stands, average biomass (aboveground and total, t ha^{-1}), production (aboveground and total, t ha^{-1} yr^{-1}) and litter fall (t ha^{-1} yr^{-1}) along an altitudinal gradient (1600-3700m) in Garhwal, western Himalaya.

Altitude (m)	Forest Type	Stand	Biomass		Production		Litter fall
			Abgd	Total	Abgd	Total	
1600	Chir pine/Conifer-broadleaved	3	175.82	218.14	9.35	14.50	4.06
1700	Mixed broadleaved/Banj oak/Alder	3	134.17	164.30	4.37	7.12	2.40
1800	Mixed broadleaved/Banj oak/ Conifer-broadleaved/ Toon	4	141.78	172.18	4.65	7.59	2.50
1900	Deciduous broadleaved/ Banj oak/Alder	4	146.53	177.81	5.07	8.50	2.94
2000	Conifer-broadleaved/Banj oak	3	111.71	128.63	3.76	5.54	1.94
2100	Banj oak/Tilonj oak-mixed/ Oak/Mixed broadleaved	4	175.76	207.08	4.95	7.61	2.92
2200	Banj oak/Tilonj oak-mixed/ Oak/Mixed broadleaved	4	193.35	227.23	5.49	8.29	3.11
2300	Mixed broadleaved/Tilonj oak-mixed/Oak	4	181.31	214.79	5.13	8.05	2.83
2400	Tilonj oak/Mixed oak/ Conifer-broadleaved/Horse chestnut	4	286.90	344.06	8.10	12.86	3.91
2500	Conifer-broadleaved/Tilonj oak/Mixed oak	4	227.46	277.38	7.79	12.18	3.63
2600	Tilonj oak/Kharsu oak	4	284.19	353.09	7.81	12.79	3.57
2700	Kharsu oak/Silver fir/Oak-Conifer	4	317.65	402.11	9.37	16.46	5.23
2800	Kharsu oak/Oak-Conifer	4	329.35	418.71	9.62	17.42	5.53
2900	Kharsu oak/Oak-Conifer/ Deciduous-Conifer	4	251.62	321.73	7.53	13.89	4.09
3000	Kharsu oak/Deodar	5	276.26	353.47	7.58	14.46	4.35
3100	Kharsu oak/Conifer-broadleaved/Oak-Conifer	5	281.27	356.30	8.76	15.52	4.90
3200	Kharsu oak/Kail/Oak-Conifer	5	246.49	319.41	7.26	13.38	4.13
3300	Kharsu oak/Oak-Conifer/ Deciduous-Conifer	4	177.34	227.57	5.60	9.80	3.14
3400	Kharsu oak/Oak-Conifer/ Deciduous-Conifer	4	175.17	226.37	5.43	9.66	3.02
3500	Kharsu oak/Kail	2	151.25	192.76	4.46	8.23	2.62
3600	Kharsu oak/Birch	2	116.59	149.88	3.08	6.04	1.89
3700	Birch	1	2.90	4.00	0.15	0.29	0.09

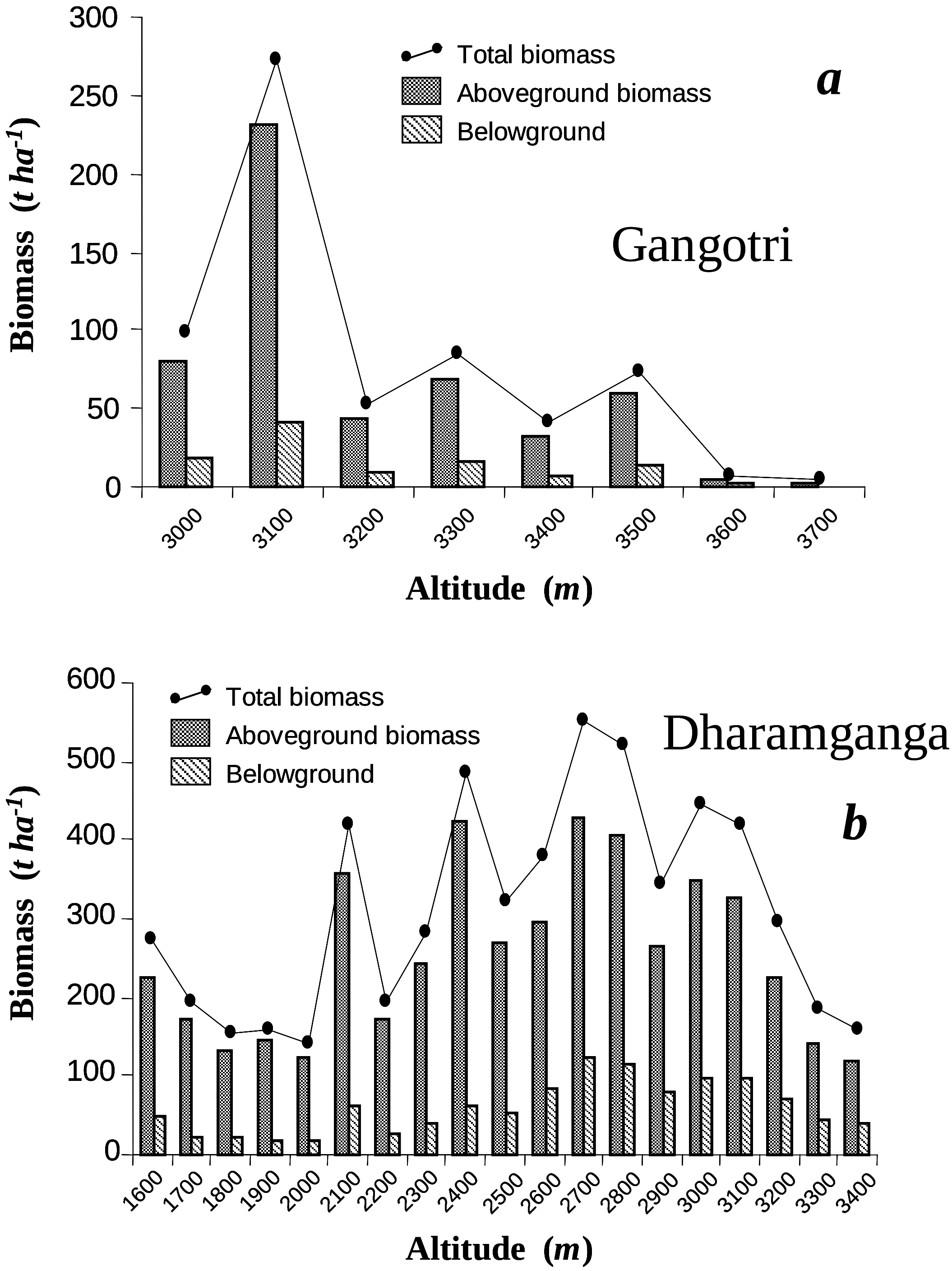
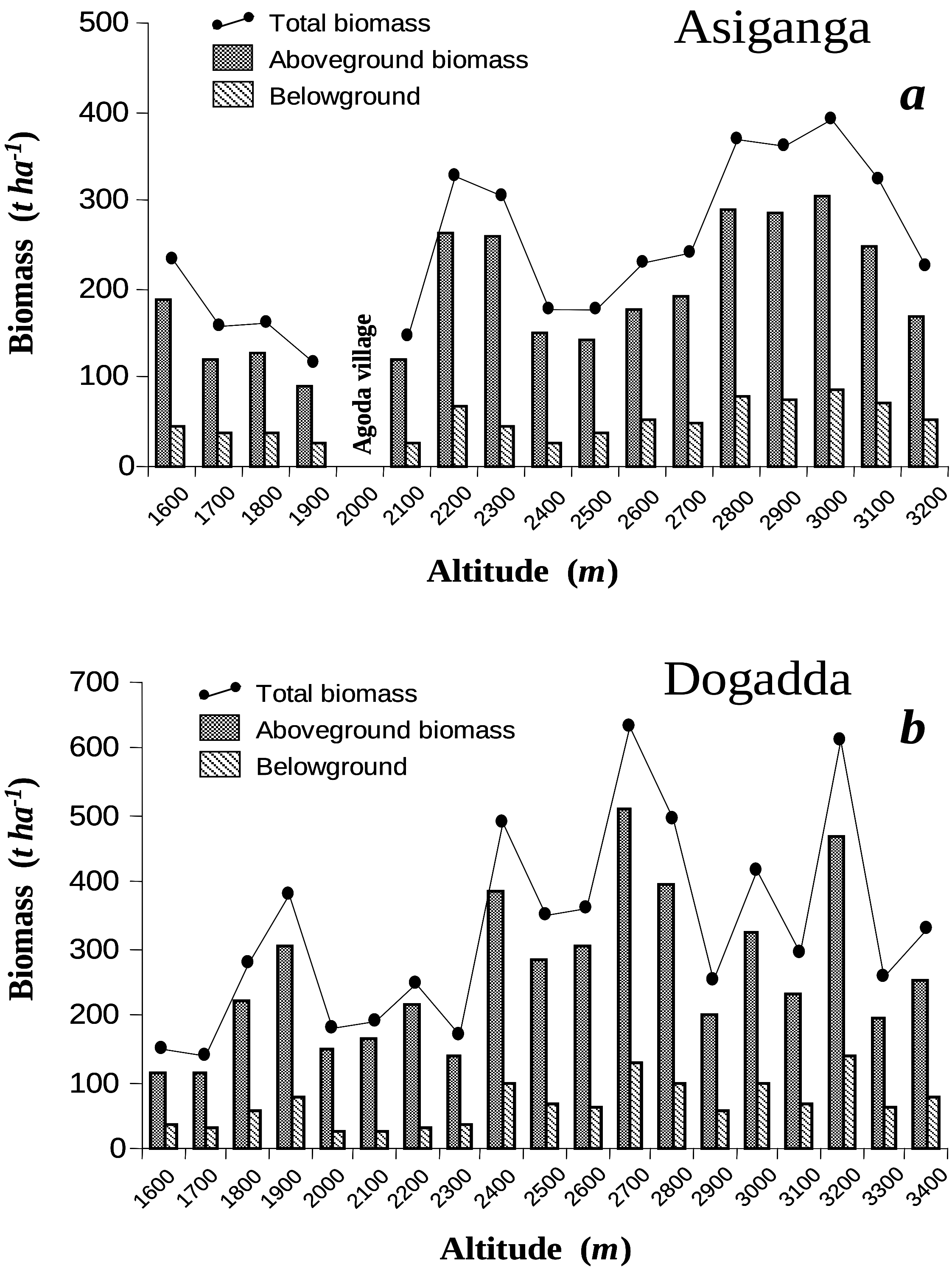

300
250
200
150
100
50
0
Biomass (t ha-1)
Total biomass
Aboveground biomass
Belowground
a
Gangotri
3000
3100
3200
3300
3400
3500
3600
3700
Altitude (m)
600
500
400
300
200
100
0
Biomass (t ha-1)
Total biomass
Aboveground biomass
Belowground
Dharamganga
b
1600
1700
1800
1900
2000
2100
2200
2300
2400
2500
2600
2700
2800
2900
3000
3100
3200
3300
3400
Altitude (m)

Fig. 2



Asiganga
a
Total biomass
Aboveground biomass
Belowground
Agoda village
Biomass (t ha-1)
Altitude (m)
Dogadda
b
Total biomass
Aboveground biomass
Belowground
Biomass (t ha-1)
Altitude (m)

Fig. 3

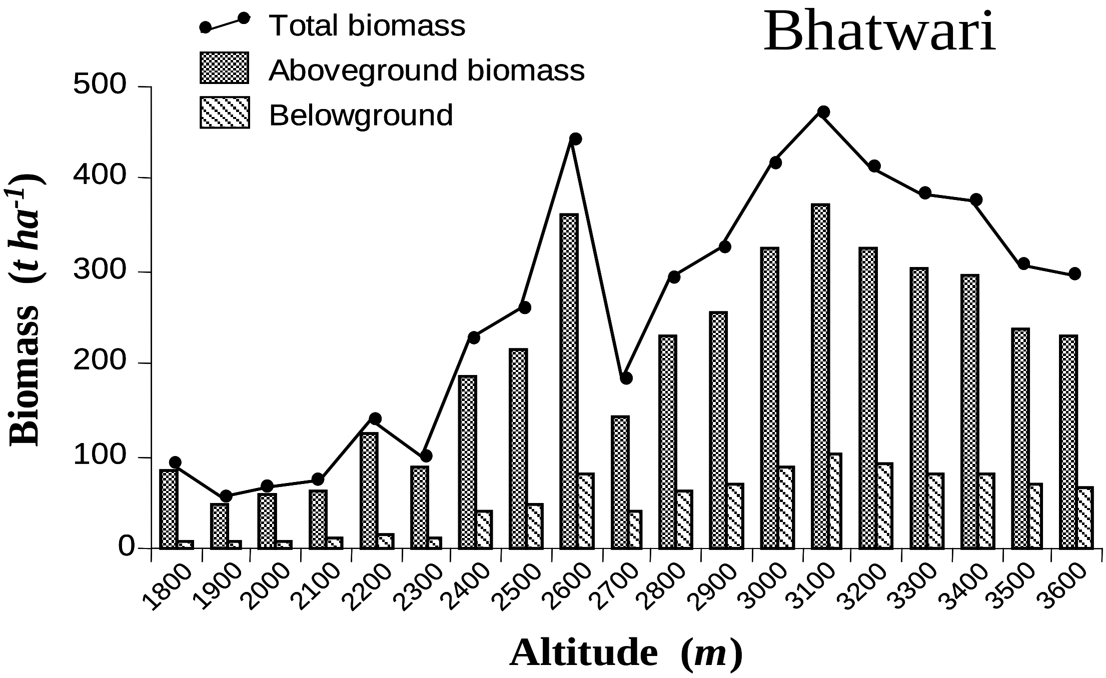


Fig. 4

3.3 Carbon storage in Tree, Litter and soil

3.3.1 Tree layer

The average carbon allocation in biomass, productivity and litter fall is given Table 9 for each watershed. Overall status (Table 10) of carbon allocation in different watersheds is in the following order:

Biomass: Dogadda > Dharamganga > Bhatwari > Asiganga > Gangotri

Productivity: Dogadda > Dharamganga > Asiganga > Bhatwari > Gangotri

Litter fall: Dogadda > Dharamganga > Asiganga > Bhatwari > Gangotri

Among forest types the carbon allocation in biomass was high in horse chestnut, oak-conifer and tilonj oak forests (243.5, 216.3 and 201.0 t C ha^{-1}, respectively, Table 11).

Table 9: Average carbon allocation (%) in different watersheds in Garhwal, western Himalaya.

Forest type	Altitude (m)	Carbon (%)		
		Biomass	Productivity	Litter fall
Dharamganga				
Chir pine	1600	135.93	9.99	2.76
Conifer-broadleaved	1800	77.21	4.15	1.35
Banj oak	1867	82.57	2.81	1.10
Tilonj oak-mixed	2200	149.64	5.62	2.31
Tilonj oak	2450	201.46	6.77	1.75
Kharsu oak	3000	183.74	7.29	2.26
Bhatwari				
Banj oak	1900	35.75	1.22	0.48
Oak-mixed	2250	74.98	2.82	0.94
Oak	2333	83.31	3.06	1.04
Tilonj oak	2600	219.96	7.39	1.83
Kharsu oak	3083	151.82	6.02	1.89
Oak-Conifer	3250	205.56	9.49	3.04
Asiganga				
Alder	1800	68.78	4.13	1.33
Toon	1800	81.67	4.23	1.39
Conifer-broadleaved	2167	98.06	5.27	1.63
Mixed broadleaved	2200	129.92	4.88	1.61
Silver fir	2700	121.13	3.75	1.14
Deciduous-conifer	2900	180.88	8.60	2.17
Kharsu oak	2940	153.16	6.07	1.90
Dogadda				
Chir pine	1600	75.24	5.53	1.42
Deciduous broadleaved	1900	189.43	9.80	3.28
Mixed broadleaved	1933	98.36	3.69	1.15
Banj oak	2150	108.92	3.71	1.43
Conifer-broadleaved	2250	131.79	7.08	2.21
Horse chestnut	2400	243.48	8.54	2.81
Tilonj oak	2600	181.02	6.08	1.53
Oak-Conifer	2800	230.57	10.65	3.46
Kharsu oak	3200	190.72	7.56	2.34
Gangotri				
Deodar	3000	48.76	3.05	0.51
Conifer-broadleaved	3100	136.58	7.34	2.35
Deciduous-conifer	3350	31.20	1.45	0.52
Kail	3350	31.60	1.76	0.54
Birch	3650	2.46	0.18	0.06

Carbon allocation was high for oak-conifer, deciduous-broadleaved and horse chestnut forests (10.0, 9.8 and 8.5 t ha^{-1} yr^{-1}, respectively) in productivity and deciduous-broadleaved and oak-conifer forest (3.3 and 3.2 t ha^{-1} yr^{-1}, respectively) in litter fall. These values were low for alder, toon, banj oak, deciduous-conifer, kail and birch forests.

Table 10: Average C allocation in tree layer in different watersheds, Garhwal Himalaya.

Watershed	Carbon storage		
	Biomass (t ha^{-1})	Productivity (t ha^{-1} yr^{-1})	Litter fall (t ha^{-1} yr^{-1})
Asiganga	119.08	5.28	1.59
Bhatwari	128.56	5.00	1.54
Dharamganga	138.42	6.10	1.92
Dogadda	161.06	6.96	2.18
Gangotri	50.12	2.76	0.79
Garhwal Himalaya (Average)	119.45	5.22	1.61

Along altitudinal gradient the carbon allocation in biomass, productivity and litter mass was high at 2700 and 2800m (Table 12). However, these values were minimum for lower (<2000m) and higher (>3500m) altitude forests.

3.3.2 Litter mass

The carbon in litter mass was high in deciduous-broadleaved forest (146.6 kg ha^{-1}) followed by kharsu oak forest (125.0 kg ha^{-1}, Table 13). However, it was low for chir pine, toon, mixed-broadleaved, mixed-oak, tilonj oak, silver fir, deodar, kail and birch forests (68.1-97.4 kg ha^{-1}, Table 13).

3.3.3 Soil

The values of carbon storage in soil (down to 10cm) were low for alder and kharsu oak forests (20.0-24.1 t ha^{-1}, Table 13). These values were higher for horse chestnut forest (100.7 t ha^{-1}) followed by silver fir forest (86.7 t ha^{-1}, Table 13).

Table 11: Average carbon allocation (%) in different forest types in Garhwal, western Himalaya.

Forest type	Carbon (%)		
	Biomass	Productivity	Litter fall
Chir pine	105.59	7.76	2.09
Alder	68.78	4.13	1.33
Toon	81.67	4.23	1.39
Deciduous broadleaved	189.43	9.80	3.28
Banj oak	71.60	2.44	0.95
Mixed-broadleaved	114.06	4.28	1.37
Tilonj oak-mixed	121.33	4.56	1.87
Conifer-broadleaved	110.22	5.92	1.86
Mixed oak	83.31	3.06	1.04
Horse chestnut	243.48	8.54	2.81
Tilonj oak	200.97	6.75	1.72
Silver fir	121.13	3.75	1.14
Deodar	48.76	3.05	0.51
Kharsu oak	171.36	6.80	2.12
Oak-conifer	216.28	9.99	3.22
Deciduous-conifer	81.09	3.84	1.07
Kail	31.60	1.76	0.54
Birch	2.46	0.18	0.06

Table 12: Average carbon allocation (%) along an altitudinal gradient in Garhwal, western Himalaya.

Altitude (m)	Forest type	Carbon (%)		
		Biomass	Productivity	Litter fall
1600	Chir pine/Conifer-broadleaved	109.07	7.25	2.03
1700	Mixed broadleaved/Banj oak/ Alder	82.15	3.56	1.20
1800	Mixed broadleaved/Banj oak/ Conifer-broadleaved/Toon	86.09	3.79	1.25
1900	Deciduous broadleaved/Banj oak/Alder	88.91	4.25	1.47
2000	Conifer-broadleaved/Banj oak	64.31	2.77	0.97
2100	Banj oak/Tilonj oak-mixed/Oak/ Mixed broadleaved	103.54	3.80	1.46
2200	Banj oak/Tilonj oak-mixed/Oak/ Mixed broadleaved	113.61	4.14	1.56
2300	Mixed broadleaved/Tilonj oak-mixed/Oak	107.39	4.02	1.42
2400	Tilonj oak/Mixed oak/Conifer-broadleaved/Horse chestnut	172.03	6.43	1.96
2500	Conifer-broadleaved/Tilonj oak/ Mixed oak	138.69	6.09	1.82
2600	Tilonj oak/Kharsu oak	176.54	6.39	1.78
2700	Kharsu oak/Silver fir/Oak-Conifer	201.06	8.23	2.61
2800	Kharsu oak/Oak-Conifer	209.36	8.71	2.77
2900	Kharsu oak/Oak-Conifer/ Deciduous-conifer	160.86	6.94	2.05
3000	Kharsu oak/Deodar	176.73	7.23	2.17
3100	Kharsu oak/Conifer-broadleaved/Oak-Conifer	178.15	7.76	2.45
3200	Kharsu oak/Kail/Oak-Conifer	159.70	6.69	2.07
3300	Kharsu oak/Oak-Conifer/ Deciduous-conifer	113.78	4.90	1.57
3400	Kharsu oak/Oak-Conifer/ Deciduous-conifer	113.19	4.83	1.51
3500	Kharsu oak/Kail	96.38	4.11	1.31
3600	Kharsu oak/Birch	74.94	3.02	0.95
3700	Birch	2.00	0.15	0.05

Table 13: Bulk density, organic carbon (%) and organic carbon in the soil (down to 10 cm) and litter organic carbon (%) and litter (kg ha^{-1}) and organic carbon in litter in different forest types in Garhwal, western Himalaya.

Forest Type	Stands (#)	Altitude (m)	Soil (organic carbon)			Litter (Organic carbon)		
			Bulk density	%	kg ha^{-1}	%	kg ha^{-1}	kg ha^{-1}
Chir pine	2	1600	0.99	7.2	71665.0	47.1	163.4	76.8
Alder	2	1800	1.10	1.9	20023.0	44.9	232.2	104.3
Toon	1	1800	0.73	9.8	71540.0	39.6	172.0	68.1
Deciduous broadleaved	1	1900	0.91	4.7	42315.0	44.9	326.8	146.6
Banj oak	8	1950	0.76	6.5	49515.1	47.3	239.7	113.7
Mixed-broadleaved	7	2114	0.82	7.4	58342.1	45.7	207.6	94.2
Tilonj oak-mixed	4	2175	0.90	4.0	36324.0	44.6	245.1	108.2
Conifer-broadleaved	7	2271	0.90	3.8	33294.4	47.2	210.1	100.5
Mixed oak	3	2333	0.86	5.9	50946.7	47.0	189.2	89.3
Horse chestnut	1	2400	0.83	12.1	100679.0	53.1	206.4	109.6
Tilonj oak	4	2525	0.82	6.0	48985.0	46.4	210.7	97.4
Silver fir	1	2700	0.64	13.6	86720.0	43.7	189.2	82.6
Deodar	1	3000	0.90	7.3	66060.0	53.2	146.2	77.8
Kharsu oak	25	3048	0.72	3.7	24077.6	45.9	275.2	125.0
Oak-conifer	7	3057	0.77	5.8	36054.7	50.6	208.9	105.8
Deciduous-conifer	3	3200	0.79	7.9	58185.3	49.0	217.9	107.9
Kail	2	3350	0.97	4.1	37955.0	50.0	154.8	77.5
Birch	2	3650	0.92	5.4	48698.0	47.5	176.3	83.5

Table 14: Carbon storage and carbon accumulation in Garhwal Himalayan forest ecosystems.

Forest	Carbon storage (t C ha^{-1})				Carbon accumulation (t C ha^{-1} yr^{-1})
	Vegetation	Forest floor	Soil	Total	
Chir pine	105.59	71.7	0.080	177.4	9.9
Alder	68.78	20.0	0.104	88.9	5.5
Toon	81.67	71.5	0.068	153.2	5.6
Deciduous-broadleaved	189.43	42.3	0.146	231.9	13.1
Banj oak	71.6	49.5	0.114	121.2	3.4
Mixed-broadleaved	114.1	58.3	0.094	172.5	5.7
Tilonj oak-mixed	121.33	36.3	0.108	157.7	6.4
Conifer-broadleaved	110.22	33.3	0.101	143.6	7.8
Mixed oak	83.31	50.9	0.089	134.3	4.1
Horse chestnut	243.48	100.7	0.110	344.3	11.4
Tilonj oak	200.97	49.0	0.097	250.1	8.5
Silver fir	121.13	86.7	0.083	207.9	4.9
Deodar	48.76	66.1	0.078	114.9	3.6
Kharsu oak	171.36	24.1	0.125	195.6	8.9
Oak-conifer	216.28	36.1	0.106	252.5	13.1
Deciduous-conifer	81.09	58.2	0.108	139.4	4.9
Kail	31.6	38	0.078	69.7	2.3
Birch	2.46	48.7	0.084	51.2	0.2

3.4 Carbon storage and accumulation in ecosystem

The total carbon storage was high (196-344 t ha^{-1}) for horse chestnut, oak-conifer, tilonj oak, deciduous-broadleaved, silver fir and kharsu oak forests, intermediate (125-195 t ha^{-1}) for chir pine, toon, mixed-broadleaved, tilonj oak-mixed, conifer-broadleaved, mixed oak and deciduous-conifer forests and low (<125 t ha^{-1}) for alder, banj oak, deodar, kail and birch forests (Table 14). The carbon accumulation was extremely high (11.4-13.1 t ha^{-1} yr^{-1}) in deciduous-broadleaved, oak-conifer and horse chestnut forests, however, extremely low for banj oak (3.4 t ha^{-1} yr^{-1}) and deodar (3.6 t ha^{-1} yr^{-1}) forests.

4.0 DISCUSSION

4.1 Relationship between abiotic (*temperature*) and biotic (*density, total basal area, biomass, productivity* and *litter fall*) traits of forest ecosystem

The relationship between trees density and total basal area within and among forest types varied widely in Garhwal Himalaya (Fig. 5a). The density values were maximum for the intermediate total basal area. The values of low density and total basal area includes the forests, such as chir pine, alder, toon, banj oak and conifer-deciduous on lower side of the altitudinal gradient, oak-mixed and oak forests on the middle of the gradient, while birch, kail, kharsu oak forests on the higher side of the gradient.

The average density and total basal area was high in Dogadda watershed, however, average density was minimum in Bhatwari watershed and average total basal area was in Gangotri watershed. The relationship between total basal area and density was also observed that for the Kumaun Himalayan forests (Singh et al. 1994, Fig. 5b). And birch, kail, chir pine and banj oak forests had low values for density and total basal area in Kumaun Himalaya. For the entire western Himalaya the pattern was observed same as depicted in Fig. 5c. The values of density and total basal area are well coincide with the values reported for the forests in the same watersheds (Uniyal 2000).

In local perspective, the relationships between mean annual temperature (MAT) and structural and functional traits in Garhwal, western Himalaya (Fig.6, west Uttaranchal State) are:

- the density and total basal area declines at 3200m and at 9.1°C MAT
- the biomass, productivity and litter fall declines at 3400m and at 8.2°C MAT

The reported values for Kumaun, western Himalaya (east Uttaranchal State; Singh et al. 1994) are:

- the density, biomass and productivity decline at 2400m and at 12.6°C MAT
- the total basal area declines at 2800m and at 10.5°C MAT
- the litter fall declines at 2700m and at 11.3°C MAT (Adhikari, unpubl.)

At a **regional scale** (*both Kumaun and Garhwal*, each value denotes a particular forest type at different altitudes, Fig. 7) the relationships between temperature and parameters for **western Himalaya** are:

- the density declines at 2750m and at 11.1°C MAT
- the total basal area declines at 2650m and at 11.5°C MAT
- the biomass, productivity and litter fall decline at 3050m and at 9.7°C MAT

4.2 Comparisons among other forests elsewhere

The biomass (aboveground and total) reported conifer forests of present study are well within the range reported for the other conifer forests elsewhere in the world as well as Kumaun Himalayan conifer forest. The biomass (total) reported for *Abies alba* was 144.0 t ha^{-1} (Vyskot 1972), for *A. balsamea* was 149-200 t ha^{-1} (Baskerville 1965b), for *Picea abies* was 202 t ha^{-1} (Devillez et al. 1973), for *Picea abies* was 51 t ha^{-1} (Manakov 1961), for *Pseudotsuga menziesii* was 57 t ha^{-1} (Heilman & Gessel 1963), for *Pinus roxburghii* was 113-283 t ha^{-1} (Chaturvedi & Singh 1987, Rana et al. 1989) and for *Pinus taeda* was 112 t ha^{-1} (Ralston 1973). However, the biomass of present study was quite low for silver fir forest as reported for Kumaun Himalayan silver fir forest (566 t ha^{-1}, Adhikari et al. 1995).

The biomass of deciduous-broadleaved forests (*Alnus,* toon and deciduous-conifer) of present study are comparable with the values reported for Alnus rubra (295 t ha^{-1} (Zavitkovski & Stevens 1972) and Fagus sylvatica (375 t ha^{-1}, Nihlgard 1972). The values reported for horse chestnut forest of present study are comparable with the Kumaun forest (505 t ha^{-1}, Adhikari et al. 1995). The biomass reported *for Quercus floribunda*, *Q. leucotrichophora* and *Q. lanuginosa* forests (467, 391 and 294 t ha^{-1}, respectively, Rawat & Singh 1988), for *Q. ilex* forest (322 t ha^{-1}, Lossaint & Rapp, 1978), for *Q. petraea* forest (314 t ha^{-1}, Duvigneaud et al. 1971), for *Q. robur* forest (155-503 t ha^{-1}, Mina 1955, Anderson 1971) and for *Q. petraea-F. sylvatica* forest (320 t ha^{-1}, Drift 1981). The biomass of kharsu oak forest of present study is low than that of reported for Kumaun Himalaya (593 t ha^{-1}, Adhikari et al. 1995). The values reported for birch forest for the present study is very low as compared to birch forest of Kumaun Himalya (173 t ha^{-1}, Singh et al. 1992).

The major environmental factors, such as temperature, moisture, sunshine, cloudiness and nutrients, that influence production pattern in higher elevations of Kumaun Himalaya, play a very important role in the forest ecosystems (Singh et al. 1994). In the present study the productivity (aboveground and total) ranged from 0.4-20.0 t ha^{-1} yr^{-1}. The productivity of *P. roxburghii* forest is comparable with the conifer forests of the world, such as *P. rubens* forest (11.7 t ha^{-1} yr^{-1}, Gordon 1981), *P. strobus* forest (13.5 t ha^{-1} yr^{-1}, Swank & Schruedner 1973, 1974) and *P. roxburghii* forest of Kumaun Himalaya (9.9-21.2 t ha^{-1} yr^{-1}, Chaturvedi & Singh 1987). Other conifer forests, which are comparable with present study conifer forests are *Abies veitchii* forest (7.3 t ha^{-1} yr^{-1}, Kimura et al. 1968), *Cryptomeria japonica* forest (9.6 t ha^{-1} yr^{-1}, Satto & Senda 1966), *Pseudotsuga menziesii-Tsuga heterophylla* and *Tsuga heterophylla-Picea sitchensis* forests (12.7 and 10.3 t ha^{-1} yr^{-1}, respectively; Fujimori et al. 1976) and *Pseudotsuga menziesii* forest (6.3-10.0 t ha^{-1} yr^{-1}, Grier & Logan 1977).

The quantity and seasonal variation of forest floor litter mass depends on canopy closure, altitude, climate and pattern of litter fall. The mean total forest floor biomass of west Himalayan evergreen forests ranged from 3.9-6.3 t ha^{-1}, coniferous forests 4.7-13.6 t ha^{-1} and deciduous forests 2.1 t ha^{-1} (Singh et al. 1994). The values for present study forests of garhwal Himalaya is qite low due to sampling (at one time). In general at regional scale the comparison shows that the kharsu oak forest lies towards the lower side of the range 5.3-12.6 t ha^{-1} for different oak forests of the world (Reiners and Reiners 1970, Monk et al. 1970, Duvigneaud & Denayer De-Smet 1970). The mean total forest floor mass of silver fir forest is 3 times less than the lower side of the range 12.6-70.1 t ha^{-1} reported for *P. patula*, an exotic pine of Eastern Himalaya (Singh 1979). The value of mean total forest floor mass of horse chestnut forest comparable with mixed dry lowland (1.7-2.5 t ha^{-1}; Madge 1965), moist-deciduous (1-2.4 t ha^{-1}; Hopkins 1966) and moist semi-deciduous evergreen forests (2.2 t ha^{-1}, Nye 1961; Greenland & Kowal 1960).

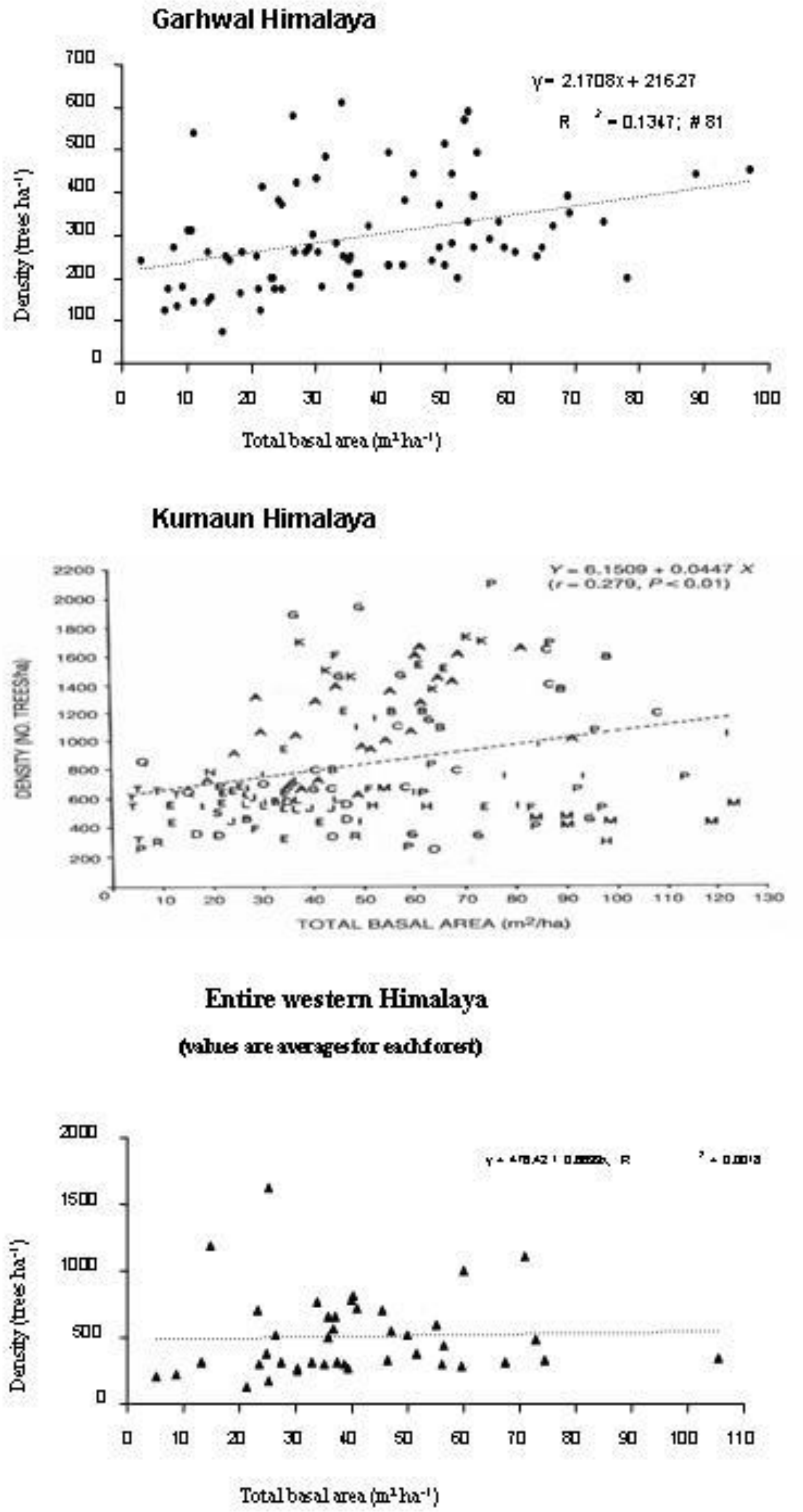
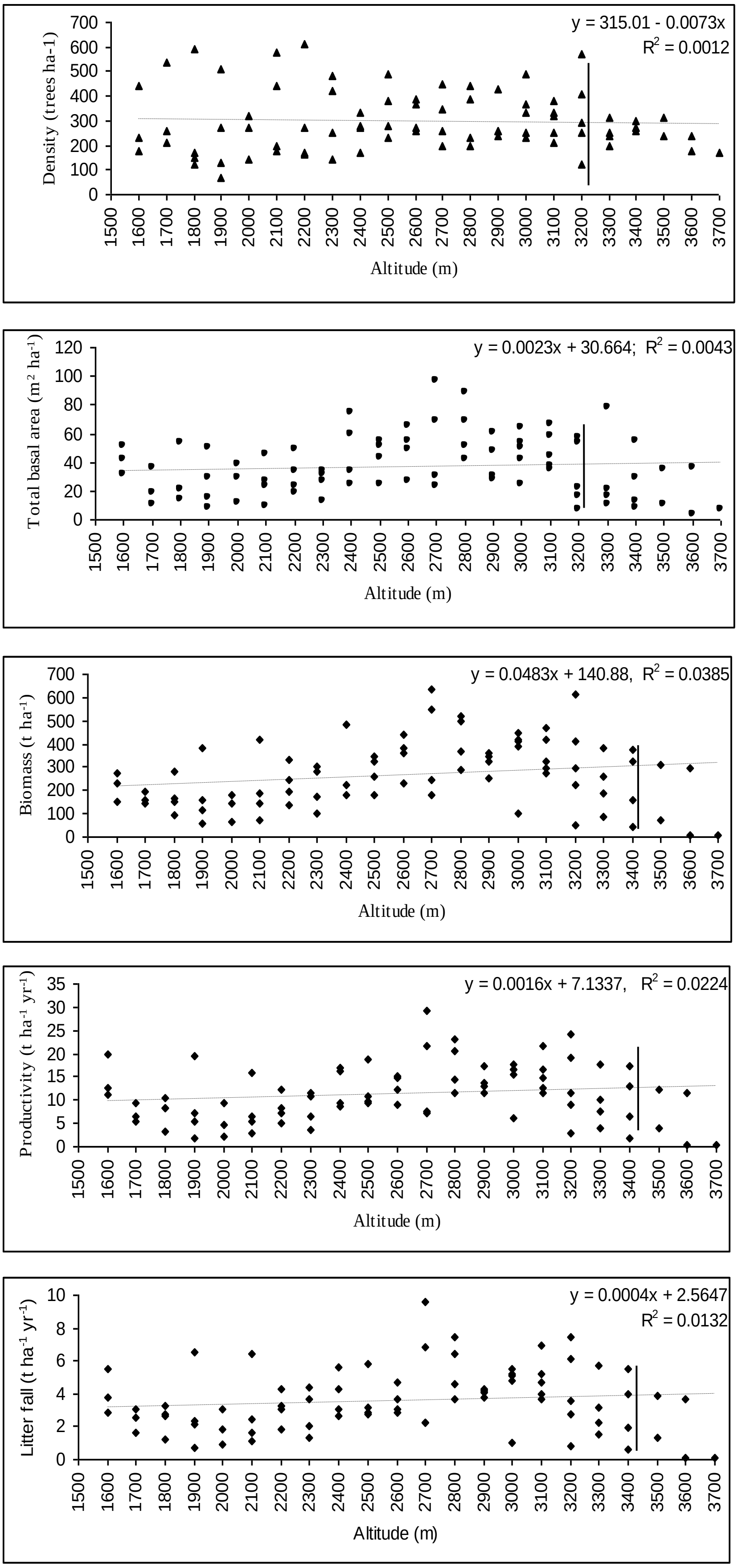

Garhwal Himalaya
y = 2.1708x + 216.27
R² = 0.1347; # 81
Density (trees ha⁻¹)
Total basal area (m² ha⁻¹)
Kumaun Himalaya
Y = 6.1509 + 0.0447 X
(r = 0.279, P < 0.01)
DENSITY (NO. TREES/ha)
TOTAL BASAL AREA (m²/ha)
Entire western Himalaya
(values are averages for each forest)
Density (trees ha⁻¹)
Total basal area (m² ha⁻¹)

Fig. 5 (a,b,c)



y = 315.01 - 0.0073x
R2 = 0.0012
Density (trees ha-1)
Altitude (m)
y = 0.0023x + 30.664; R2 = 0.0043
Total basal area (m2 ha-1)
Altitude (m)
y = 0.0483x + 140.88, R2 = 0.0385
Biomass (t ha-1)
Altitude (m)
y = 0.0016x + 7.1337, R2 = 0.0224
Productivity (t ha-1 yr-1)
Altitude (m)
y = 0.0004x + 2.5647
R2 = 0.0132
Litter fall (t ha-1 yr-1)
Altitude (m)

Fig. 6

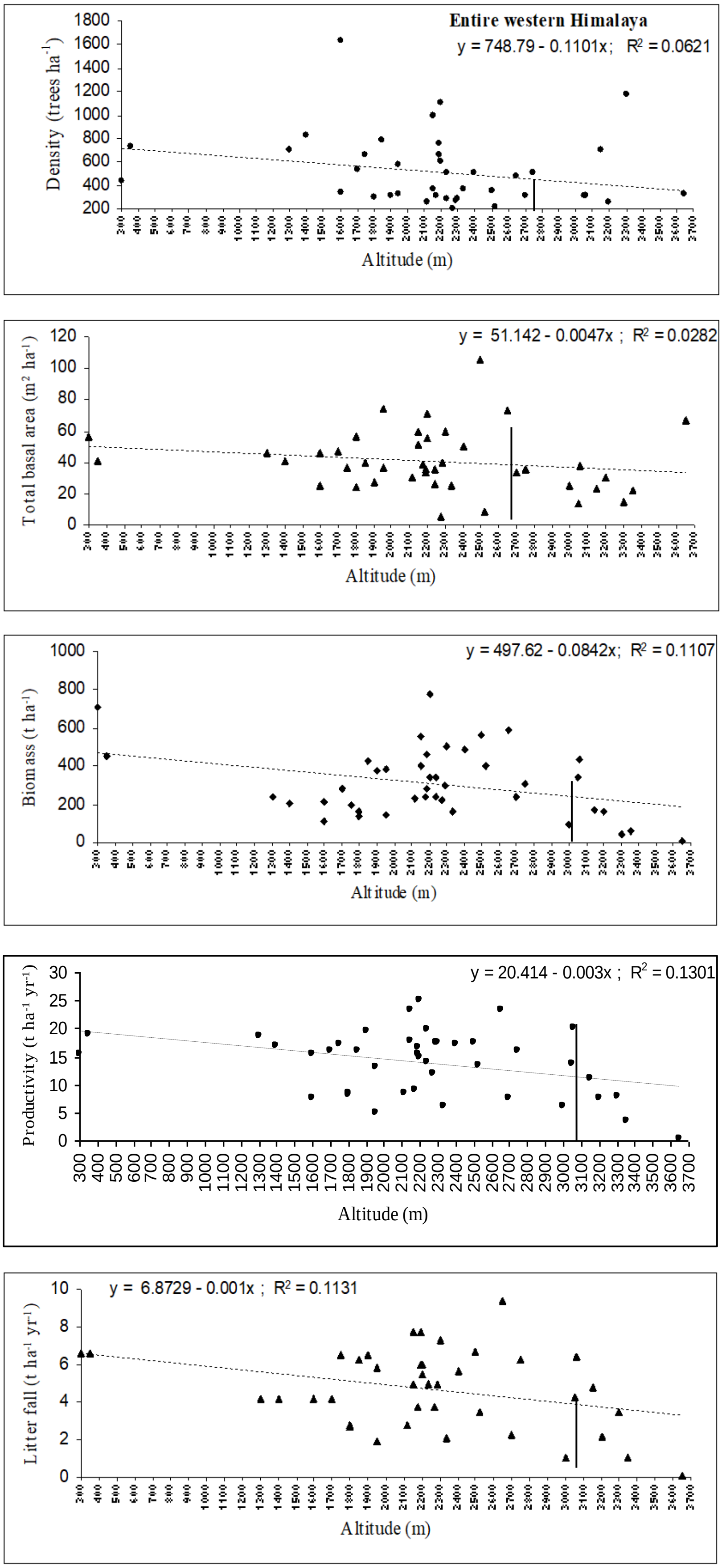

Entire western Himalaya
y = 748.79 - 0.1101x; R² = 0.0621
Density (trees ha⁻¹)
Altitude (m)
y = 51.142 - 0.0047x ; R² = 0.0282
Total basal area (m² ha⁻¹)
Altitude (m)
y = 497.62 - 0.0842x; R² = 0.1107
Biomass (t ha⁻¹)
Altitude (m)
y = 20.414 - 0.003x ; R² = 0.1301
Productivity (t ha⁻¹ yr⁻¹)
Altitude (m)
y = 6.8729 - 0.001x ; R² = 0.1131
Litter fall (t ha⁻¹ yr⁻¹)
Altitude (m)

Fig. 7

The productivity values for broadleaved-deciduous forests of present study are comparable with the values of *Fagus crenata* forest (6.5-8.2 t ha^{-1} yr^{-1}, Kakubari 1977) and *F. sylvestris-A. alba* forest (9.3 t ha^{-1} yr^{-1}, Bindiu et al. 1981). The productivity values for oak forests of present study are comparable with the values reported *for Q. coccinea-Q. alba* mixed forest (12.5 t ha^{-1} yr^{-1}, Whittaker & Woodwell 1969), *Q. petraea* forest (14.9 t ha^{-1} yr^{-1}, Drift 1974, 1981), *Q. robur* forest (9.2 t ha^{-1} yr^{-1}, Medwicka-Kornas et al. 1974, 1981), *Q. robur* mixed (12.1 t ha^{-1} yr^{-1}, Duvigneaud et al. 1971) *and Q. robur-Tilia cordata* forest (8.9 t ha^{-1} yr^{-1}, Andersson 1971). The values of horse chestnut anf kharsu oak forests of present study are lower than the values reported for Kumaun Himalaya (19.6 and 24.6 t ha^{-1} yr^{-1}, Adhikari et al. 1995).

West Himalayan forests indicated that all the dominant tree species are evergreen with concentrated summer leaf drop between throughout the altitudinal range, except deciduous forests in high altitude regions. The individual evergreen and deciduous tree species differ from one another in different phenological parameters, such as leaf expansion period (week). The total annual litter fall in the west Himalayan forests ranged from 4.2-15.4 t ha^{-1} yr^{-1} (Singh et al. 1994). The values for Garhwal Himalayan forests are lower than the values reported for Kumaun Himalaya and lies within the range reported for warm temperate (5.4 t ha^{-1} yr^{-1}) forests (11.0 t ha^{-1} yr^{-1}, Bray & Gorham 1964). The value of kharsu oak is also comparable with the values of higher side of the range (3.8-7.0 t ha^{-1} yr^{-1}) reported for temperate mixed-oak and oak forests (Rapp 1969, Reiners 1972, Lang 1974, De Angelis et al. 1980). The litter fall in silver fir forest is 2.2 times higher than *A. amabilis - P. menziesii* forest (Fujimori et al. 1976) and 1.4 times that of *A. firma* and *T. suboldii* forest (Furuno et al. 1979). The litter fall value of horse chestnut forest lies within the range reported for *A. rubra* forest (4.5-9.9 t ha^{-1} yr^{-1}; Zavitkovaski & Newton 1971) and comparable with dry deciduous forest (7.7 t ha^{-1} yr^{-1}; Singh 1968) and *F. crenata* forest (6.6-6.9 t ha^{-1} yr^{-1}; Tadaki et al. 1969).

Satoo (1970, 1971) have classified 258 forests of Japan in five major types, viz., in warm temperate zone the productivity of coniferous forests was around 10 t ha^{-1} yr^{-1}, that of pine and conifer forests around 10-15 t ha^{-1} yr^{-1} and that of evergreen broadleaf forests around 20 t ha^{-1} yr^{-1}, which are more productive, while in cool temperate zone the productivity of deciduous broadleaf forests was poorest. The present forests have the productivity similar to those of evergreen broadleaf forests.

The range of carbon storage in different forest categories in the west Himalaya (Singh et al. 1985) suggests that the carbon allocation in biomass of present forests of Garhwal Himalaya comes under medium forest category (92.8-162.4 t C ha^{-1}). However, productivity and return to the soil (through litter fall) of Garhwal Himalayan forests comes under poor forest category (2.6-5.6 and 1.5-3.3 t C ha^{-1} yr^{-1}, respectively) for the period 1972-1973. The carbon storage and annual carbon budget reported for chir pine forest (105.6 t C ha^{-1} and 7.8 t C ha^{-1} yr^{-1}), mixed banj oak-chir pine forest (210.7 t C ha^{-1} and 9.1 t C ha^{-1} yr^{-1}) and oak forest (328.3 t C ha^{-1} and 11.9 t C ha^{-1} yr^{-1}) of Kumaun Himalaya (Singh 1987) are comparable with the present study (Table 14).

The total carbon storage in Garhwal Himalayan forests are comparable with the forests in Kumaun Himalaya (174.6-368.3 t C ha^{-1}, Singh & Singh 1992). The overall average allocation of carbon in biomass, productivity and litter fall are 119.5 t C ha^{-1}, 5.2 t C ha^{-1} yr^{-1} and 1.6 t C ha^{-1} yr^{-1}, respectively in Garhwal Himalayan watersheds. The relationship with temperature shows that the carbon allocation (%) in biomass declines at 3100m (9.5°C MAT), while in productivity and litter fall declines at 3200m (9.1°C MAT).

In nutshell, the preponderance of kharsu oak in Garhwal Himalaya govern the density and total basal area in those sites where the timberline is away from the glacial valleys. In these areas the germination of seeds of dominant species, i.e. kharsu oak is very difficult, as very few seeds occupy the same habitat, while the soil is nutrient rich. The seeds do not restrict themselves in the same habitat due to their heavy mass and roll down to the lower areas. At the same time locals collect the forest floor litter for their cattle bed and rest of the remaining litter either blown by the wind or washed off by rains. The moisture in the soil and litter in these forests is very less and does not allow the seed to germinate. However, it is evident from the data that the glacial valleys support the distribution of deciduous species, which may be due to their light seed weight and germination capabilities in the nutrient poor soils. Garhwal Himalaya has relatively a mixture of dry and moist temperate climate, which influences the growth and vitality of the forests through the water balance in the watersheds. Therefore, in each watershed of the region the projected changes in the climate are most likely to have distinct impact on the forest ecosystems, such as recession of birch forest in to alpine meadows and several other changes i.e., composition of mid altitudinal forests.

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Eroded bouldery slopes best among the preferred habitats for birch (*Betula utilis*) in Gangotri watershed

In gaps between huge bouldery area kail (*Pinus wallichiana*) establishes its seedlings and hence after develops a forest in Gangotri watershed

Bouldery habitats mainly used by male Bharal (*Pseudois nayaur*) herd during winters in Gangotri watershed

Some times fine debris in the form of lateral moraine occupied by seedlings of kail at the same time in Gangotri watershed

Lateral moraines mainly used by female Bharal (*Pseudois nayaur*) herd during winters in Gangotri watershed

PLATE 1

A homogenous patch of kail forest develops in above mentioned lateral moraines in Gangotri watershed

Small rivulets carry heavy lode of fine debris, which widens the width either side of the rivulet and ultimately ends with lateral moraine, provide base to birch and kail-birch forest, respectively to grow in Gangotri watershed

Large girth class trees of birch forms forest along river Bhagirathi on stable slopes and flat areas in Gangotri watershed

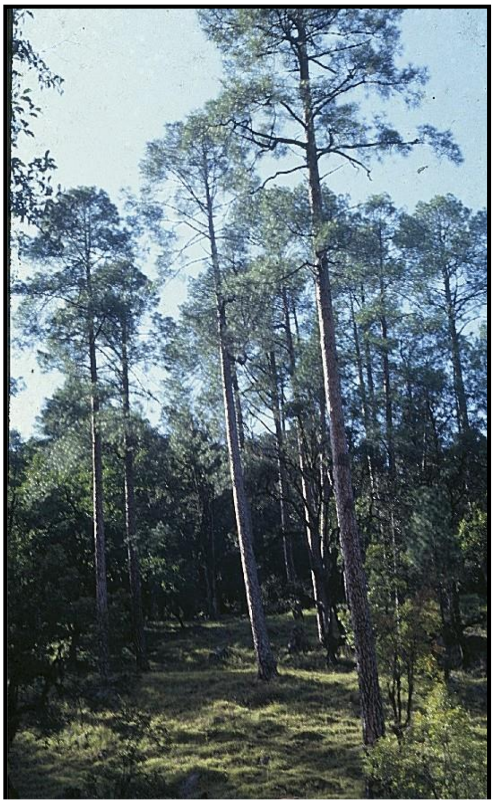
Populus-Alnus forms forest along riverine area at low altitude, oaks (banj, *Quercus leucotrichophora* & *tilonj, Q. floribunda*) at mid altitude and kharsu (*Q. semecarpifolia*) forms a forest on high altitude areas in Dogadda watershed watershed

Kharsu oak (*Q. semecarpifolia*) at and around Dodital area (3100m) and above forms forest in Asiganga watershed

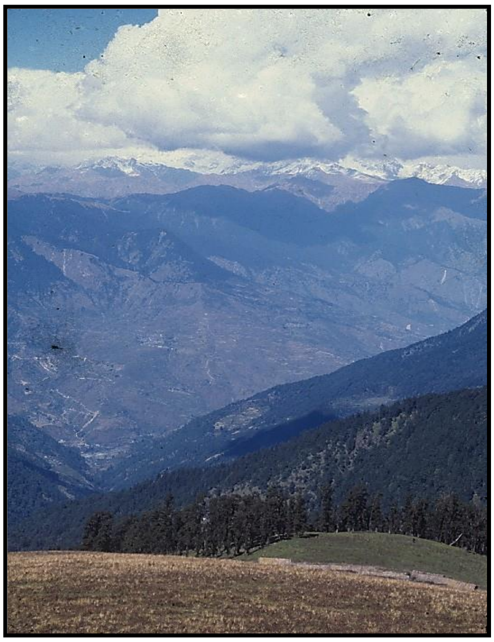
PLATE 2

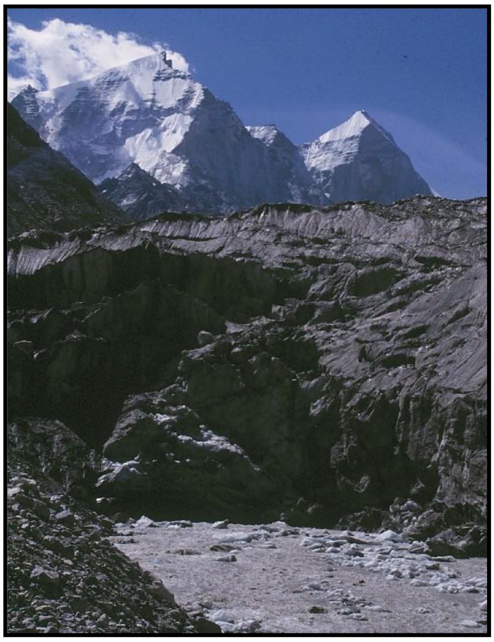
Mid altitude region mainly occupied by oak-conifer forest in Dogadda watershed

Mid altitude area provides ringal *Chimonobambusa falcata*) livelihood to the locals at the cost of threatened habitats in Dharamganga watershed



Chir pine (*Pinus roxburghii*) forms extensive forest at low altitude, which is disaster to the multi-purpose oak forest of mid altitude in Uttaranchal





Most impacted zones of the study area is high altitude region, such as timberline at Jorai, Dogadda watershed and Gaumukh glacier at Gangotri watershed are reciting very fast due to human pressure and global warming, respectively

PLATE 3

5.0 REFERENCES

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Appendix I: Composition of forests along an altitudinal gradient in different watersheds in Garhwal Himalaya.

Altitude *(m)*	Species name	***Density (trees ha^{-1})***	**Total basal** ***area (m^2 ha^{-1})***	***Importance Value Index (IVI)***
		Dharamganga		
1600	*Pinus roxburghii*	230.0	41.4	300.0
	Total	**230.0**	**41.4**	
1700	*Quercus leucotrichophora*	80.0	24.3	134.7
	Acer oblongum	40.0	8.4	65.7
	Cornus macrophylla	30.0	1.5	36.2
	Pyrus pashia	60.0	2.0	63.4
	Total	**210.0**	**36.2**	
1800	*Quercus leucotrichophora*	90.0	7.4	133.6
	Pinus roxburghii	60.0	13.2	135.4
	Lyonia ovalifolia	20.0	0.8	31.0
	Total	**170.0**	**21.3**	
1900	*Quercus leucotrichophora*	80.0	22.5	138.8
	Machilus duthii	60.0	2.4	46.3
	Rhododendron arboretum	70.0	2.3	54.8
	Lyonia ovalifolia	30.0	1.1	30.6
	Carpinus viminea	30.0	0.8	29.5
	Total	**270.0**	**29.0**	
2000	*Quercus leucotrichophora*	80.0	20.8	130.8
	Rhododendron arboretum	140.0	6.1	114.2
	Lyonia ovalifolia	50.0	2.0	55.0
	Total	**270.0**	**28.9**	
2100	*Quercus floribunda*	170.0	29.8	132.9
	Betula alnoides	30.0	7.4	30.4
	Machilus duthii	150.0	5.1	77.5
	Rhododendron arboreum	70.0	2.3	46.1
	Carpinus viminea	20.0	0.7	13.1
	Total	**440.0**	**45.3**	
2200	*Quercus floribunda*	60.0	20.2	148.7
	Machilus duthii	60.0	1.8	78.5
	Carpinus viminea	30.0	1.2	43.9
	Eunymus lacerus	20.0	0.7	28.9
	Total	**170.0**	**23.9**	
2300	*Quercus floribunda*	110.0	20.0	112.4
	Machilus duthii	220.0	5.7	103.2
	Litsea umbrosa	150.0	5.8	84.4
	Total	**480.0**	**31.5**	
2400	*Quercus floribunda*	180.0	56.7	212.2
	Pyrus pashia	30.0	0.9	29.3
	Lyonia ovalifolia	30.0	0.9	29.3
	Ilex dipyrena	20.0	0.6	19.5
	Aesculus indica	10.0	0.3	9.8
	Total	**270.0**	**59.3**	
2500	*Quercus floribunda*	160.0	43.4	184.7
	Ilex dipyrena	50.0	1.0	43.6

	Eurya acuminata	30.0	0.8	26.6
	Acer acuminatum	20.0	1.6	19.9
	Aesculus indica	20.0	4.4	25.3
	Total	**280.0**	**51.2**	
2600	*Quercus semecarpifolia*	180.0	49.0	183.2
	Rhododendron arboreum	190.0	4.9	98.8
	Ilex dipyrena	20.0	0.6	17.9
	Total	**390.0**	**54.5**	
2700	*Quercus semecarpifolia*	320.0	68.6	267.4
	Rhododendron arboretum	30.0	0.7	32.6
	Total	**350.0**	**69.3**	
2800	*Quercus semecarpifolia*	280.0	65.7	225.8
	Rhododendron arboreum	110.0	3.3	74.2
	Total	**390.0**	**69.0**	
2900	*Quercus semecarpifolia*	310.0	27.4	215.2
	Rhododendron arboreum	110.0	2.5	76.0
	Ilex dipyrena	10.0	0.4	8.8
	Total	**430.0**	**30.2**	
3000	*Quercus semecarpifolia*	270.0	51.1	243.9
	Taxus baccata	60.0	2.4	56.1
	Total	**330.0**	**53.5**	
3100	*Quercus semecarpifolia*	300.0	41.2	231.8
	Taxus baccata	80.0	2.6	68.2
	Total	**380.0**	**43.8**	
3200	*Quercus semecarpifolia*	330.0	20.1	231.9
	Taxus baccata	80.0	1.6	68.1
	Total	**410.0**	**21.7**	
3300	*Quercus semecarpifolia*	290.0	9.8	271.4
	Taxus baccata	20.0	0.6	28.6
	Total	**310.0**	**10.3**	
3400	*Quercus semecarpifolia*	270.0	8.1	300.0
	Total	**270.0**	**8.1**	

Asiganga

1600	*Pinus roxburghii*	110.0	21.4	188.3
	Cedrella toona	70.0	9.7	111.7
	Total	**180.0**	**31.1**	
1700	*Alnus nepalensis*	520.0	10.4	273.5
	Cornus macrophylla	20.0	0.7	26.55
	Total	**540.0**	**11.1**	
1800	*Cedrella toona*	100.0	20.9	258.6
	Pyrus pashia	20.0	0.5	41.39
	Total	**120.0**	**21.4**	
1900	*Alnus nepalensis*	70.0	15.7	300
	Total	**70.0**	**15.7**	
2000	***Village Agora***			
2100	*Quercus floribunda*	60.0	17.2	127.7
	Alnus nepalensis	60.0	1.3	64.95
	Betula alnoides	40.0	1.8	51.32
	Rhododendron arboreum	40.0	2.9	56
	Total	**200.0**	**23.2**	
2200	*Alnus nepalensis*	70.0	14.9	77.18

	Betula alnoides		50.0	13.0	65.85
	Quercus floribunda		60.0	16.2	76.05
	Rhododendron arboreum		60.0	1.7	50.72
	Acer caesium		30.0	3.2	30.19
		Total	**270.0**	**49.1**	
2300	*Quercus floribunda*		100.0	21.9	143.9
	Litsea umbrosa		30.0	1.1	30.25
	Machilus duthii		70.0	2.3	54.72
	Betula alnoides		30.0	5.9	44.18
	Cornus macrophylla		20.0	3.1	26.98
		Total	**250.0**	**34.3**	
2400	*Cedrus deodara*		100.0	16.1	109.1
	Rhododendron arboreum		30.0	1.1	26.37
	Betula alnoides		30.0	3.7	34.42
	Alnus nepalensis		40.0	1.6	35.67
	Lyonia ovalifolia		40.0	1.1	34.37
	Quercus leucotrichophora		40.0	9.7	60.06
		Total	**280.0**	**33.3**	
2500	*Pinus wallichiana*		130.0	7.2	95.48
	Cedrus deodara		100.0	11.3	99.96
	Quercus semecarpifolia		120.0	4.6	77.87
	Lyonia ovalifolia		30.0	1.3	26.69
		Total	**380.0**	**24.4**	
2600	*Quercus semecarpifolia*		150.0	22.4	184.4
	Rhododendron arboreum		90.0	3.8	91.59
	Pyrus pashia		20.0	0.6	24.05
		Total	**260.0**	**26.7**	
2700	*Abies pindrow*		160.0	27.0	200.6
	Quercus semecarpifolia		60.0	1.9	60.74
	Taxus baccata		40.0	1.4	38.67
		Total	**260.0**	**30.4**	
2800	*Quercus semecarpifolia*		180.0	48.0	262.5
	Juglans regia		20.0	3.9	37.48
		Total	**200.0**	**51.8**	
2900	*Acer pictum*		160.0	45.3	183.1
	Abies pindrow		60.0	12.4	72.95
	Taxus baccata		40.0	3.1	43.97
		Total	**260.0**	**60.8**	
3000	*Quercus semecarpifolia*		210.0	46.4	266
	Abies pindrow		20.0	3.5	33.95
		Total	**230.0**	**50.0**	
3100	*Quercus semecarpifolia*		210.0	36.9	300
		Total	**210.0**	**36.9**	
3200	*Quercus semecarpifolia*		250.0	16.1	300
		Total	**250.0**	**16.1**	

Gangotri

3000	*Cedrus deodara*		370.0	24.8	300.0
		Total	**370.0**	**24.8**	
3100	*Cedrus deodara*		140.0	27.5	127.5
	Pinus wallichiana		120.0	15.8	101.5
	Populus ciliate		70.0	15.2	71.0
		Total	**330.0**	**58.4**	
3200	*Pinus wallichiana*		90.0	6.1	232.0

	Populus ciliate		30.0	0.7	68.0
		Total	**120.0**	**6.7**	
3300	*Populus ciliate*		60.0	5.8	89.3
	Betula utilis		100.0	6.3	114.6
	Pinus wallichiana		80.0	4.6	96.1
		Total	**240.0**	**16.7**	
3400	*Betula utilis*		170.0	8.2	188.9
	Pinus wallichiana		90.0	5.2	111.1
		Total	**260.0**	**13.4**	
3500	*Pinus wallichiana*		260.0	10.4	250.3
	Betula utilis		50.0	0.5	49.7
		Total	**310.0**	**10.9**	
3600	*Betula utilis*		170.0	2.4	211.6
	Salix sp.		70.0	0.7	88.4
		Total	**240.0**	**3.1**	
3700	*Betula utilis*		170.0	7.2	300.0
		Total	**170.0**	**7.2**	

Dogadda

1600	*Lyonia ovalifolia*		60.0	2.3	44.2
	Pinus roxburghii		170.0	31.3	134.6
	Rhododendron arboretum		200.0	17.3	114
	Carpinus viminea		10.0	0.3	7.2
		Total	**440.0**	**51.2**	
1700	*Pinus roxburghii*		70.0	9.1	97.7
	Alnus nepalensis		50.0	2.8	50.7
	Cedrella toona		40.0	3.5	50.6
	Rhododendron arboreum		60.0	2.0	61.3
	Lyonia ovalifolia		40.0	1.4	39.6
		Total	**260.0**	**18.8**	
1800	*Rhododendron arboreum*		180.0	8.7	67.8
	Lyonia ovalifolia		30.0	1.7	13.5
	Cedrella toona		30.0	5.8	21.1
	Cornus macrophyla		80.0	4.6	32.6
	Carpinus viminea		40.0	2.2	18.9
	Quercus leucotrichophora		60.0	4.0	30.7
	Alnus nepalensis		70.0	12.0	44.8
	Pinus roxburghii		20.0	6.8	21.2
	Betula alnoides		10.0	2.6	9.2
	Machilus odoratissima		10.0	1.2	6.6
	Pyrus pashia		30.0	0.7	14.2
	Symplocos chinensis		10.0	0.3	4.8
	Fraxinus micrantha		10.0	0.9	6
	Ulmus wallichiana		10.0	2.2	8.5
		Total	**590.0**	**53.6**	
1900	*Populus ciliate*		220.0	33.9	137.7
	Alnus nepalensis		80.0	6.8	46
	Cedrella toona		50.0	0.7	24.5
	Litsea umbrosa		50.0	2.5	28.1
	Cornus macrophyla		40.0	1.9	21.6
	Betula alnoides		40.0	3.2	24.2
	Meliosma odoratissima		10.0	0.7	6.7
	Quercus leucotrichophora		20.0	0.3	11.2

	Total	**510**.0	**50.0**	
2000	*Quercus leucotrichophora*	70.0	13.5	82.2
	Pinus roxburghii	90.0	6.5	57.7
	Rhododendron arboretum	100.0	10.2	95.5
	Lyonia ovalifolia	40.0	3.6	38.7
	Alnus nepalensis	20.0	4.3	25.9
	Total	**320**.0	**38.2**	
2100	*Quercus leucotrichophora*	320.0	14.4	147.1
	Rhododendron arboretum	110.0	6.6	64.8
	Lyonia ovalifolia	100.0	4.1	57.8
	Carpinus viminea	40.0	1.1	23.5
	Ulmus wallichiana	10.0	0.2	6.7
	Total	**580.0**	**26.5**	
2200	*Quercus leucotrichophora*	370.0	22.9	162.4
	Lyonia ovalifolia	140.0	4.8	71.7
	Rhododendron arboreum	100.0	6.4	66
	Total	**610.0**	**34.2**	
2300	*Quercus leucotrichophora*	80.0	4.7	51.2
	Lyonia ovalifolia	50.0	1.9	30.6
	Eunymous lacerus	50.0	4.0	38.4
	Ilex dipyrena	50.0	2.0	31.1
	Rhododendron arboreum	60.0	4.7	46.1
	Buxus sempervirens	40.0	1.0	22
	Litsea umbrosa	30.0	1.6	21.7
	Aesculus indica	40.0	6.8	46.4
	Carpinus viminea	20.0	0.5	12.5
	Total	**420.0**	**27.2**	
2400	*Aesculus indica*	130.0	63.8	166.2
	Buxus sempervirens	130.0	3.7	79.6
	Acer caesium	40.0	2.0	26.6
	Quercus floribunda	20.0	1.7	14.2
	Juglans regia	10.0	3.3	13.3
	Total	**330.0**	**74.5**	
2500	*Quercus floribunda*	120.0	15.7	71.2
	Ilex dipyrena	50.0	1.2	27.4
	Abies pindrow	90.0	25.7	80.1
	Machilus odoratissima	40.0	4.0	24.6
	Symplocos chinensis	40.0	0.9	21.9
	Lyonia ovalifolia	60.0	2.8	29.4
	Rhododendron arboretum	90.0	4.8	45.3
	Total	**490.0**	**55.0**	
2600	*Quercus floribunda*	250.0	43.7	201.7
	Rhododendron arboretum	10.0	0.2	7.7
	Acer caesium	20.0	1.1	16.7
	Ilex dipyrena	30.0	0.5	22.8
	Symplocos chinensis	30.0	0.4	22.6
	Carpinus viminea	10.0	0.2	7.7
	Picea smithiana	10.0	2.6	12.5
	Abies pindrow	10.0	0.5	8.3
	Total	**370.0**	**49.2**	
2700	*Aesculus indica*	60.0	19.3	46.1
	Quercus floribunda	110.0	24.8	72.5
	Abies pindrow	80.0	29.1	67
	Rhododendron arboretum	80.0	5.0	39.1

	Acer caesium		40.0	3.8	25.7
	Quercus semecarpifolia		80.0	15.2	49.5
		Total	**450.0**	**97.2**	
2800	*Abies pindrow*		130.0	41.6	99.4
	Taxus baccata		60.0	13.1	51.4
	Acer caesium		90.0	5.4	38.1
	Pyrus foliosa		70.0	4.3	40
	Quercus semecarpifolia		90.0	24.6	71.1
		Total	**440.0**	**88.9**	
2900	*Quercus semecarpifolia*		120.0	11.4	126.1
	Taxus baccata		60.0	2.9	59.8
	Abies pindrow		80.0	14.3	114.1
		Total	**260.0**	**28.5**	
3000	*Quercus semecarpifolia*		320.0	34.0	158.2
	Rhododendron arboretum		60.0	2.9	48.1
	Taxus baccata		110.0	4.5	93.7
		Total	**490.0**	**41.5**	
3100	*Quercus semecarpifolia*		170.0	32.2	218.8
	Taxus baccata		80.0	3.3	81.2
		Total	**250.0**	**35.4**	
3200	*Quercus semecarpifolia*		550.0	52.9	279.5
	Viburnum erubecense		20.0	0.2	20.5
		Total	**570.0**	**53.1**	
3300	*Quercus semecarpifolia*		250.0	20.8	300
		Total	**250.0**	**20.8**	
3400	*Quercus semecarpifolia*		280.0	29.2	282.5
	Acer caesium		20.0	0.5	17.5
		Total	**300.0**	**29.7**	

Bhatwari

1800	*Quercus leucotrichophora*		100.0	12.4	214.4
	Rhododendron arboretum		30.0	1.0	51.9
	Lyonia ovalifolia		20.0	0.5	33.7
		Total	**150.0**	**13.9**	**300.0**
1900	*Quercus leucotrichophora*		50.0	6.6	149.4
	Rhododendron arboretum		40.0	0.9	74.6
	Lyonia ovalifolia		30.0	0.8	56.9
	Ilex dipyrena		10.0	0.3	19.0
		Total	130.0	8.6	300.0
2000	*Quercus leucotrichophora*		60.0	8.9	156.5
	Symplocos chinensis		30.0	0.7	52.3
	Lyonia ovalifolia		20.0	0.5	35.5
	Rhododendron arboretum		30.0	1.0	55.7
		Total	140.0	11.1	300.0
2100	*Cedrus deodara*		20.0	2.2	46.8
	Quercus floribunda		40.0	2.1	68.1
	Quercus leucotrichophora		50.0	2.4	77.2
	Rhododendron arboretum		30.0	1.2	47.7
	Ilex dipyrena		20.0	0.6	28.9
	Lyonia ovalifolia		20.0	0.8	31.4
		Total	180.0	9.4	300.0
	Quercus leucotrichophora		60.0	10.5	129.8

	Quercus floribunda	50.0	6.4	94.2
	Ilex dipyrena	20.0	0.6	30.0
	Lyonia ovalifolia	30.0	1.1	46.0
	Total	160.0	18.5	300.0
2300	*Quercus leucotrichophora*	40.0	7.0	109.7
	Lyonia ovalifolia	30.0	1.0	50.4
	Quercus floribunda	40.0	4.3	89.8
	Rhododendron arboretum	10.0	0.4	17.2
	Ilex dipyrena	20.0	0.6	32.9
	Total	140.0	13.3	300.0
2400	*Quercus floribunda*	90.0	9.6	134.6
	Aesculus indica	40.0	14.1	109.3
	Symplocos chinensis	20.0	0.3	27.4
	Ilex dipyrena	20.0	0.7	28.8
	Total	170.0	24.7	300.0
2500	*Quercus floribunda*	110.0	28.9	155.2
	Quercus semecarpifolia	40.0	10.1	64.2
	Rhododendron arboretum	50.0	3.1	52.3
	Lyonia ovalifolia	30.0	1.5	28.3
	Total	230.0	43.6	300.0
2600	*Quercus floribunda*	170.0	42.5	172.6
	Aesculus indica	40.0	9.8	52.0
	Quercus semecarpifolia	30.0	8.3	40.5
	Acer caesium	30.0	4.6	34.9
	Total	270.0	65.1	300.0
2700	*Quercus semecarpifolia*	100.0	19.1	168.7
	Rhododendron arboretum	40.0	1.8	52.6
	Lyonia ovalifolia	40.0	1.4	50.9
	Taxus baccata	20.0	1.2	27.7
	Total	200.0	23.5	300.0
2800	*Quercus semecarpifolia*	130.0	30.6	168.0
	Rhododendron arboretum	50.0	2.5	58.9
	Acer caesium	30.0	6.1	46.5
	Taxus baccata	20.0	2.2	26.5
	Total	230.0	41.4	300.0
2900	*Quercus semecarpifolia*	150.0	44.7	202.5
	Taxus baccata	30.0	2.2	34.6
	Rhododendron arboretum	30.0	0.8	31.8
	Syringa emodi	30.0	0.4	31.1
	Total	240.0	48.1	300.0
3000	*Quercus semecarpifolia*	170.0	54.9	200.1
	Abies pindrow	30.0	7.7	44.0
	Rhododendron arboretum	50.0	1.7	55.9
	Total	250.0	64.2	300.0
3100	*Quercus semecarpifolia*	200.0	48.6	179.9
	Abies pindrow	60.0	15.7	70.1
	T. buccata	60.0	2.3	50.0
	Total	320.0	66.6	300.0
3200	*Quercus semecarpifolia*	200.0	42.9	194.3
	Viburnum erubesence	50.0	0.8	43.6
	Abies pindrow	40.0	13.3	62.1
	Total	290.0	57.0	300.0

3300	*Abies pindrow*	80.0	36.5	116.2
	Quercus semecarpifolia	80.0	40.0	138.2
	Rhododendron arboretum	40.0	1.7	45.6
	Total	200.0	78.2	300.0
3400	*Quercus semecarpifolia*	170.0	37.5	181.7
	Rhododendron arboreum	60.0	0.9	48.9
	Abies pindrow	40.0	16.2	69.4
	Total	270.0	54.6	300.0
3500	*Quercus semecarpifolia*	200.0	34.3	249.9
	Rhododendron campanulatum	40.0	0.9	50.1
	Total	240.0	35.2	300.0
3600	*Quercus semecarpifolia*	180.0	35.6	300.0
	Total	180.0	35.6	300.0

Appendix II: Biomass (t ha^{-1})of different components of different species along an altitudinal gradient in upper Bhagirathi, Asiganga, Dharamganga, Dogadda and Bhatwari watersheds.

Altitude	*Species*	*Bole*	*Bole bark*	*Branch*	*Twig*	*Foliage*	*Stump root*	*Lateral root*	*Fine root*
				Gangotri					
3000	*C. deodara*	51.41	2.82	14.90	6.42	4.50	11.40	5.38	0.69
	Total	***51.41***	***2.82***	***14.90***	***6.42***	***4.50***	***11.40***	***5.38***	***0.69***
3100	*C. deodara*	68.65	3.50	11.18	3.37	2.30	8.48	2.91	0.35
	P. wallichiana	54.46	1.73	13.44	4.01	2.21	10.50	4.26	0.39
	P. ciliata	49.39	7.31	6.31	2.28	0.82	10.80	3.57	0.94
	Total	***172.50***	***12.54***	***30.94***	***9.66***	***5.32***	***29.79***	***10.74***	***1.67***
3200	*P. wallichiana*	23.30	0.83	6.34	2.13	1.11	4.88	2.29	0.12
	P. ciliata	7.53	0.88	0.99	0.51	0.11	1.85	0.67	0.11
	Total	***30.83***	***1.71***	***7.33***	***2.64***	***1.23***	***6.72***	***2.96***	***0.23***
3300	*P. ciliata*	29.51	4.02	3.81	1.55	0.47	6.72	2.30	0.51
	B. utilis	1.99	0.22	0.39	0.09	0.06	0.68	0.27	0.07
	P. wallichiana	17.62	0.66	4.97	1.74	0.89	3.81	1.87	0.08
	Total	***49.12***	***4.90***	***9.18***	***3.39***	***1.42***	***11.20***	***4.44***	***0.66***
3400	*B. utilis*	2.43	0.28	0.48	0.11	0.07	0.84	0.34	0.08
	P. wallichiana	19.99	0.75	5.63	1.97	1.01	4.31	2.11	0.09
	Total	***22.42***	***1.02***	***6.11***	***2.08***	***1.08***	***5.15***	***2.45***	***0.18***
3500	*P. wallichiana*	37.72	1.63	12.00	4.68	2.30	9.04	5.07	0.08
	B. utilis	0.12	0.01	0.02	0.01	0.00	0.04	0.02	0.00
	Total	***37.83***	***1.64***	***12.02***	***4.69***	***2.31***	***9.08***	***5.09***	***0.08***
3600	*B. utilis*	0.54	0.07	0.11	0.02	0.01	0.20	0.08	0.02
	Salix	1.65	0.15	1.10	0.60	0.23	0.88	0.09	0.08
	Total	***2.19***	***0.22***	***1.21***	***0.62***	***0.25***	***1.08***	***0.17***	***0.10***
3700	*B. utilis*	2.09	0.24	0.41	0.10	0.06	0.73	0.29	0.07
	Total	***2.09***	***0.24***	***0.41***	***0.10***	***0.06***	***0.73***	***0.29***	***0.07***
				Dharamganga					
1600	*P. roxburghii*	170.03	0.00	37.56	10.77	6.07	35.95	10.68	0.82
	Total	*170.03*	*0.00*	*37.56*	*10.77*	*6.07*	*35.95*	*10.68*	*0.82*
1700	*Q. leucotrichophora*	64.21	0.00	37.50	8.42	2.73	3.53	4.18	0.30
	A. oblongum	25.25	1.71	7.60	2.50	0.79	7.43	2.12	0.62
	C. macrophylla	9.67	1.68	2.60	0.71	0.29	2.74	1.28	0.36
	P. pashia	2.34	0.17	1.43	0.75	0.24	1.09	0.10	0.07
	Total	***101.46***	***3.56***	***49.13***	***12.37***	***4.04***	***14.79***	***7.68***	***1.36***
1800	*Q. leucotrichophora*	29.44	0.00	17.94	5.26	1.75	2.19	2.76	0.25
	P. roxburghii	57.37	0.00	13.16	3.64	1.91	11.95	3.60	0.26
	L. ovalifolia	1.05	0.08	0.73	0.40	0.12	0.49	0.04	0.03
	Total	***87.86***	***0.08***	***31.83***	***9.30***	***3.77***	***14.63***	***6.41***	***0.53***
1900	*Q. leucotrichophora*	60.92	0.00	35.66	8.13	2.64	3.41	4.05	0.30
	M. duthii	10.99	0.00	6.90	2.89	1.68	3.09	0.40	0.03
	R. arboreum	4.01	0.00	2.68	1.05	0.47	2.29	0.73	0.14
	L. ovalifolia	1.44	0.11	1.01	0.55	0.16	0.69	0.06	0.04
	C. viminea	1.04	0.08	0.65	0.34	0.11	0.50	0.05	0.04
	Total	***78.39***	***0.19***	***46.91***	***12.95***	***5.07***	***9.97***	***5.28***	***0.54***

2000	*Q. leucotrichophora*	57.62	0.00	33.82	7.84	2.55	3.28	3.92	0.29
	R. arboreum	8.90	0.00	5.87	2.22	0.96	5.20	1.68	0.29
	L. ovalifolia	2.60	0.20	1.82	0.98	0.29	1.21	0.11	0.07
	Total	***69.12***	***0.20***	***41.51***	***11.04***	***3.80***	***9.70***	***5.71***	***0.65***
2100	*Q. floribunda*	110.81	0.00	61.86	31.16	50.30	33.49	5.24	0.20
	B. alnoides	26.67	4.02	7.97	2.16	0.86	7.68	3.24	0.98
	M. duthii	24.48	0.00	15.50	6.64	3.86	7.15	0.93	0.08
	R. arboreum	4.04	0.00	2.70	1.05	0.47	2.31	0.73	0.14
	C. viminea	0.77	0.06	0.48	0.25	0.08	0.36	0.03	0.02
	Total	***166.77***	***4.07***	***88.52***	***41.26***	***55.57***	***50.99***	***10.18***	***1.43***
2200	*Q. floribunda*	64.33	0.00	34.29	16.66	27.95	16.98	2.57	0.08
	M. duthii	8.91	0.00	5.68	2.48	1.44	2.69	0.35	0.03
	C. viminea	1.26	0.09	0.76	0.39	0.12	0.58	0.05	0.04
	Eunymus	3.28	0.00	2.07	0.89	0.52	0.96	0.12	0.01
	Total	***77.78***	***0.09***	***42.81***	***20.43***	***30.03***	***21.20***	***3.09***	***0.16***
2300	*Q. floribunda*	73.76	0.00	41.07	20.64	33.40	22.12	3.46	0.13
	M. duthii	29.76	0.00	19.09	8.51	4.94	9.26	1.19	0.11
	L. umbrosa	7.67	0.38	2.46	0.63	0.39	2.89	1.34	0.28
	Total	***111.19***	***0.38***	***62.63***	***29.79***	***38.73***	***34.27***	***5.99***	***0.51***
2400	*Q. floribunda*	183.12	0.00	98.09	47.85	79.92	49.04	7.45	0.23
	P. pashia	1.11	0.08	0.69	0.36	0.12	0.52	0.05	0.04
	L. ovalifolia	1.30	0.10	0.91	0.50	0.15	0.64	0.06	0.04
	I. dipyrena	1.18	0.06	0.42	0.07	0.05	0.31	0.14	0.07
	A. indica	3.96	1.03	1.52	0.38	0.19	1.54	0.78	0.26
	Total	***190.67***	***1.27***	***101.63***	***49.15***	***80.42***	***52.06***	***8.48***	***0.63***
2500	*Q. floribunda*	130.41	11.30	55.77	7.72	8.04	23.34	11.24	3.45
	I. dipyrena	2.51	0.13	0.82	0.15	0.10	0.63	0.29	0.13
	E. acuminata	4.10	0.00	2.63	1.17	0.68	1.27	0.16	0.01
	A. acuminatum	5.03	0.33	1.42	0.48	0.15	1.46	0.41	0.11
	A. indica	20.85	4.03	8.34	1.67	0.78	5.84	3.47	1.07
	Total	***162.91***	***15.79***	***68.98***	***11.19***	***9.75***	***32.54***	***15.57***	***4.79***
2600	*Q. semecarpifolia*	193.23	16.91	50.25	7.09	5.68	47.40	20.97	7.67
	R. arboreum	11.46	0.32	4.83	4.12	1.02	5.20	2.07	0.32
	I. dipyrena	1.17	0.06	0.42	0.07	0.05	0.31	0.14	0.06
	Total	***205.86***	***17.29***	***55.49***	***11.27***	***6.75***	***52.91***	***23.18***	***8.05***
2700	*Q. semecarpifolia*	300.35	26.32	78.09	11.35	9.12	75.17	33.11	12.27
	R. arboreum	1.67	0.05	0.71	0.61	0.15	0.78	0.31	0.05
	Total	***302.02***	***26.37***	***78.80***	***11.96***	***9.27***	***75.95***	***33.42***	***12.32***
2800	*Q. semecarpifolia*	276.47	24.22	71.89	10.33	8.29	68.68	30.29	11.17
	R. arboreum	7.16	0.20	2.99	2.56	0.63	3.15	1.27	0.19
	Total	***283.64***	***24.42***	***74.88***	***12.89***	***8.92***	***71.83***	***31.56***	***11.36***
2900	*Q. semecarpifolia*	176.84	15.58	45.95	7.48	6.08	47.66	20.67	8.05
	R. arboreum	6.28	0.18	2.67	2.27	0.57	2.91	1.15	0.18
	I. dipyrena	0.64	0.03	0.24	0.04	0.03	0.18	0.08	0.04
	Total	***183.77***	***15.79***	***48.86***	***9.79***	***6.67***	***50.75***	***21.90***	***8.27***
3000	*Q. semecarpifolia*	236.14	20.71	61.39	9.07	7.30	59.72	26.25	9.80
	T. buccata	8.93	0.38	2.82	1.09	0.54	2.12	1.18	0.02
	Total	***245.07***	***21.09***	***64.21***	***10.16***	***7.84***	***61.85***	***27.43***	***9.82***
3100	*Q. semecarpifolia*	219.35	19.27	57.01	8.78	7.09	56.98	24.90	9.46
	T. buccata	8.64	0.42	3.06	1.29	0.62	2.27	1.41	0.00
	Total	***227.99***	***19.70***	***60.07***	***10.07***	***7.71***	***59.25***	***26.31***	***9.46***
3200	*Q. semecarpifolia*	152.75	13.49	39.68	6.78	5.54	42.47	18.30	7.28

	T. buccata	2.82	0.27	1.82	1.00	0.44	1.28	1.11	-0.06
	Total	***155.57***	***13.75***	***41.50***	***7.78***	***5.97***	***43.75***	***19.41***	***7.22***
3300	*Q. semecarpifolia*	96.31	8.53	25.01	4.61	3.79	28.13	12.00	4.94
	T. buccata	1.69	0.09	0.67	0.30	0.14	0.49	0.33	-0.01
	Total	***98.00***	***8.63***	***25.67***	***4.91***	***3.93***	***28.62***	***12.33***	***4.93***
3400	*Q. semecarpifolia*	84.35	7.48	21.90	4.09	3.37	24.86	10.58	4.38
	Total	***84.35***	***7.48***	***21.90***	***4.09***	***3.37***	***24.86***	***10.58***	***4.38***
	Asiganga								
1600	*P. roxburghii*	90.04	0.00	20.19	5.71	3.12	18.92	5.65	0.42
	C. toona	43.84	6.85	12.80	3.47	1.39	12.58	5.44	1.62
	Total	***133.89***	***6.85***	***32.99***	***9.18***	***4.51***	***31.51***	***11.09***	***2.04***
1700	*A. nepalensis*	74.62	16.39	15.76	4.34	1.90	20.54	11.38	2.86
	C. macrophylla	4.69	0.88	1.18	0.32	0.13	1.32	0.65	0.18
	Total	***79.31***	***17.27***	***16.94***	***4.66***	***2.03***	***21.86***	***12.03***	***3.04***
1800	*C. toona*	80.36	12.22	23.89	6.48	2.57	23.13	9.82	2.96
	P. pashia	0.71	0.05	0.44	0.23	0.08	0.34	0.03	0.02
	Total	***81.07***	***12.27***	***24.33***	***6.71***	***2.65***	***23.47***	***9.85***	***2.99***
1900	*A. nepalensis*	58.72	8.89	17.50	4.74	1.88	16.91	7.16	2.16
	Total	***58.72***	***8.89***	***17.50***	***4.74***	***1.88***	***16.91***	***7.16***	***2.16***
2000	**Village Agora**								
2100	*Q. floribunda*	50.12	4.34	21.40	2.93	3.06	8.87	4.26	1.31
	A. nepalensis	9.24	1.98	2.02	0.55	0.24	2.55	1.39	0.35
	B. alnoides	11.69	2.08	3.09	0.84	0.34	3.31	1.56	0.44
	R. arboreum	3.03	0.00	1.95	0.69	0.29	1.85	0.61	0.09
	Total	***74.07***	***8.40***	***28.46***	***5.02***	***3.93***	***16.58***	***7.83***	***2.19***
2200	*A. nepalensis*	57.00	8.66	16.96	4.60	1.83	16.41	6.96	2.10
	B. alnoides	45.76	6.88	13.70	3.72	1.47	13.19	5.55	1.69
	Q. floribunda	48.83	4.23	20.88	2.89	3.01	8.75	4.21	1.29
	R. arboreum	3.28	0.00	2.21	0.88	0.40	1.85	0.58	0.12
	Acer	9.87	0.65	2.84	0.95	0.30	2.87	0.81	0.23
	Total	***164.74***	***20.41***	***56.60***	***13.03***	***7.01***	***43.07***	***18.12***	***5.42***
2300	*Q. floribunda*	77.21	0.00	42.43	21.11	34.53	22.29	3.45	0.12
	L. umbrosa	1.51	0.08	0.48	0.12	0.08	0.57	0.26	0.05
	M. duthii	11.16	0.00	7.08	3.05	1.77	3.29	0.43	0.04
	B. alnoides	23.24	3.55	6.89	1.87	0.74	6.69	2.85	0.86
	C. macrophylla	13.37	2.07	3.92	1.06	0.42	3.84	1.65	0.49
	Total	***126.49***	***5.69***	***60.81***	***27.22***	***37.54***	***36.67***	***8.64***	***1.56***
2400	*C. deodara*	38.94	2.01	7.05	2.27	1.55	5.35	1.95	0.24
	R. arboreum	1.76	0.00	1.17	0.46	0.20	1.01	0.32	0.06
	B. alnoides	17.58	2.77	5.10	1.38	0.55	5.04	2.19	0.65
	A. nepalensis	10.51	1.92	2.72	0.74	0.31	2.97	1.43	0.39
	L. ovalifolia	1.71	0.14	1.20	0.65	0.20	0.84	0.07	0.05
	Q. leucotrichophora	27.51	0.00	16.18	3.80	1.24	1.59	1.91	0.14
	Total	***98.00***	***6.83***	***33.43***	***9.31***	***4.05***	***16.80***	***7.87***	***1.53***
2500	P. wallichiana	27.60	1.04	7.86	2.78	1.42	6.01	2.99	0.12
	C. deodara	25.75	1.36	5.63	2.04	1.41	4.29	1.73	0.22
	Q. semecarpifolia	43.13	3.82	11.20	2.03	1.66	12.45	5.32	2.17
	L. ovalifolia	1.59	0.12	1.11	0.60	0.18	0.74	0.06	0.04
	Total	***98.07***	***6.35***	***25.80***	***7.44***	***4.67***	***23.49***	***10.11***	***2.55***

2600	*Q. semecarpifolia*	114.90	10.09	29.87	4.55	3.67	29.64	12.97	4.91
	R. arboreum	6.88	0.20	2.81	2.42	0.59	2.84	1.16	0.17
	P. pashia	0.72	0.05	0.45	0.23	0.08	0.34	0.03	0.02
	Total	***122.50***	***10.34***	***33.12***	***7.20***	***4.34***	***32.83***	***14.17***	***5.10***
2700	*A. pindrow*	113.32	4.40	23.88	10.22	5.03	22.52	11.84	4.37
	Q. semecarpifolia	19.52	1.73	5.07	0.94	0.77	5.72	2.44	1.01
	T. buccata	4.72	0.22	1.62	0.67	0.32	1.21	0.72	0.00
	Total	***137.57***	***6.36***	***30.56***	***11.82***	***6.13***	***29.44***	***15.00***	***5.38***
2800	*Q. semecarpifolia*	190.82	16.70	49.62	7.02	5.62	46.90	20.73	7.59
	J. regia	13.42	1.96	1.72	0.63	0.22	2.95	0.98	0.25
	Total	***204.24***	***18.66***	***51.34***	***7.65***	***5.84***	***49.85***	***21.71***	***7.84***
2900	*A. pictum*	136.13	9.28	41.80	13.67	4.28	40.23	11.58	3.44
	A. pindrow	47.10	1.81	9.91	4.17	2.02	9.44	4.91	1.72
	T. buccata	11.67	0.40	3.10	1.01	0.54	2.39	1.08	0.07
	Total	***194.90***	***11.49***	***54.81***	***18.86***	***6.84***	***52.06***	***17.58***	***5.23***
3000	*Q. semecarpifolia*	200.53	17.57	52.14	7.55	6.06	50.06	22.06	8.16
	A. pindrow	14.49	0.56	3.05	1.30	0.64	2.88	1.51	0.55
	Total	***215.02***	***18.13***	***55.19***	***8.85***	***6.70***	***52.94***	***23.57***	***8.71***
3100	*Q. semecarpifolia*	176.34	15.47	45.84	6.84	5.51	44.87	19.69	7.38
	Total	***176.34***	***15.47***	***45.84***	***6.84***	***5.51***	***44.87***	***19.69***	***7.38***
3200	*Q. semecarpifolia*	119.60	10.56	31.07	5.27	4.30	33.09	14.27	5.66
	Total	***119.60***	***10.56***	***31.07***	***5.27***	***4.30***	***33.09***	***14.27***	***5.66***

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1600	*L. ovalifolia*	3.01	0.23	2.10	1.14	0.34	1.42	0.12	0.08
	R. arboreum	17.91	0.00	11.03	3.52	1.32	11.77	4.14	0.48
	P. roxburghii	57.03	0.00	10.96	3.57	2.66	12.74	3.59	0.33
	C. viminea	0.38	0.03	0.23	0.12	0.04	0.18	0.02	0.01
	Total	***78.33***	***0.26***	***24.33***	***8.34***	***4.35***	***26.10***	***7.87***	***0.90***
1700	*P. roxburghii*	34.13	0.00	7.09	2.15	1.37	7.39	2.14	0.18
	A. nepalensis	17.13	2.94	4.66	1.27	0.52	4.87	2.25	0.64
	C. toona	18.67	3.04	5.30	1.44	0.58	5.34	2.37	0.69
	R. arboreum	3.44	0.00	2.30	0.90	0.40	1.97	0.63	0.12
	L. ovalifolia	1.93	0.15	1.35	0.73	0.22	0.92	0.08	0.05
	Total	***75.31***	***6.13***	***20.71***	***6.49***	***3.08***	***20.48***	***7.46***	***1.68***
1800	*P. roxburghii*	24.19	0.00	4.16	1.50	1.39	5.64	1.52	0.16
	A. nepalensis	10.37	1.78	2.82	0.77	0.31	2.95	1.36	0.39
	C. toona	23.01	3.51	6.82	1.85	0.73	6.62	2.82	0.85
	R. arboreum	5.58	0.00	3.63	1.33	0.56	3.33	1.09	0.18
	L. ovalifolia	2.48	0.19	1.72	0.93	0.26	1.10	0.10	0.06
	C. macrophyla	23.18	3.89	6.42	1.75	0.71	6.60	3.00	0.86
	C. viminea	5.91	0.36	3.36	1.68	0.42	2.43	0.19	0.11
	Q. leucotrichophora	17.26	0.00	10.04	2.21	0.71	0.93	1.09	0.08
	B. alnoides	9.16	1.38	2.74	0.74	0.29	2.64	1.11	0.34
	M. odoratissima	4.02	0.00	2.39	0.85	0.50	0.87	0.12	0.01
	P. pashia	0.99	0.08	0.62	0.33	0.11	0.48	0.05	0.04
	S. chinensis	0.26	0.02	0.09	0.04	0.02	0.07	0.01	0.01
	F. micrantha	4.80	0.78	1.37	0.37	0.15	1.37	0.61	0.18
	U. wallichiana	8.34	1.26	2.48	0.67	0.27	2.40	1.02	0.31
	Total	***139.53***	***13.24***	***48.68***	***15.01***	***6.44***	***37.44***	***14.07***	***3.56***
1900	*P. ciliata*	133.10	19.03	17.10	6.50	2.16	29.62	9.93	2.42
	A. nepalensis	36.67	5.98	10.38	2.82	1.13	10.48	4.66	1.36

	C. toona	4.74	1.24	0.75	0.21	0.10	1.27	0.81	0.19
	L. umbrosa	2.87	0.14	0.93	0.23	0.14	1.04	0.48	0.10
	C. macrophyla	12.10	2.13	3.22	0.88	0.36	3.43	1.61	0.45
	B. alnoides	17.53	2.88	4.94	1.34	0.54	5.01	2.24	0.65
	M. odoratissima	2.74	0.00	1.68	0.64	0.38	0.67	0.09	0.01
	Q. leucotrichophora	2.09	0.00	1.35	0.55	0.19	0.23	0.31	0.04
	Total	***211.85***	***31.41***	***40.34***	***13.18***	***5.01***	***51.74***	***20.13***	***5.21***
2000	*Q. leucotrichophora*	41.19	0.00	24.41	6.01	1.97	2.51	3.04	0.24
	P. roxburghii	20.52	0.00	3.82	1.28	1.02	4.64	1.29	0.13
	R. arboreum	8.56	0.00	5.42	1.85	0.74	5.36	1.82	0.25
	L. ovalifolia	3.21	0.23	2.21	1.20	0.32	1.33	0.12	0.06
	A. nepalensis	16.44	2.49	4.89	1.33	0.53	4.73	2.01	0.61
	Total	***89.93***	***2.73***	***40.76***	***11.67***	***4.57***	***18.58***	***8.28***	***1.28***
2100	*Q. leucotrichophora*	69.76	0.00	43.34	14.34	4.83	5.96	7.73	0.75
	R. arboreum	7.83	0.00	5.08	1.85	0.78	4.70	1.55	0.25
	L. ovalifolia	5.23	0.40	3.65	1.97	0.58	2.43	0.21	0.13
	C. viminea	1.43	0.11	0.89	0.47	0.15	0.68	0.06	0.05
	U. wallichiana	1.55	0.33	0.34	0.09	0.04	0.43	0.23	0.06
	Total	***85.79***	***0.84***	***53.30***	***18.73***	***6.38***	***14.20***	***9.78***	***1.24***
2200	*Q. leucotrichophora*	100.12	0.00	61.57	19.11	6.39	7.95	10.15	0.94
	L. ovalifolia	6.65	0.52	4.65	2.52	0.76	3.17	0.28	0.18
	R. arboreum	7.27	0.00	4.71	1.70	0.71	4.38	1.45	0.23
	Total	***114.04***	***0.52***	***70.93***	***23.32***	***7.86***	***15.51***	***11.88***	***1.35***
2300	*Q. leucotrichophora*	21.01	0.00	12.94	4.05	1.36	1.69	2.16	0.20
	L. ovalifolia	2.48	0.19	1.74	0.94	0.28	1.17	0.10	0.07
	I. odorata	4.42	0.26	1.94	0.26	0.16	1.37	0.64	0.26
	I. dipyrena	3.37	0.18	1.28	0.20	0.13	0.94	0.43	0.19
	R. arboreum	4.67	0.00	2.99	1.06	0.43	2.86	0.96	0.14
	B. sempervirens	1.36	0.10	0.85	0.45	0.15	0.66	0.06	0.05
	L. umbrosa	1.77	0.09	0.58	0.14	0.09	0.64	0.29	0.06
	A. indica	36.73	7.38	14.61	3.01	1.43	10.74	6.24	1.95
	C. viminea	0.69	0.05	0.43	0.23	0.08	0.33	0.03	0.02
	Total	***76.52***	***8.26***	***37.37***	***10.34***	***4.10***	***20.39***	***10.91***	***2.94***
2400	*A. indica*	200.54	34.43	81.57	14.96	6.83	49.06	31.16	9.37
	B. sempervirens	4.71	0.36	2.93	1.53	0.50	2.24	0.21	0.16
	A. caesium	6.19	0.40	1.70	0.57	0.18	1.78	0.49	0.13
	Q. floribunda	7.50	0.00	4.41	2.31	3.57	2.63	0.43	0.02
	J. regia	8.58	1.33	1.09	0.37	0.14	1.84	0.60	0.17
	Total	***227.51***	***36.52***	***91.69***	***19.73***	***11.23***	***57.55***	***32.88***	***9.85***
2500	*Q. floribunda*	70.90	6.16	30.88	4.96	5.03	14.70	7.32	2.26
	I. dipyrena	2.69	0.14	0.91	0.16	0.11	0.69	0.32	0.15
	A. pindrow	82.97	3.12	17.43	7.15	3.35	16.84	8.64	2.77
	M. odoratissima	14.12	0.00	8.48	3.09	1.81	3.19	0.42	0.03
	S. chinensis	0.98	0.06	0.34	0.14	0.07	0.27	0.05	0.05
	L. ovalifolia	3.35	0.26	2.33	1.26	0.37	1.53	0.13	0.08
	R. arboreum	6.14	0.00	4.01	1.48	0.63	3.65	1.19	0.20
	Total	***181.15***	***9.73***	***64.39***	***18.25***	***11.36***	***40.87***	***18.08***	***5.53***
2600	*Q. floribunda*	167.73	14.55	72.53	10.99	11.25	32.82	16.13	4.97
	R. arboreum	0.59	0.02	0.25	0.21	0.05	0.27	0.11	0.02
	A. caesium	3.31	0.21	0.91	0.31	0.10	0.95	0.26	0.07
	I. dipyrena	1.43	0.07	0.45	0.08	0.06	0.35	0.16	0.08
	S. chinensis	0.60	0.04	0.20	0.09	0.05	0.14	0.04	0.03

	C. viminea	0.33	0.03	0.21	0.11	0.04	0.16	0.02	0.01
	P. smithiana	7.29	0.22	1.71	0.47	0.27	1.34	0.50	0.06
	A. pindrow	3.87	0.16	0.82	0.39	0.21	0.73	0.41	0.21
	Total	***185.14***	***15.30***	***77.08***	***12.65***	***12.03***	***36.77***	***17.62***	***5.45***
2700	*A. indica*	75.25	13.76	30.34	5.83	2.70	19.77	12.12	3.70
	Q. floribunda	82.61	7.16	35.49	5.11	5.27	15.35	7.46	2.29
	A. pindrow	83.35	3.09	17.49	7.04	3.22	17.09	8.66	2.61
	R. arboreum	7.44	0.22	2.95	2.58	0.62	2.85	1.19	0.16
	A. caesium	11.68	0.77	3.34	1.11	0.35	3.40	0.95	0.27
	Q. semecarpifolia	70.06	6.14	18.22	2.69	2.17	17.72	7.79	2.91
	Total	***330.39***	***31.14***	***107.83***	***24.35***	***14.33***	***76.17***	***38.17***	***11.93***
2800	*A. pindrow*	127.07	4.75	26.68	10.85	5.02	25.92	13.22	4.11
	T. baccata	39.00	1.17	9.23	2.59	1.47	7.26	2.74	0.30
	A. caesium	16.71	1.09	4.64	1.56	0.50	4.82	1.34	0.36
	P. foliosa	3.63	0.25	2.15	1.10	0.32	1.60	0.14	0.09
	Q. semecarpifolia	96.67	8.46	25.14	3.54	2.84	23.71	10.49	3.84
	Total	***283.08***	***15.72***	***67.84***	***19.64***	***10.15***	***63.33***	***27.92***	***8.71***
2900	*Q. semecarpifolia*	71.39	6.29	18.55	2.99	2.43	19.12	8.30	3.22
	T. baccata	10.85	0.43	3.23	1.19	0.60	2.45	1.28	0.04
	A. pindrow	58.20	2.25	12.26	5.22	2.56	11.59	6.08	2.21
	Total	***140.43***	***8.97***	***34.04***	***9.41***	***5.59***	***33.16***	***15.66***	***5.47***
3000	*Q. semecarpifolia*	202.70	17.84	52.68	8.38	6.79	53.79	23.40	9.02
	R. arboreum	4.90	0.14	1.98	1.71	0.42	1.97	0.81	0.11
	T. baccata	16.60	0.70	5.21	2.01	0.99	3.93	2.18	0.04
	Total	***224.20***	***18.68***	***59.87***	***12.11***	***8.20***	***59.69***	***26.39***	***9.18***
3100	*Q. semecarpifolia*	148.78	13.05	38.68	5.71	4.60	37.62	16.54	6.17
	T. baccata	11.90	0.51	3.75	1.46	0.72	2.83	1.58	0.03
	Total	***160.68***	***13.56***	***42.43***	***7.17***	***5.32***	***40.46***	***18.11***	***6.20***
3200	*Q. semecarpifolia*	329.20	28.99	85.55	13.78	11.19	88.09	38.26	14.84
	V. erubescens	0.44	0.04	0.30	0.16	0.07	0.24	0.03	0.02
	Total	***329.64***	***29.03***	***85.85***	***13.94***	***11.25***	***88.33***	***38.29***	***14.86***
3300	*Q. semecarpifolia*	138.08	12.17	35.88	5.89	4.79	37.39	16.20	6.33
	Total	***138.08***	***12.17***	***35.88***	***5.89***	***4.79***	***37.39***	***16.20***	***6.33***
3400	*Q. semecarpifolia*	175.31	15.43	45.56	7.26	5.89	46.60	20.27	7.82
	A. caesium	1.59	0.10	0.42	0.14	0.05	0.45	0.12	0.03
	Total	***176.90***	***15.53***	***45.97***	***7.41***	***5.94***	***47.05***	***20.39***	***7.86***

Bhatwari

1800	*Q. leucotrichophora*	43.49	0.00	26.15	7.05	2.32	2.94	3.63	0.30
	R. arboreum	1.71	0.00	1.14	0.45	0.20	0.97	0.31	0.06
	L. Ovalifolia	0.80	0.06	0.57	0.31	0.10	0.40	0.03	0.02
	Total	**46.00**	**0.06**	**27.86**	**7.80**	**2.62**	**4.31**	**3.98**	**0.39**
1900	*Q. leucotrichophora*	22.80	0.00	13.68	3.63	1.20	1.52	1.87	0.15
	R. arboreum	2.01	0.00	1.37	0.56	0.26	1.11	0.35	0.07
	L. Ovalifolia	1.20	0.10	0.85	0.46	0.14	0.60	0.05	0.04
	I. Dipyrena	0.56	0.03	0.20	0.03	0.02	0.15	0.07	0.03
	Total	**26.58**	**0.13**	**16.09**	**4.68**	**1.62**	**3.38**	**2.33**	**0.29**
2000	*Q. leucotrichophora*	29.49	0.00	17.63	4.58	1.51	1.91	2.34	0.19
	S. chinensis	0.73	0.04	0.26	0.11	0.05	0.20	0.04	0.03
	L. Ovalifolia	0.80	0.06	0.56	0.30	0.10	0.40	0.03	0.02
	R. Arboreum	1.75	0.00	1.17	0.45	0.20	1.00	0.32	0.06
	Total	**32.77**	**0.11**	**19.62**	**5.45**	**1.85**	**3.51**	**2.74**	**0.31**

2100	*C. deodara*	5.07	0.27	1.12	0.41	0.28	0.85	0.34	0.04
	Q. floribunda	10.41	0.00	6.33	3.41	5.12	4.04	0.67	0.04
	Q. leucotrichophora	11.44	0.00	7.09	2.31	0.78	0.96	1.24	0.12
	R. arboreum	1.87	0.00	1.24	0.47	0.21	1.09	0.35	0.06
	I. Dipyrena	1.17	0.06	0.41	0.07	0.05	0.31	0.14	0.06
	L. ovalifolia	1.03	0.08	0.72	0.39	0.12	0.48	0.04	0.03
	Total	**30.99**	**0.41**	**16.91**	**7.05**	**6.55**	**7.73**	**2.79**	**0.36**
2200	*Q. leucotrichophora*	32.99	0.00	19.62	4.93	1.61	2.06	2.50	0.20
	Q. floribunda	25.57	0.00	14.60	7.48	11.86	8.25	1.31	0.06
	I. Dipyrena	1.20	0.06	0.43	0.07	0.05	0.32	0.15	0.07
	L. ovalifolia	1.45	0.11	1.02	0.55	0.16	0.69	0.06	0.04
	Total	**61.22**	**0.18**	**35.66**	**13.03**	**13.69**	**11.32**	**4.03**	**0.36**
2300	*Q. leucotrichophora*	22.01	0.00	13.09	3.29	1.08	1.37	1.67	0.13
	L. ovalifolia	1.40	0.11	0.98	0.53	0.16	0.67	0.06	0.04
	Q. floribunda	18.14	0.00	10.47	5.41	8.50	6.05	0.97	0.05
	R. arboreum	0.61	0.00	0.40	0.15	0.07	0.35	0.11	0.02
	I. Dipyrena	1.18	0.06	0.42	0.07	0.05	0.31	0.14	0.07
	Total	**43.34**	**0.17**	**25.36**	**9.45**	**9.85**	**8.76**	**2.96**	**0.30**
2400	*Q. floribunda*	40.23	0.00	23.26	12.04	18.88	13.47	2.16	0.10
	A. indica	52.55	9.47	21.23	4.04	1.86	13.59	8.39	2.55
	S. chinensis	0.43	0.03	0.15	0.06	0.03	0.11	0.02	0.02
	I. Dipyrena	1.25	0.07	0.46	0.07	0.05	0.34	0.16	0.07
	Total	**94.47**	**9.57**	**45.10**	**16.21**	**20.82**	**27.50**	**10.74**	**2.75**
2500	*Q. floribunda*	88.39	7.66	37.83	5.27	5.48	15.93	7.68	2.36
	Q. semecarpifolia	41.25	3.61	10.73	1.53	1.22	10.18	4.50	1.65
	R. arboreum	3.57	0.00	2.32	0.84	0.35	2.15	0.71	0.11
	L. ovalifolia	1.75	0.13	1.22	0.66	0.19	0.79	0.07	0.04
	Total	**134.96**	**11.40**	**52.09**	**8.30**	**7.25**	**29.04**	**12.96**	**4.17**
2600	*Q. floribunda*	133.64	11.58	57.26	8.06	8.37	24.32	11.76	3.61
	A. indica	43.79	8.34	17.55	3.48	1.63	12.05	7.22	2.22
	Q. semecarpifolia	32.40	2.84	8.43	1.19	0.95	7.94	3.51	1.28
	A. caesium	14.01	0.94	4.13	1.37	0.43	4.10	1.17	0.33
	Total	**223.85**	**23.70**	**87.38**	**14.10**	**11.37**	**48.42**	**23.66**	**7.45**
2700	*Q. semecarpifolia*	87.90	7.71	22.85	3.37	2.71	22.21	9.76	3.64
	R. arboreum	3.16	0.09	1.28	1.11	0.27	1.29	0.53	0.08
	L. ovalifolia	1.91	0.15	1.33	0.72	0.22	0.91	0.08	0.05
	T. buccata	4.74	0.17	1.31	0.45	0.23	1.01	0.49	0.02
	Total	**97.70**	**8.12**	**26.78**	**5.65**	**3.43**	**25.42**	**10.86**	**3.79**
2800	*Q. semecarpifolia*	128.67	11.27	33.46	4.81	3.86	31.95	14.09	5.20
	R. arboreum	4.13	0.12	1.67	1.44	0.35	1.66	0.68	0.10
	A. caesium	18.41	1.24	5.53	1.82	0.57	5.41	1.55	0.45
	T. buccata	7.95	0.26	2.00	0.61	0.33	1.56	0.65	0.05
	Total	**159.15**	**12.89**	**42.65**	**8.68**	**5.11**	**40.57**	**16.97**	**5.80**
2900	*Q. semecarpifolia*	169.25	14.80	44.02	6.14	4.91	41.21	18.26	6.64
	T. buccata	8.23	0.29	2.21	0.73	0.39	1.71	0.79	0.05
	R. arboreum	1.85	0.05	0.78	0.66	0.16	0.83	0.33	0.05
	S. emodi	0.81	0.07	0.53	0.28	0.10	0.42	0.04	0.03
	Total	**180.14**	**15.21**	**47.53**	**7.82**	**5.56**	**44.17**	**19.41**	**6.77**
3000	*Q. semecarpifolia*	200.68	17.54	52.19	7.20	5.76	48.54	21.53	7.80
	A. pindrow	26.25	0.99	5.52	2.28	1.08	5.31	2.73	0.90
	R. arboreum	3.41	0.10	1.41	1.21	0.30	1.47	0.59	0.09
	Total	**230.34**	**18.64**	**59.12**	**10.70**	**7.13**	**55.32**	**24.86**	**8.79**

3100	*Q. semecarpifolia*	201.3	17.6	52.4	7.5	6.0	49.9	22.0	8.1
	A. pindrow	53.04	2.01	11.15	4.61	2.17	10.73	5.52	1.81
	T. buccata	8.28	0.36	2.68	1.06	0.52	2.01	1.15	0.01
	Total	**262.7**	**20.0**	**66.2**	**13.2**	**8.7**	**62.6**	**28.7**	**9.9**
3200	*Q. semecarpifolia*	187.8	16.5	48.8	7.1	5.7	47.0	20.7	7.7
	V. erubesenc	1.41	0.12	0.91	0.48	0.18	0.71	0.07	0.06
	A. pindrow	39.84	1.49	8.36	3.39	1.56	8.14	4.14	1.28
	Total	**229.06**	**18.06**	**58.11**	**10.97**	**7.44**	**55.85**	**24.91**	**9.01**
3300	*A. pindrow*	93.55	3.42	19.61	7.75	3.47	19.36	9.71	2.75
	Q. semecarpifolia	120.65	10.52	31.39	4.10	3.26	28.14	12.58	4.45
	R. arboreum	3.03	0.09	1.24	1.07	0.26	1.26	0.51	0.07
	Total	**217.24**	**14.03**	**52.23**	**12.91**	**6.98**	**48.76**	**22.80**	**7.27**
3400	*Q. semecarpifolia*	162.12	14.20	42.15	6.11	4.90	40.48	17.84	6.60
	R. arboreum	2.79	0.08	1.22	1.03	0.26	1.40	0.54	0.09
	A. pindrow	43.97	1.62	9.22	3.68	1.67	9.06	4.57	1.33
	Total	**208.88**	**15.90**	**52.59**	**10.81**	**6.83**	**50.93**	**22.95**	**8.03**
3500	*Q. semecarpifolia*	165.51	14.52	43.03	6.44	5.19	42.21	18.52	6.95
	R. campanulatum	0.74	0.80	0.44	0.15	1.67	3.80	0.65	0.20
	Total	**166.25**	**15.32**	**43.47**	**6.59**	**6.85**	**46.00**	**19.17**	**7.15**
3600	*Q. semecarpifolia*	161.44	14.15	41.97	6.17	4.96	40.68	17.89	6.66
	Total	**161.44**	**14.15**	**41.97**	**6.17**	**4.96**	**40.68**	**17.89**	**6.66**