CHAPTER – 5
RESULTS

In the present study hills of Darjiling district in the state of West Bengal have been considered for plant biodiversity characterisation and to understand the vegetation structure in the area. Only hill areas with elevation ranging from 180 m amsl and above have been considered. The plains of Terai and Duars of Siliguri sub-division of Darjiling district have been excluded in the present work. The study area covers eight administrative Blocks with a total area of 2228.13 km^2. Twenty three land use/land cover categories have been delineated from the region, of which seventeen belonging to forest classes and six to non-forest classes.

It was found that the region is well represented by different types of vegetation. Four distinct zones could be observed in Darjiling hills. The tropical vegetation in the lower hills meets Sub-Tropical as we move upward along altitudinal gradient followed by temperate and a narrow zone of sub-alpine vegetation in the highest elevation within the district boundary. The tropical zone in the lower hills shows great diversity in forests and is represented by at least six different types. During the study it was observed that at lower hills, tropical flora intermixed with subtropical and temperate zones through both upward and downward migration exhibiting one of the richest floristic areas. For vegetation characterisation, covering all these four climatic zones, a total of 172 sample plots were laid in 16 forest types and the sampling intensity of 0.01 – 0.185% of the forest types have been achieved.

The flora of the region is richest both in extent and in diversity of species composition. A large number of tree species have been recorded from the lower hills and herbaceous species from the upper hills. Shrub species also shows high preponderance in the mid elevation zone. The epiphytes lianas and the climbers equally show good number in high altitude as well as in the lower hills. Such great floristic diversity is largely attributed to its geographical and climatic factors that have not only helped the local flora to evolve but also to some plant species from surrounding places like China, Malaysia, Africa, Europe to migrate and successfully established in the region. This has been reflected through the

records of numerous naturalised exotics (Das, 2002) and a high proportion of endemics in the flora (Bhujel and Das, 2002; Das, 2004).

Digital satellite data gives a better perspective in understanding the wide and prominent differences in vegetation structure occurring over a landscape. The satellite imagery has been successfully used to delineate different such forest types existing in Darjiling hills based on tone and texture and other image elements. Different thematic maps could be prepared on landscape parameters with the help of GIS.

The chapter discusses the results on vegetation mapping, phyto-sociological analysis, various landscape parameters contributing to disturbance regime and finally different parameters used in deriving biological richness of the study area.

5.1. Vegetation cover type mapping

Vegetation cover/ land cover mapping was done using the IRS 1D LISS III satellite data. These were mapped at 1:50,000 scale. (Fig 5.1). Mapping of vegetation has been done only for Darjiling hills, which covers about 2228.13 km^2 of the total 3077.710 km^2 for the district. Vegetation cover/ land use categories include: 17 forest and 6 non-forest classes. Area statistic is given in (Table 5.1). The forest types includes: (i) Tropical Semi-evergreen Forests, (ii) Himalayan Sal Forests, (iii) Moist Mixed Deciduous Forests, (iv) Riverine Forests, (v) Sub-Tropical Broad Leaved Hill Forests, (vi) Wet Temperate Forests, (vii) Temperate Broad Leaved Forests, (viii) *Alnus* Forests, (ix) Conifer Forests, (x) Sub-Alpine Scrub, (xi) Bamboo Brakes, (xii) Rhododendron Forests, (xiii) Open Scrub, (xiv) Teak Plantations, (xv) *Cryptomeria* Plantations (xvi) Degraded Forests and (xvii) Cinchona Plantation . The non-forest categories include (i) Agriculture, (ii) Tea Garden, (iii) Barren Land, (iv) River bed/ Water Body, (v) Settlements and (vi) Cloud and Shadow.

The grassland and Riverine Forests have been merged into a single class owing to similar origin and spectral signature. Although Bamboo Brakes, *Alnus* Plantations, *Rhododendron* Forests, Open Scrub and Barren lands have a very small coverage, but have been segregated as distinct classes, because of their distinctiveness in spectral signature and spatial distribution. The satellite data based vegetation map has been compared with Champion and Seth's (1968) classification (Table 5.2). Area analysis of the vegetation

cover/ land cover map indicates that the forest holding for the hills is 49.14% (excluding area covered by cloud and shadow). They alone represent 35.58% of the total geographic area of the district (Fig 5.2). Wet Temperate Forests occupies maximum area followed by Sub-Tropical Broad Leaved Hill Forests and Moist Mixed Deciduous Forests contributing 282.47 km^2, 225.33 km^2 and 222.28 km^2 contributing 9.18 %, 7.32 % and 7.22 % respectively of the total district area, rest 13 forest types covers 327.18 km^2. Area estimation of land use/ land cover for the Darjiling hills is provided in Table 5.1.

Table 5.1: Area estimation of Land use/ Land cover in Darjiling Hills

Sl. No.	Land use/ Land cover Type	Area (km^2)	% Area
	Forested Categories		
1	Tropical Semi-evergreen Forests	18.50	0.60
2	Himalayan Sal Forests	74.14	2.41
3	Moist Mixed Deciduous Forests	222.28	7.22
4	Riverine Forests	9.33	0.30
5	Sub-Tropical Broad Leaved Hill Forests	225.33	7.32
6	Wet Temperate Forests	282.47	9.18
7	Temperate Broad Leaved Forests	70.31	2.28
8	*Alnus* Forests	1.95	0.06
9	Conifer Forests	21.50	0.70
10	Sub-Alpine Scrub	12.93	0.42
11	Bamboo Brakes	6.33	0.21
12	*Rhododendron* Forests	1.64	0.05
13	Open Scrub	21.85	0.71
14	Teak Plantations	6.33	0.21
15	*Cryptomeria* Plantations	34.09	1.11
16	Degraded Forests	48.28	1.57
17	*Cinchona* Plantations	37.75	1.23
	Non-forest Categories		
18	Tea Gardens	346.95	11.27
19	Agriculture	682.24	22.17
20	Barren Lands	8.01	0.26
21	River bed/ Water Bodies	39.90	1.30
22	Settlements	19.28	0.63
23	Clouds and shadow	36.75	1.19
	Plains of Darjiling district	849.58	27.60
	Total	**3077.710**	**100.00**

CLASSIFIED VEGETATION COVER MAP OF DARJILING HILLS

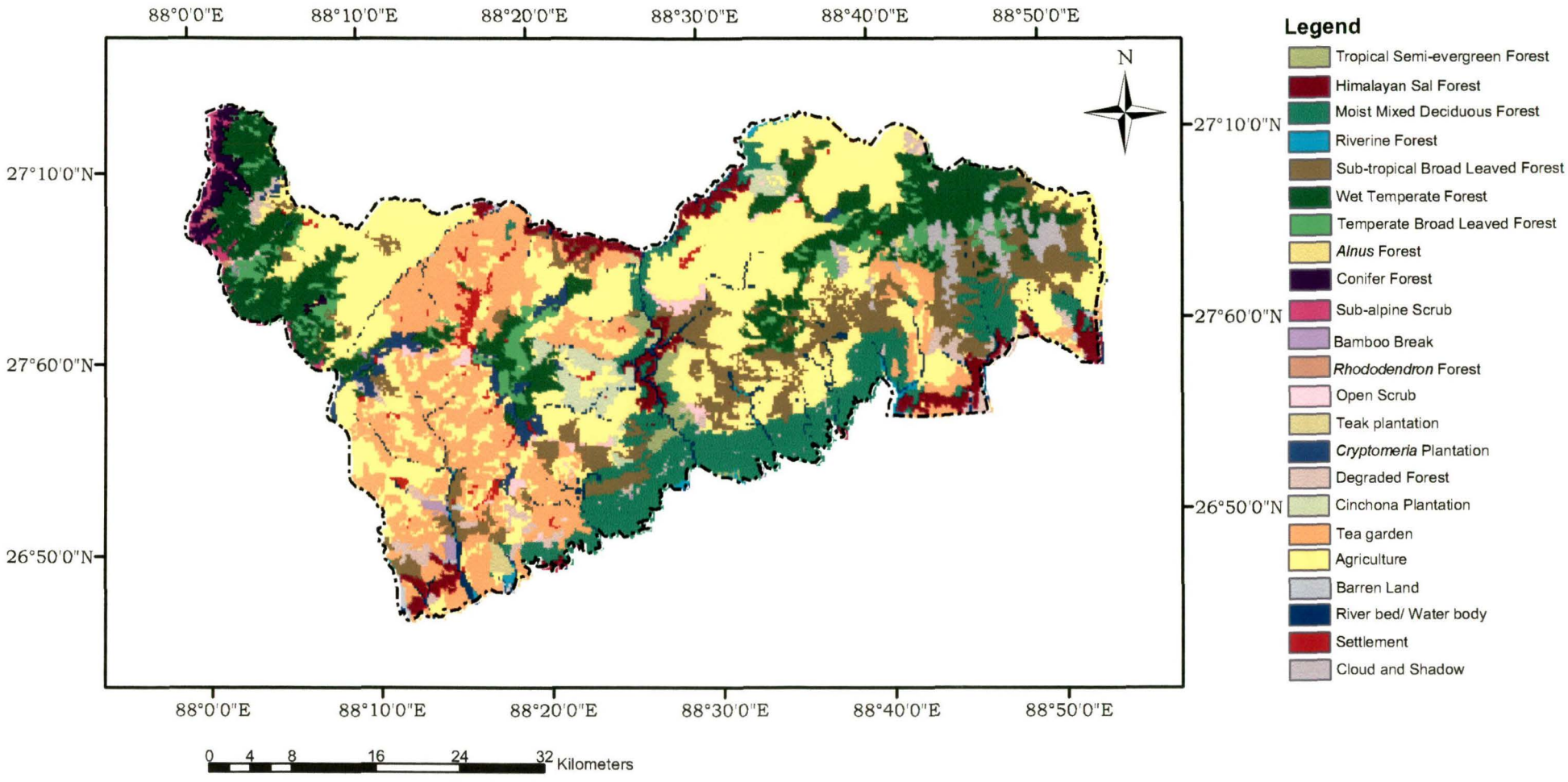


Fig. 5.1

FOREST COVER MAP OF DARJILING HILLS

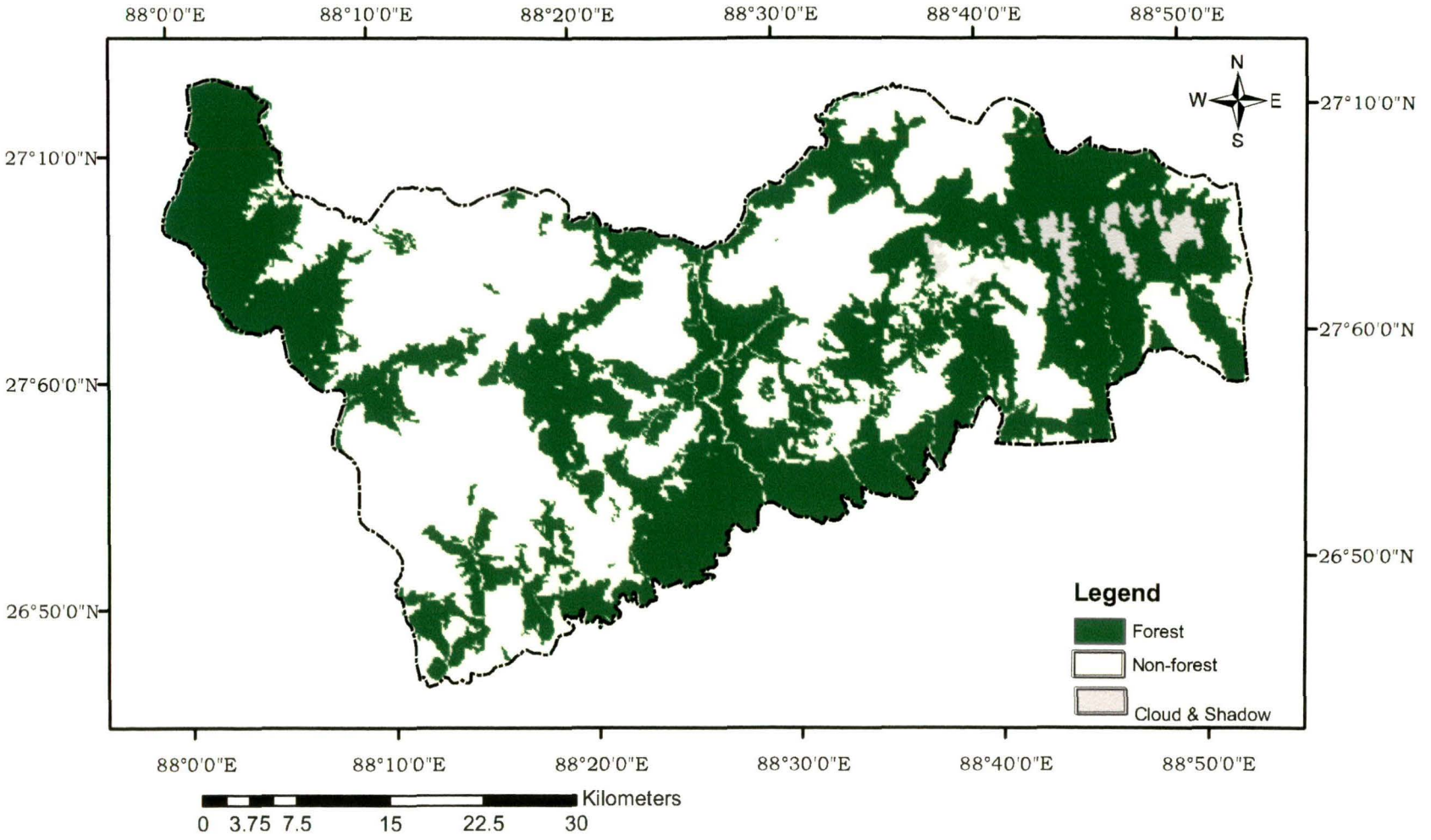


Fig. 5.2

5.1.1 Tropical Semi-evergreen Forests

This type of forest is particularly found along the river banks at lower elevation. Though sporadic in distribution, large area of this forest type is prominently seen on the western bank of river Teesta, which falls under the jurisdiction of Mahananda Wildlife Sanctuary near Kalijhora. It extends up to an elevation of 600 m and is characterized by very moist condition and is in a consistently higher temperature zone than rest of the hills.

This forest type has been described by Champion and Seth (1968) under their 2B/C1*b* *Eastern Submontane semi-evergreen forest*. It occupies a rather small area of 18.50 km^2 constituting 0.60% of the district and accounts to 0.83% of the study area. Small patches of this type can be seen all along the banks of Teesta, Chel and Relli rivers but due to narrowness it could not be discerned in the satellite imagery. Thus only the visibly bigger area has been mapped. On satellite imagery this forest types appears in medium red tone with coarse to molted texture.

This forest is characterized by dense multi-layered canopy. However, for simplification description of species composition of only two canopies *viz.* upper canopy and the middle canopy have been recognized. The upper canopy mainly consisted of species like *Aglaia lawii* (Wight) Ramamoorthy, *Michelia champaca* L., *Pterospermum acerifolium* (L.) Willdenow, *Duabanga grandiflora* (DC.) Walper, *Sapindus rarak* DC., *Aglaia spectabilis* (Miquel) Jain and Bennet, *Chukrasia tabularis* Jussieu, *Terminalia myriocarpa* Heurck and Mueller, *Schima wallichii* (DC.) Korthals etc. The middle canopy consists of *Nayariophyton zizyphifolium* (Griffith) Paul, *Callicarpa vestita* Wallich, *Mallotus philippensis* (Lamarck) Mueller, etc. Some dominant shrub-species includes *Clerodendrum viscosum* Ventenat, *Boehmeria glomerulifera* Miquel, *Coffea bengalensis* Schultes, *Colebrookea oppositifolia* Smith, *Smilax lanceifolia* Roxburgh etc. The ground-cover consisting of the herbaceous plants includes *Oplismenus burmanii* (Retzius) P. Beauvois, *Aneilema thomsonii* (C. B. Clarke) C. B. Clarke, *Elatostema obtusum* Weddell, *Commelina suffruticosa* Blume etc. In addition, because of the moist ambience this vegetation type houses myriad of epiphytic species, lianas and a host of climbers, this includes species of *Eria*, *Dendrobium*, *Combretum decandrum* Roxburgh, *Argyreia roxburghii* Choisy, *Gouania leptostachya* DC., etc respectively. All the layers of this vegetation type are well represented by a good number of species.

Table 5.2: Comparison of remote sensing based vegetation cover classification with Champion and Seth (1968) with dominant species

Sl. No.	Classification based on Remote sensing	Champion and Seth's Classification (1968)	Dominant trees
1	Tropical Semi-evergreen Forests	**2B/C1*b*** Eastern Submontane semi-evergreen forest	*Aglaia chittagonga, Michelia champaca, Aglaia spectabilis, Pterospermum acerifolium,*
2	Himalayan Sal Forests	**3C/C1** Very moist sal-bearing forest **C1a(i)** East Himalayan sal **C1b** Eastern bhabar sal forest	*Shorea robusta, Pinus roxburghii, Lagerstroemia parviflora, Bauhinia purpurea, Aporosa octandra, Terminalia bellirica*
3	Moist Mixed Deciduous Forests	**3C/C3b** East Himalayan moist mixed deciduous forest	*Shorea robusta, Schima wallichii, Lagerstroemia parviflora, Chisocheton paniculatus, Mallotus philippensis*
4	Riverine Forests	**5/1S2** *Khair-sissoo* forest	*Holarrhena pubescens, Terminalia bellirica, Sterculia villosa, Syzygium cumini, Syzygium claviflorum*
5	Sub-Tropical Broad Leaved Forests	**8B/C1** East Himalayan Sub-Tropical wet hill forest	*Schima wallichii, Brassaiopsis hainla, Ostodes paniculatus, Litsea glutinosa, Bassia butyracea*
6	Wet Temperate Forests	**11B/C1** East Himalayan wet temperate forests **11B/C1a** Lauraceous forest	*Lithocarpus pachyphylla, Acer campbellii, Rhododendron grande, Dodecadenia grandiflora, Symplocos thaefolia*
7	Temperate Broad Leaved Forests	**11B/(C1)** East Himalayan wet temperate forests **11B/C1b** Buk oak forest **11B/C1c** High-level oak forest	*Lithocarpus pachyphylla, Quercus oxydon, Symplocos theifolia, Symplocos caudata, Rhododendron grande,*
8	*Alnus* Forests	**11/1S1** Alder forest	*Alnus nepalensis*
9	Conifer Forests	**12/C3/3a** East Himalayan mixed coniferous forest	*Tsuga dumosa, Abies densa, Rhododendron sp*
10	Sub-Alpine Scrub	**16/C1** Dry alpine scrub	** Trees absent
11	Bamboo Brakes	**2B/2S1** secondary moist bamboo brakes	*Dendrocalamus hamiltonii, Bombax ceiba, Sterculia villosa*
12	*Rhododendron* Forests	--	*Rhododendron arboreum, Rhododendron falconeri, Eurya*
13	Open Scrub	--	** Trees absent
14	Teak Plantations	--	*Tectona grandis*
15	*Cryptomeria* Plantations	--	*Cryptomeria japonica*
16	Degraded Forests	--	*Dendrocalamus hamiltonii, Heteropanax fragrans, Terminalia alata*
17	Cinchona Plantation	--	*Cinchona sp,* poor floral diversity. Sampling not done.

** The occurrence of smaller trees was considered as shrub.

5.1.2 Himalayan Sal Forests

This forest type is typical of the sub-Himalayan region. It occurs in areas receiving moderate rainfall and consistently higher temperature. It is confined to lower elevation especially in the southern region of Darjiling hills and sporadic places in the northern region along Sikkim boarder. This forest type is commonly met along the lower elevation but is also evident in upper *bhabar* reaches up to an altitude of 800 m. Their spatial distribution extends from Sukhna, Panighatta, Sumbuk, along the Teesta and Gorubathan region. Though *Shorea robusta* is the dominant species, it is hard to find sal in a pure stand in this part of hill, which is quite evident in the plains of the district. It has few close associates mostly of deciduous nature. The altitudinal distribution of this vegetation type ranges up to 800 m in the upper reaches.

The vegetation type corresponds to two forest types *viz.* C1a(i) *East Himalayan sal* and C1b *Eastern bhabar sal forest* under 3C/C1 *Very moist sal-bearing forest* described by Champion and Seth (1968). These two forest types have been treated here in a single class based on tonal, textural and overall similarity in floristic composition. This forest type occupies an area of 74.14 km^2, which is 2.41% of the district and accounts to 3.33 % of the study area. The satellite image shows a dark brownish red tone with molted texture.

Schima wallichii (DC.) Korthals, *Pinus roxburghii* Sargent, *Terminalia bellirica* (Gaertner) Roxburgh, *Lagerstroemia parviflora* Roxburgh, *Sterculia villosa* Smith, *Bauhinia purpurea* L. are some of the important associates of *Shorea robusta* Gaertner f. The middle layer consists of species like, *Mallotus philippensis* (Lamarck) Mueller, *Syzygium cumini* (L.) Skeels, *Aporosa octandra* (D. Don) Vickery, *Bridelia retusa* (L.) Sprengel, *Dalbergia stipulacea* Roxburgh, *Grewia optiva* Burret etc. The Shrub layer consists of *Clerodendrum viscosum* Ventenat, *Uraria lagopodioides* (L.) Desveaux, *Eupatorium odoratum* L., *Coffea bengalensis* Schultes, *Blumea densiflora* DC., *Desmodium motorium* (Houttyn) Merrill etc. Among the ground cover species the commonly occurring are *Oplismenus burmanii* (Retzius) P. Beauvois, *Eupatorium odoratum* L., *Clerodendrum viscosum* Ventenat, *Pronephrium nudatum* (Roxburgh) Chandra, *Arundinella bengalensis* (Sprengel) Druce, *Borreria alata* (Blume) DC. etc. Large number of lianas species are found to occur throughout in this vegetation; commonly met includes *Millettia extensa* (Bentham) Baker,

Combretum decandrum Roxburgh, *Bauhinia vahlii* Wight and Arnott etc. The ground cover and the shrub layer are equally rich in their floral composition.

5.1.3 Moist Mixed Deciduous Forests

This forest type spreads over entire foothills of the district and is characterized by seasonal shedding of leaves lasting for 2 – 3 months. It shares the same climatic condition as that of sal forest with high temperature and moderate rainfall. Starting from Lohagarh in the western flank to Gorubathan in the east, entire landscape shows Moist Mixed Deciduous Forests in varying degree. Intercalated within this vegetation are small patches of Bamboo Brakes, and occasional sal association. The forest type is seen co-existing in parallel to sal forest sharing same altitudinal range of 800 m amsl. As this forest type lies in the gentle terrain it has easy accessibility, hence are prone to human interference. Extension of agriculture and human settlement in the southern region of Kurseong and Kalimpong sub-division are evidence of increased anthropogenic activities. The vegetation types corresponds forest type described by Champion and Seth (1968) under C3b. *East Himalayan moist mixed deciduous forest.* It occupies an area of 222.28 km^2, which is 7.22% of the district and accounts to 9.98 % of the study area. The satellite imagery shows dark red tone with medium texture.

With respect to species abundance/composition this forest type is one of the most heterogeneous of all types. There are few species co-dominating the vegetation. Among the trees, dominant species in the top canopy includes *Shorea robusta* Gaertner f., *Schima wallichii* (DC.) Korthals, *Chisocheton paniculatus* Hiern, *Lagerstroemia parviflora* Roxburgh, *Terminalia bellirica* (Gaertner) Roxburgh. The middle canopy is composed of variety of medium sized tree-species such as *Mallotus philippensis* (Lamarck) Mueller, *Dalbergia stipulacea* Roxburgh, *Syzygium cumini* (L.) Skeels, *Albizia procera* (Roxburgh) Benth., *Holarrhena pubescens* (Buchanan-Hamilton) G. Don etc. The shrub layer comprises of dominant species like *Clerodendrum viscosum* Ventenat, *Coffea bengalensis* Schultes, *Eupatorium odoratum* L., *Urena lobata* L., *Boehmeria glomerulifera* Miquel and *Clerodendrum japonicum* (Thunberg) Sweet. The ground cover consists of herbaceous species; most abundant and dominant species includes *Peperomia pellucida* (L.) Kunth, *Clerodendrum viscosum* Ventenat, *Oplismenus burmanii* (Retzius) P. Beauvois, *Phyllanthus virgatus* Forster f. species of *Cyperus,* ferns like *Cheilanthes farinosa* (Forsk.)

Kaulf. and *Pronephrium nudatum* (Roxburgh) Chandra are also frequently encountered which are abundant as a ground cover species. Excessive anthropogenic interference has resulted in the introduction of exotic species like *Mikania micrantha* Kunth, *Eupatorium odoratum* L. which are making rapid ingress into the natural ecosystem. The forest type is also characterized by a large number of climbers, lianas, orchids and epiphytic flora.

5.1.4 Riverine Forests

This type of forest occurs in sandy and physiologically dry soil condition and is prevalent along the river banks throughout the district. Small patches of Riverine Forests can be seen at sporadic places along the banks of River Teesta, Balasun, Mechi, Jaldhaka, Nandi, Mahananda, Rangit, Lis and Chel extending upto 500 m amsl. They are not encountered in other general soil types. Savannah type of grassland is generally associated with this type of vegetation. The forest type has been described by Champion and Seth (1968) under their *Khair-sissoo forest* (5/1S2). It occupies relatively small area of 9.33 km^2 accounting to 0.30% of the district and contributes 0.42 % of the study area. They impart brownish green with medium texture in the satellite imagery.

Basically, it houses deciduous species, with dense shrubby undergrowths. This forest type is at various stages of succession from early colonizer to more transformed vegetation. The dominant species includes *Sterculia villosa* Smith, *Terminalia bellirica* (Gaertner) Roxburgh and *Terminalia alata* Roth, among the top canopy species, whereas *Holarrhena pubescens* (Buchanan-Hamilton) G. Don, *Syzygium cumini* (L.) Skeels, *Syzygium claviflorum* (Roxburgh) Cowan and Cowan, *Acacia catechu* (L.f.) Willdenow, *Aglaia spectabilis* (Miquel) Jain and Bennet, *Aphanamixis polystachya* (Wallich) Parker etc. in the middle canopy layer. The undergrowth has numerous young trees. The shrubby layer consists of *Sauropus androgynous* (L.) Merrill, *Coffea bengalensis* Schultes, *Sida acuta* Burman f., *Clerodendrum viscosum* Ventenat, *Triumfetta rhomboidea* Jacquin, *Eranthemum pulchellum* Andrews, *Jusminium dispermum* Wallich, *Murraya exotica* L. etc. which forms the dominant composition. *Oplismenus burmanii* (Retzius) P. Beauvois, *Pupalia atropurpurea* (Lamarck) Moquin, *Dicliptera bupleuroides* Nees, *Saccharum* spp. are some of the common species occurring in this forest type. Older trees with higher CBH houses a good number of epiphytes, climbers are also encountered in good number.

5.1.5 Sub-Tropical Broad Leaved Hill Forests

This forest type occurs throughout the district in mid elevation region, between 900 – 1700 m amsl. The mean annual temperature ranges between 12°C – 20°C with relatively high humidity. These forests are very much disturbed and fragmented due to their close proximity to human habitation.

Champion and Seth (1968) have recognised this under *East Himalayan Sub-Tropical wet hill forest* - 8B/C1. It occupies second place only to Wet Temperate forest in terms of area holding with 225.33 km^2 accounting to 7.32% of the district and contributes 10.11 % of the study area. In satellite imagery these forest type is seen as light red with medium texture.

The vegetation is basically evergreen, though some deciduous trees do occur in very low frequency. Small and medium sized trees make a distinct second story. The dominant tree species of the top canopy includes *Schima wallichii* (DC.) Korthals, *Bombax ceiba* L., *Bassia butyracea* Roxburgh, *Duabanga grandiflora* (DC.) Walper, *Castanopsis lanceifolia* (Roxburgh) Hickel and Camus, *Engelhardtia spicata* Blume and *Magnolia pterocarpa* Roxburgh The middle story comprises of species like, *Brassaiopsis hainla* (D. Don) Seemann, *Ostodes paniculata* Blume, *Ficus neriifolia* Smith, *Grewia asiatica* L., *Ficus semicordata* Smith etc. The shrub layer is represented with species like, *Boehmeria macrophylla* Hornemann var *scabrela* (Roxburgh) Long, *Dendrocnide sinuata* (Blume) Chew, *Clerodendrum viscosum* Ventenat, *Rubus moluccanus* L., species of *Strobilanthes, Boehmeria glomerulifera* Miquel, *Phlogacanthus thyrsiformis* (Hardwicke) Mabberley etc. Among the ground cover species the common and the abundant ones are *Oplismenus burmanii* (Retzius) P. Beauvois, *Ajuga macrosperma* Bentham, *Elatostema hookerianum* Weddell, *Commelina suffruticosa* Blume, *Aneilema thomsonii* (C. B. Clarke) C. B. Clarke, ferns are also quite abundant in this vegetation type, *Polystichum lentum* (D. Don) Moore, *Bolbitis heteroclita* (C. Presl) Ching *Diplazium esculantum* (Retzius) Sw., *Nephrolepis cordifolia* (L.) C. Presl. Epiphytic orchids, climbers and lianas are a regular feature.

5.1.6 Wet Temperate Forests

This forest type is distributed throughout upper elevation of the Darjiling hills in three protected areas viz. Singalila National Park, Neora valley National Park and Senchal Wildlife Sanctuary. The altitudinal distribution ranges from 1800 – 2800 m amsl., where

very moist and cold climatic condition prevails. There are less numbers of large tree species in comparison to lower hills; consequently the vegetation has a few dominant species at the top canopy layer. The middle layer has a number of species belonging to medium and small sized trees. Maling (*Arundinaria racemosa* Munro) forms extensive bamboo brake in almost all places. Sometimes, they are found in pure stand in open areas inside the forest. The forest type appears dark red with coarse texture.

This forest is described by Champion and Seth (1968) under *East Himalayan wet temperate forests* 11B/C1 subtype *High-level Oak forest* 11B/C1c. It occupies an area of 282.47 km^2, which constitutes 9.18% of the district and accounts to 12.68 % of the study area. Some of the dominant tree species in the upper canopy are *Lithocarpus pachyphylla* (Kurz) Rehder, *Quercus oxydon* Miquel, *Tsuga dumosa* (D. Don) Eichler, *Quercus lamellosa* Smith etc. *Cryptomeria japonica* (L.f.) D. Don, an exotic species have naturalised in the Senchal area and has invaded well inside the natural forests. Species of *Symplocos, Eurya* and *Euonymus* are a regular feature, which constitutes the middle canopy. Maling with other shrubby species forms a dense thicket often impenetrable. Lianas are almost absent, however, mosses, orchids like *Celogyne cristata* Lindley, *Celogyne corymbosa* Lindley, *Oberonia* sp., various angiosperms species like, *Cautleya spicata* Baker, *Begonia picta* Smith, *Pilea ternifolia* Hara, species of *Vaccinium*, *Agapetes,* etc. and pteridophytes (*Selaginella* sp, *Pleopeltis* sp.) etc forms a rich epiphytic flora.

5.1.7 Temperate Broad Leaved Forests

Wet Temperate and Temperate Broad Leaved forests exist in tandem sharing the same climatic and altitudinal zone. But this forest type is more scattered and fragmented in nature. Because of its close proximity to the human habitation, they are facing serious threat by anthropogenic disturbances. This forest type corresponds to *East Himalayan wet temperate forests* 11B/C1 with its sub-type *Lauraceous forest* 11B/C1a and *Buk oak forest* 11B/C1b of Champion and Seth (1968) classification and constitute 70.31 km^2 accounting to 2.28% of the district that contributes 3.16 % of the study area. On the satellite imagery Temperate Broad Leaved Forests can be distinguished by its light red tone and medium texture compared to dark red tone and more coarse texture of the wet temperate forest.

Though there are few dominant species, some of the commonly found species are *Lithocarpus pachyphylla* (Kurz) Rehder, *Quercus lamellosa* Smith, *Acer campbellii* Hiern, *Rhododendron grande* Wight, *Quercus glauca* Thunberg, *Quercus thomsoniana* A. DC., *Magnolia campbellii* Hook. f. and Thomson, *Actinodaphne longipes* Kostermans Species of *Symplocos* and *Eurya* forms the second layer. Maling is present almost everywhere, sometimes forms impenetrable brakes. Host of angiosperms and pteridophytes form rich the epiphytic flora; lianas are almost absent, climbers are few in numbers.

5.1.8 *Alnus* Forests

Alnus nepalensis shows a scattered distribution with fairly good presence of this species along the mid elevation region ranging from 1400 to 2100 m amsl. They as such do not form a distinct forest type. However, some old plantation shows characteristics of a natural forest ecosystem. Very few small patches of this forest are seen near Lava in the Kalimpong sub-division and at Mirik. This forest type has been characterized by Champion and Seth (1968) as *Alder forest* 11/1S1 and occupies 1.95 km^2. They are generally poor in species diversity with less number of shrubby species and also the epiphytic flora is poorly represented. The satellite image shows brown tone with smooth texture.

5.1.9 Conifer Forests

Under this forest type, temperate and sub-alpine conifers have been clubbed into one group because of their spectral similarity. The forest type is confined to the upper elevation in Singalila National Park extending from Kalipokhri to Phalut. They are generally found in the altitudinal range of 2900 to 3700 m beyond the Wet Temperate Forest zone. Along the lower limits, between 2900 – 3100 m *Tsuga dumosa* (D. Don) Eichler is the principle component of conifer, however, *Abies densa* Miller are typically absent. Common associates in this belt being *Rhododendron arboreum* Smith, *Magnolia campbellii* Hook. f. and Thomson, *Acer campbellii* Hiern. Above 3100 m *Abies densa* becomes increasingly prominent and completely replaces *Tsuga dumosa* of lower belt. *Abies* forest can be seen all along Sandakphu-Phalut ridge. Except for small trees, very few trees of *Abies* stature can be seen in this belt. Among the second story, *Rhododendron campanulatum* D. Don forms an important association. *Arundinaria racemosa* Munro still form an important component of shrub layer in the lower altitude but they are completely replaced by species

of *Berberis* in the upper zone. The herbaceous layer species are seasonal and grows abundantly. Epiphytes in temperate zone are absent, but luxuriant graminaceous floras are seen to decorate the branches of *Abies* trees.

This vegetation type represents *East Himalayan mixed coniferous forest* 12/C3a of Champion and Seth's (1968) classification. On satellite image, they impart bluish-dark to dull red tone with coarse texture. It occupies 21.50 km^2 accounting to 0.70% of the district that constitutes 0.96% of the study area.

5.1.10 Sub-Alpine Scrub

This type is also typical of Singalila range and can be found nowhere in other parts of the district. They are generally found on northern slope and along the ridges of Singalila range. This type has resulted due to the harsh weather condition like heavy snow fall throughout the winters and continuous lashing by strong winds. Various shrubby species like *Berberis spp*, *Rubus spp, Rosa spp*, *Viburnum erubescens* DC., *Daphne bholua* D. Don etc. forms a community. Occasional occurrence of *Rhododendron barbatum* G. Don, *Sorbus cuspidata* (Spanch) Hedlund, *Acer campbellii* Hiern, is a common feature. Herbaceous species are seasonal and numerous. Relatively a good number of climbers are found. Champion and Seth (1968) has characterized this vegetation type in *Dry alpine scrub* 16/C1. It covers an area of 12.93 km^2 (0.58 %) of the study area. On satellite image, it imparts light dull red tone.

5.1.11 Bamboo Brakes

In lower elevation (400–1200 m) *Dendrocalamus hamiltonii* Munro are often seen forming extensive brakes at places where clearing of tree species has occurred. The species is also frequently seen where the forest has experienced regular anthropogenic and other biotic activities along with sudden natural disaster (Rai and Das 2005). This forest type occurs in small patches throughout the district. Among the commonly occurring tree species in this biotically stressed environment are *Bombax ceiba* L., *Sterculia villosa* Smith, *Schima wallichii* (DC.) Korthals. The undergrowth is poorly represented. Grasses are an important component of the ground cover vegetation.

This forest type corresponds to *Secondary moist bamboo brakes* B/2S1 of Champion and Seth's (1968) classification. It covers an area of 6.33 km^2 accounting to 0.28 % of the study area. On satellite image it imparts a light pink tone with smooth texture.

5.1.12 *Rhododendron* Forests

These are generally found between 2900 – 3660 m elevation in Singalila National Park and Neora Valley National Park. However, species of *Rhododendron* may descend up to an altitude of 2100 m and intermix with the temperate species, but it does not form a distinct forest. *Rhododendron arboreum* Smith and *R. falconeri* Hook. f. forms the bulk of this forest. It covers a small area of 1.64 km^2 and imparts light red tone with medium texture on satellite image.

5.1.13 Open Scrub

This type is found to occur throughout the district from Sub-Tropical to temperate climatic zones. This is the result of natural and anthropogenic activities, where the forest has failed to regain its equilibrium. The consistent survivor species after the onslaught of human intervention are *Eupatorium adenophorum* Sprengel, *Aconogonum molle* (Meisner) Reichenbach, *Osbeckia stellata* Ker-Gawler, *Dichroa febrifuga* Loureiro, *Rubus moluccanus* L. This type of vegetation occupies 21.85 km^2 constituting 0.98% of the study area. In Satellite image the vegetation shows a light faded yellow tone with smooth texture.

5.1.14 Teak Plantations

Few small patches of plantation forest are found at the lower hills extending up to 800 m amsl. Their distribution is restricted to reserve forest at places like Bamanpokhri, Teesta valley etc. These plantations are of recent origin that has come up after clearing of forest. Teak plantation occupies small area of 6.33 km^2 and exhibits a chocolate brown tone on the satellite image.

5.1.15 *Cryptomeria* Plantations

Scattered patches of *Cryptomeria* plantations can be seen throughout Kurseong and Darjiling sub-divisions, however its presence in Kalimpong sub-division has been limited to few isolated places. Large tracts of plantation can be seen along the southern aspect of Sukhia spur, Tiger hill range, Takdah range, few places at Ramam and near Algarah in

Kalimpong. In most of the plantation areas, the under growth is very poor in species richness. But plantation along the Tiger Hill and Sukhia are matured and have naturalised in the region. They are well established along with the natural species of the region and have developed a character of natural system. The altitudinal distribution of these plantation forests ranges from 1600–2500 m amsl, where cool and humid climatic condition prevails. This forest type contributes a significant portion of the hill forest ecosystem accounting to 1.53 % of the study area covering 34.09 km^2. It imparts a dark brownish red tone with coarse texture on the satellite image.

5.1.16 Degraded Forests

These forests are the results of prevailing anthropogenic activities and destructive natural forces. Among the human induced activities, the main reason being timber extraction and firewood collections from the forest that has caused considerable damage. Human induced forest fire in Ramam range in Singalila National Park and Alubari beat in the Neora valley National Park in 1992 have caused extensive damage. Natural factors like landslide are of frequent occurrence in the hills, which destroys good part of forest area every year. The stand density and the basal area of the tree species in these forests is less but the species diversity is relatively high, which may be due to intermediate disturbance level. These types of forests are seen more frequently near the human settlements and are directly proportional to the terrain accessibility.

They are frequently invaded by Bamboo species. Small trees and the economically unviable species support this vegetation. Different shrubby species forms dense hedges, grasses are found in abundance as ground cover.

On satellite image, they exhibit irregular patches having light maroon with cyan tone with coarse texture. They occupy 48.28 km^2 accounting to 2.17% of the study area.

5.1.17 *Cinchona* Plantations

Cinchona plantation is another source of livelihood set up as a government undertaking under Directorate of Cinchona plantation and other medicinal plant. These plantations are located at Mangpu, Latpanchor and Mansong. Plantations at Gairibans in Jaldakha are small and could not be mapped owing to its size. They occupy an area of 37.75 km^2

accounting to 1.69% of the study area and are characterized by dark brownish red with coarse texture in the satellite imagery.

5.1.18 Agriculture

Of the 5,90,293 hill population 1,56,932 are engaged in agriculture and agriculture related activities (Census, 2001). Kalimpong sub-division is almost entirely agrarian, Rimbick-Lodhoma in the north-west of Darjiling sub-division also heavily depends on agriculture and related activities. In the tea garden dominated areas land holding is small, nonetheless, agriculture supports livelihood to large extent. Agriculture in the hills is more of a subsistence type. Because of its hilly terrain, terrace farming is prevalent. Chief agricultural crops include potato, maize, millet, buckwheat, barley, oats and paddy in the lower elevation where water supply is plenty. In addition, cash crops like, oranges, squash, peas, cabbages, carrot, radish; condiments as gingers, cardamom, pepper etc are generally cultivated. The hills have a significant agriculture holding with 682.24 km^2 accounting to 30.62 % of the study area. On satellite image the agricultural areas show light pink tone with standing crop and cyanish white when the field is without a crop.

5.1.19 Tea Gardens

Darjiling is world famous for its naturally aromatic tea. It produces one of the finest teas in the world, sometimes also referred to as the champagne of teas, and has been granted a geographical indication patent. Besides tourism, tea industry is the largest employment sector in the hills with an annual turnover of nearly US $ 7.5 million. Cultivation of tea dates back to pre independence period in 1847 by Dr. Campbell, who championed the cultivation in Darjiling. Today, there are 86 functional gardens employing 52,000 people in this sector (Paramanatham, 2003; http://www.teaindia.org). These tea gardens are spread throughout the district from the plains upto an elevation of 2100 m. Darjiling and Kurseong sub-divisions are the centers for tea cultivation and has maximum number of gardens whereas Kalimpong has few tea gardens in the south-eastern part otherwise it is basically an agrarian country side. Tea garden with 346.95 km^2 constitutes 15.57 % of the study area. It imparts red to pinkish red colour with medium texture in fully leafy condition in the satellite image.

5.1.20 Barren Lands

Patches of barren land are scattered irregularly in the landscape. Unclassified land-use category, agriculturally unviable land contributing little or no biodiversity value viz. landslips, fallow land etc. have been clubbed in this group. These jointly contribute 8.01 km^2 accounting to 0.36% of the study area. On the satellite image they impart light blue-green to cyanish tone.

5.1.21 River beds/ Water bodies

Rivers, dry river beds and lakes are included in this category. Mirik lake and Senchal lake are two artificial lakes which serves as a purpose of recreation and essential drinking water source could be discerned and have been delineated. However, only the major rivers and its main tributaries could be delineated due to its spatial dimension. Water bodies usually reflect less electromagnetic radiations, thus reflects a dark to deep blue tone on the satellite image. They together occupy 39.90 km^2 accounting for 1.79 % of the study area.

5.1.22 Settlements

According to population census (Anonymous, 2001) the total population of Darjiling district is 16,05,900 of which 5,90,293 resides in the hills and majority in the plains. Majority of the hill population lives in villages. These villages have a very scattered distribution throughout the district, especially in mid-elevation region where teagardens have being setup and the lands are fertile for agriculture. Except few major township like Darjiling, Kurseong, Kalimpong and Mirik along with other smaller settlements viz. Lebong, Rimbick, Sukhia, Pokhriabung, Mangpu, Takdah, Sonada, Tindharia, Lava and Pedong village settlements could not be mapped owing to its small size. This landuse class occupies 19.28 km^2 accounting to a meagre 0.87 % of the hills area. On the satellite image it imparts dull to dark bluish-green tone with coarse texture.

5.1.23 Cloud and shadow

Most of the places of high-altitude almost always remain covered with cloud. The cloud and its shadow effect have been observed above the Neora Valley National Park region in the Kalimpong sub-division. This class covered 36.75 km^2 accounting to 1.65 % of the study area. These were treated as rejected class while doing biological richness

characterisation as they fall under unclassified category and thus loose their significance for any further use and analysis.

5.2 Community analysis

Ground truth data from 172 sample plots distributed in 16 forest types recorded a total of 1109 species. Quantitative analysis for the three tiers (i.e. tree, shrub and herb layers) were done separately; Frequency (F), Density (D), Abundance (A) [in case of herb and shrubby layers] Relative Frequency (RF), Relative Density (RD), Relative Abundance (RA)/ or Relative Dominance (RDm) [for tree layer only] and Importance Value Index (IVI) were calculated to understand the importance of different species in forest community. Total Basal area (BA), stands density and distribution of different girth classes of individual tree species in these forests have been studied and analysed to understand the structure, density and over all health of each forest types.

Various diversity indices are computed for evaluating species richness in these forest types. Comparisons of species similarity between different forest types, their taxonomic distribution along with the presence of medicinal plants and endemic status have been computed, which are discussed in detail below.

5.2.1 Tropical Semi-evergreen Forests

In this forest type 7 sample plots were laid covering an area of 0.28 ha. A total of 164 species distributed among 131 genera and 71 families has been recorded (Table 5.3b). Of these, 51 are trees species, whereas 41 and 71 species each were recorded for shrub and herb layers respectively (Table 5.3a). The total number of individuals or stands encountered in this forest was found to be 1679 in the 7 sample plots studied; of these, 170 are of trees. Tree density for this forest is calculated to be 607.143 individuals/ha and total basal area was 44.271m^2/ha (Table 5.4). Highest number of species was recorded for Euphorbiaceae (8 spp), Lauraceae (8 spp), Verbenaceae (8 spp) and Vitaceae (8 spp). Family Orchidaceae also shows high species representation with its 7 species in this forest type. There are at least 34 families with two or more species. Rest 36 families are represented by only a single species (Figure 5.7f).

Table 5.3a: Habit-class distribution of flora in total samples with the number of species in various forest types

Sl.	Forest Types	Trees	Shrubs	Herbs
1	Tropical Semi-evergreen Forests	51	41	71
2	Himalayan Sal Forests	77	126	187
3	Moist Mixed Deciduous Forests	80	107	128
4	Riverine Forests	42	50	55
5	Sub-Tropical Broad Leaved Hill Forests	60	62	78
6	Wet Temperate Forests	44	76	179
7	Temperate Broad Leaved Forests	35	45	116
8	*Alnus* Forests	12	23	48
9	Conifer Forests	9	17	49
10	Sub-Alpine Scrub	-	35	71
11	Bamboo Brakes	41	55	84
12	*Rhododendron* Forests	19	22	81
13	Open Scrub	-	25	55
14	Teak Plantation	19	53	68
15	*Cryptomeria* Plantation	6	29	60
16	Degraded Forests	31	44	53

Table 5.3b: Distribution of taxa in different forest types of Darjiling Hills

Sl. No.	Forest Types	Species	Genera	Family	Individ-uals
1	Tropical Semi-evergreen Forests	164	131	71	1679
2	Himalayan Sal Forests	318	211	74	7515
3	Moist Mixed Deciduous Forests	266	192	75	5616
4	Riverine Forests	152	123	56	3765
5	Sub-Tropical Broad Leaved Hill Forests	167	140	74	940
6	Temperate Broad Leaved Forests	213	138	72	5631
7	Wet Temperate Forests	273	171	80	9020
8	*Alnus* Forests	87	80	47	4109
9	Conifer Forests	81	61	35	2462
10	Sub-Alpine Scrub	100	76	42	5884
11	Bamboo Brake	142	118	61	2282
12	*Rhododendron* Forests	121	92	51	2600
13	Open Scrub	75	69	45	3101
14	Teak Plantation	132	110	54	5693
15	*Cryptomeria* Plantation	107	82	48	1905
16	Degraded Forests	164	125	67	2855

Quantitative phyto-sociological analysis of tree layer for this forest type is provided in (Annexure I, Table 1). This forest type shows a heterogeneous distribution without clear dominance by a single species. Few species that form co-dominant association are *Aglaia lawii* (Wight) Ramamoorthy [IVI = 29.48; F = 71.43%], *Michelia champaca* L. [IVI =

23.99; F = 42.86%], *Pterospermum acerifolium* (L.) Willdenow [IVI = 21.92; F = 71.43%], and *Duabanga grandiflora* (DC.) Walper [IVI = 21.52; F = 57.14%]. The first two species show high Density of 67.86 and 64.29 per hectare. All these species exhibit high RF, RD and RDm, which are reflected in their higher IVI scores. In the shrub layer, *Clerodendrum viscosum* Ventenat is the dominant species. This is followed by *Boehmeria glomerulifera* Miquel, *Leea indica* (Burman) Merrill etc. (Annexure II, Table 1). In the herb layer *Elatostema obtusum* Weddell, *Coffea bengalensis* Schultes, *Chloranthus erectus* (Buchanan-Hamilton) Verdecourt etc. are some other important species in this layer (Annexure III, Table 1).

Shannon-Weiner index of diversity in this forest type was calculated to be 4.12 for the vegetation. The tree layer was observed to be highly diverse compared to shrub and herb layers. The determined value for species diversity for tree layer was 3.724, for shrub layer 2.648 and for herb layer it was 0.961, which is lowest among the three layers (Fig 5.3). Similarly, *Simpson's index* for concentration of dominance was observed to be 0.03 for the vegetation, 0.058 for tree layer (lowest among all the forest types), 0.14 for shrub layer and 0.004 for the herb layer, lowest in three tiers in this forest type (Fig 5.4). These values suggest that the species in the ground cover is highly dispersed, while they are of higher concentration in the shrub layer. *Menhinick's index* for species richness was calculated at 4.08 for the vegetation, 3.912 for tree layer, 1.89 and 3.14 respectively for shrub and herb layers (Fig 5.5) and *Margalef's index* for species richness as 22.35 for the vegetation, 9.74 for tree layer, 6.503 for shrub layer and 11.83 for herb layer (Fig 5.6). Various diversity indices worked out for each forest type is furnished in the Table 5.5.

This forest type shows good species diversity and species richness with low concentration of dominance. Tree layer is more heterogeneous and exhibit good diversity than the shrub or herb layer with low concentration of dominance. The shrub layer exhibits moderate species diversity and low species richness and has a high concentration of dominance. Interestingly the ground cover vegetation is highly diverse and shows a unique blend of high species richness and poor species diversity.

Table 5.4: Forest type-wise stand density and total basal area

Sl. No.	Forest Type	No. of Plots	No. of Stands	Density/ ha	Basal area m^2/ ha
1	Tropical Semi-evergreen Forests	7	170	607.14	44.27
2	Himalayan Sal Forests	26	650	625	51.03
3	Moist Mixed Deciduous Forests	15	329	548.33	45.4
4	Riverine Forests	9	173	480.56	51.02
5	Sub-Tropical Broad Leaved Hill	6	172	716.67	52.64
6	Wet Temperate Forests	22	518	588.64	82.37
7	Temperate Broad Leaved Forests	9	199	552.78	97.64
8	*Alnus* Forests	9	106	294.44	50.17
9	Conifer Forests	3	106	883.33	100.42
10	Sub-alpine Scrub	-	-	-	-
11	Bamboo Brakes	12	1104	2333 (214.6)	23.64
12	*Rhododendron* Forests	5	122	610	82.67
13	Open scrub	-	-	-	-
14	Teak Plantation	11	152	345.45	36.51
15	*Cryptomeria* Plantation	4	123	768.75	64.53
16	Degraded Forests	7	699	2389.29 (271.43)	25.82

5.2.2 Himalayan Sal Forests

A total of 26 sample plots were laid in this forest covering an area of 1.04 ha. A total of 318 species distributed in 211 genera and 74 families has been recorded (Table 5.3b). Of these 77 species are trees, where as 126 and 187species were registered respectively in the shrub and herb layers (Table 5.3a). The total number of individuals encountered in this forest was 7515 in which 650 were of trees leading to tree density of 625 individuals/ha. Total basal area was calculated at 51.03 m^2/ha (Table 5.4). Family-wise representation showed highest number of species for Fabaceae (27 spp) followed by Asteraceae (23 spp), Orchidaceae (21 spp), Poaceae (20 spp) and Euphorbiaceae (17 spp) respectively. There are at least 50 families having 2 or more species and 24 families are represented by single species (Fig 5.7a).

The forest is clearly dominated by *Shorea robusta* Gaertner f. with an IVI score of 119.49 in which RDm contribute 64.24 followed by RD (43.54) and RF (11.71). *Shorea robusta* shows 100% Frequency and a Density of 272.12 individuals/ha. *Schima wallichii* (DC.) Korthals [IVI = 13.87; F = 30.77), *Pinus roxburghii* Sargent [IVI = 13.41; F = 19.23] and *Terminalia belirica* (Gaertner) Roxburgh [IVI = 10.86; F = 42.23] are some of the species

with good IVI scores. However, these species are not frequent associates as can be seen from Frequency distribution (Annexure I, Table 2). *Shorea robusta* Gaertner f. occupies an important position in this forest ecosystem. The shrub layer is dominated by species like *Clerodendrum viscosum* Ventenat, *Uraria lagopodioides* (L.) Desveaux and *Eupatorium odoratum* L. (Annexure II, Table 2). Whereas, *Oplismenus burmanii* (Retzius) P. Beauvois seedlings of *Shorea robusta* Gaertner f. and *Eupatorium odoratum* L. dominates the ground cover vegetation (Annexure III, Table 2).

This forest type showed relatively high species diversity index. *Shannon-Weiner index* was recorded at 4.31 for the vegetation, 2.812 for tree layer, 3.316 and 4.109 for the shrub and herb layers respectively (Fig 5.3). Herb layer is very rich in this forest type, unlike the Tropical Semi-evergreen Forest, the tree layer is poor in species diversity. Almost gregarious nature of Sal dominating the forest has impeded the development of other tree species. Similarly, *Simpson's index* of dominance was calculated to be 0.04 for the vegetation, 0.20 for tree layer, 0.09 for shrub layer and for herb layer it is 0.032 (Fig 5.4). The herb layer is better dispersed with low concentration than other two layers. High concentration in the tree layer is due to high concentration of Sal in this forest type. *Menhinick's index* of species richness was found to be 3.70 for the vegetation, 3.02 for tree layers, 2.18 for shrub layer and 3.59 for herb layer (Fig 5.5). *Margalef's index* for species richness shows highest values except for the tree layer in this forest types and the overall vegetation. It is 35.86 for the vegetation, 11.73 for the tree layer, 15.41 for shrub and 24.75 for the herb layers (Fig 5.6). The herb layer shows good species richness than the two upper layers.

This vegetation shows high species diversity with low concentration of dominance and moderate species richness. Herb layer exhibits high species diversity and richness with low concentration of dominance, thereby indicating rich ground cover vegetation. The tree layer on the other hand was poor in species diversity and richness with high concentration of dominance in comparison to other two layers. This is due to complete dominance by *Shorea robusta* in this layer. Shrub layer showed moderate values.

Table 5.5: Diversity indices for different vegetation types in Darjiling Hills

Sl. No	Forest types	Shannon index	Simpson's index	Menhinick's index	Margalef index
1	Tropical Semi-evergreen Forests	4.12	0.034	4.076	35.86
2	Himalayan Sal forests	4.31	0.037	3.703	30.53
3	Moist Mixed Deciduous Forests	4.06	0.055	3.576	30.93
4	Riverine Forests	4.51	0.040	2.472	15.27
5	Sub-Tropical Broad Leaved Hill Forests	3.81	0.017	5.48	24.78
6	Wet Temperate Forests	4.06	0.05	2.938	22.35
7	Temperate Broad Leaved Forest	3.99	0.046	2.865	24.39
8	*Alnus* Forests	3.14	0.079	1.404	15.39
9	Conifer Forests	3.18	0.082	1.632	20.72
10	Sub-alpine scrub	3.58	0.047	1.343	18.34
11	Bamboo Brakes	3.00	0.206	2.973	14.30
12	*Rhododendron* Forests	3.86	0.036	2.393	18.23
13	Open scrub	3.13	0.069	1.365	10.70
14	Teak plantations	3.17	0.105	1.763	10.24
15	*Cryptomeria* plantations	3.86	0.034	2.497	11.75
16	Degraded Forests	3.85	0.062	3.837	9.33

5.2.3 Moist Mixed Deciduous Forests

Fifteen sample plots covering and area of 0.60 ha were laid in this forest type. A total of 266 species with all forms of life distributed in 192 genera and 75 families are recorded (Table 5.3b). Here, the tree layer constitutes 80 species, whereas in shrub and herb layers there are 107 and 128 species respectively (Table 5.3a). A total number of individuals encountered in this forest were found to be 5616. In the tree layer 329 stands were recorded leading to a tree density of 548.33 individuals/ha and a total basal area of 45.4 m^2/ha (Table 5.4). Highest number of species was recorded for Euphorbiaceae (20 spp), Rubiaceae (14 spp), Fabaceae (14 spp), Orchidaceae (10 spp) and Poaceae (10 spp). There are at least 45 families having 2 or more species and 29 families are represented by single species (Fig 5.7c).

Deciduous tree species forms the co-dominant association in this vegetation type; most important species being *Shorea robusta* Gaertner f. with an IVI score of 34.33 in which RDm forms 17.37 followed by RD (10.64) and RF (6.33). *Schima wallichii* (DC.) Korthals is a close associate which shows an IVI score of 28.29; where RDm contributes 13.20 followed by RD (10.03) and RF (5.06). These two species have fairly good distribution with a Frequency of 66.67% and 53.33% and Density of 58.33 and 55 individuals/ha respectively. Other equally important species, though having low IVI, are *Chisocheton*

paniculatus Hiern [IVI = 12.41; F = 33.33%] and *Lagerstroemia parviflora* Roxburgh [IVI = 12.14; F = 40%] (Annexure I, Table 3). These species have a rather low density of 30 and 36.67 individuals/ha. Here too, *Clerodendrum viscosum* Ventenat, *Coffea bengalensis* Schultes and *Eupatorium odoratum* L. dominates the shrub layer (Annexure II, Table 3). In the herb layer, *Peperomia pellucida* (L.) Kunth, *Clerodendrum viscosum* Ventenat and *Oplismenus burmanii* (Retzius) P. Beauvois are the prominent species (Annexure III, Table 3).

Shannon-Weiner index of diversity was found to be 4.06 for the vegetation, 3.746 for tree layer, 2.867 for shrub layer and 3.102 for herb layer (Fig 5.3). The diversity of the overall vegetation showed a high value. The tree layer showed highest species diversity compared to other two layers. Similarly, *Simpson's index* for concentration of dominance was found to be 0.05 for the vegetation. For the tree layer it was 0.04, 0.16 in shrub and 0.019 in herbaceous layer (Fig 5.4). Concentration of dominance for the overall vegetation was low, thereby indicating a heterogeneous species distribution. Tree and herb layer has low value, whereas shrub layer shows considerably high value. This means species belonging to the shrub layer are more abundant and concentrated. *Menhinick's index* for species richness was found to be 3.58 for the vegetation, 4.41 in case of tree layer, 2.08 for shrub layer and 2.83 in the herb layer (Fig 5.5). *Margalef's index* value for the vegetation was 30.93, the three layer showed 13.63, shrub layer 13.45 and herb layer showed maximum value of 17.44 (Fig 5.6). Species richness for the vegetation was fairly good, the tree layer shows better species richness followed by the herb and the shrub layer.

The forest type shows good species diversity and richness with correspondingly low concentration of dominance. The tree layer is more rich and diverse in species composition with low concentration of dominance. The shrub layer, like other vegetation shows low diversity with high species concentration. Herb layer on the other hand is rich and diverse only next to tree layer, but in this layer species are more dispersed.

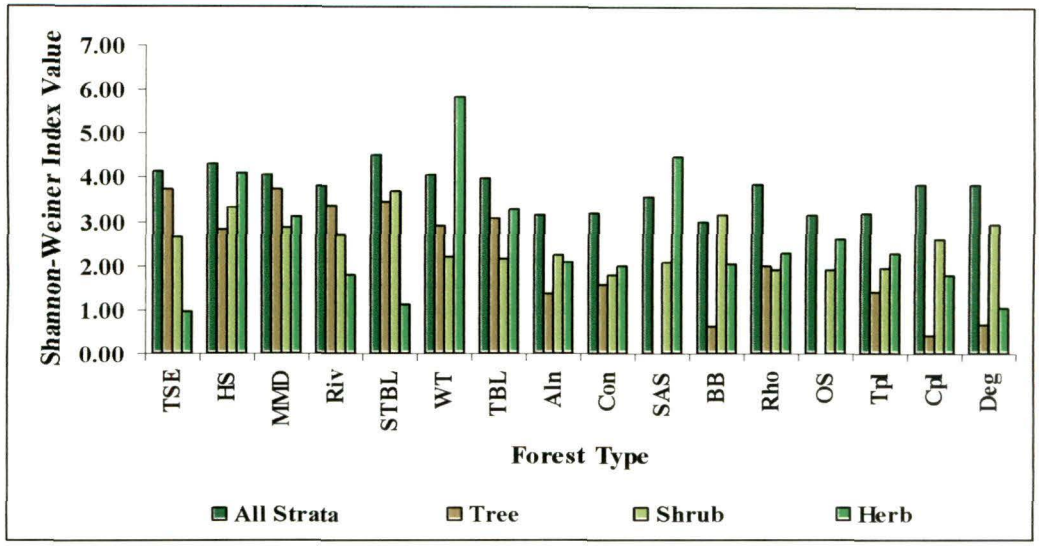


Fig 5.3 Shannon-Weiner Index of species diversity for various forest types in different strata

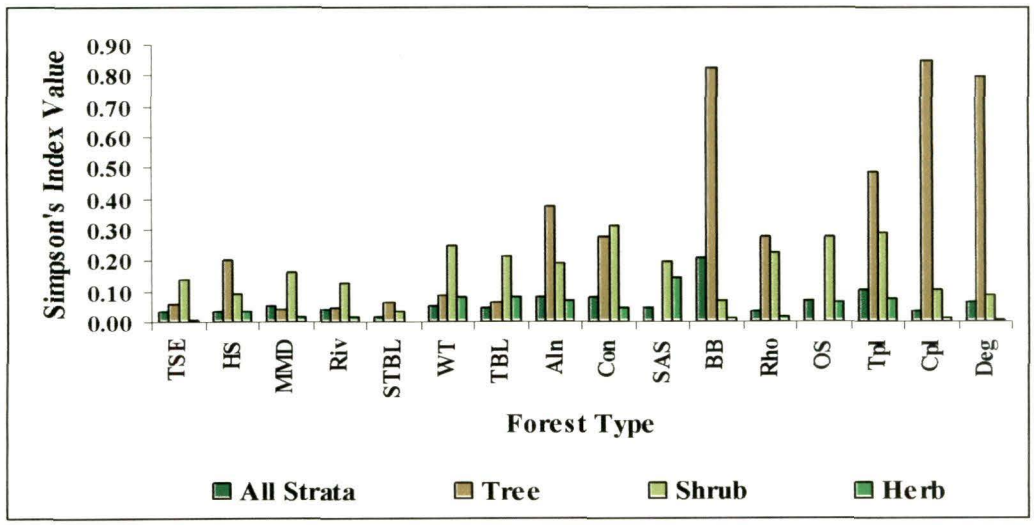


Fig 5.4 Simpson's Index of concentration of dominance for various forest types in different strata

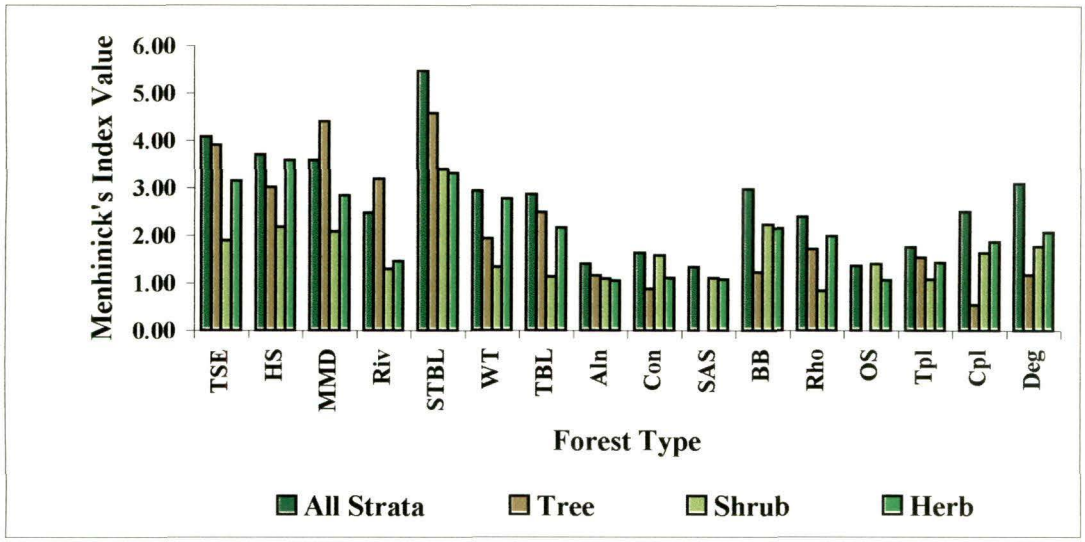


Fig 5.5 Menhinick's Index of species richness for various forest types in different strata

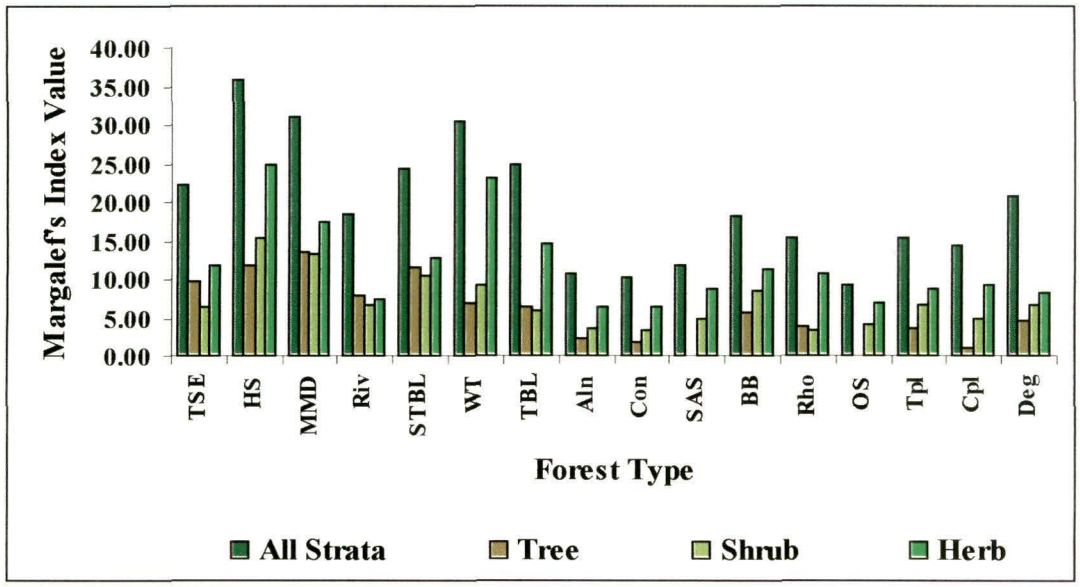


Fig 5.6 Margalef's Index of species richness for various forest types in different strata

5.2.4 Riverine Forests

In this forest type 9 sample plots covering 0.36 ha have been studied. Total number of species encountered is 152 distributed in 123 genera and 56 families (Table 5.3b). Of the total, 42 species belongs to tree layer, 50 in shrub layer and 56 in herb layer (Table 5.3a). A total of 3765 individuals were recorded out of which 173 stands belong to tree species. Tree density for this forest is calculated to be 480.56 individuals/ha and a total basal area is

determined at 51.02 m^2/ha (Table 5.4). Family representation showed highest number of species for Acanthaceae (11 spp), Orchidaceae (11 spp) and Fabaceae (10 spp). There are at least 30 families having 2 or more species and 26 families with single species (Fig 5.7h).

The forest type is very heterogeneous with somewhat equal representation of more than 5 species. However, *Sterculia villosa* Smith exhibits highest IVI score of 37.97; where RDm contributes 24.14 followed by RD (7.51) and RF (6.32). This species shows good presence in this forest with 66.67% Frequency and a Density of 36.11 individuals/ha. Other species having higher IVI value and Frequency includes *Terminalia bellirica* (Gaertner) Roxburgh [IVI = 26.80; F = 77.78%]. This species has Density of 41.67 individuals/ha. *Terminalia alata* Roth, [IVI = 20.32; F = 33.33%], *Syzygium cumini* (L.) Skeels [IVI = 19.10; F = 55.56%] are other important associates of this forest (Annexure I, Table 4). *Sauropus androgynous* (L.) Merrill, *Coffea bengalensis* Schultes, *Clerodendrum viscosum* Ventenat and *Sida acuta* Burman f. are some prominent species found in the shrub layer (Annexure II, Table 4). In the herb layer, *Oplismenus burmanii* (Retzius) P. Beauvois, *Dicliptera bupleuroides* Nees and *Pupalia atropurpurea* (Lamarck) Moquin are some of the notable species occurring in this layer (Annexure III, Table 4).

Shannon-Weiner index value for diversity was found to be 3.81 for the vegetation; 3.335 for tree layer, 2.687 for shrub layer and 1.783 for the herb layer (Fig 5.3). The vegetation shows a diversity gradient with habit groups. Tree layer is more diverse with respect to species composition, followed by shrub layer and the herb layer having least species diversity. This trend is uncommon of other vegetation, where ground cover shows high species diversity. *Simpson's index* for dominance was found to be 0.04 for the vegetation, 0.05 for tree layer, 0.12 for shrub layer and 0.018 for the herb layer (Fig 5.4). Here too, tree layer and herb layer shows low species concentration, shrub layer exhibit consistently higher species concentration. *Menhinick's index* of species richness was found to be 2.48 for the vegetation, 3.19 for tree layer, 1.30 for shrub layer and 1.46 for the herb layer (Fig. 5.4). *Margalef's index* for richness was calculated to be 18.34 for the vegetation, the values recorded for tree shrub and herb layers are 7.96, 7.54 and 6.71 respectively (Fig 5.6). The species richness also shows similar trend; tree layers having rich species composition.

Generally the forest type exhibit fairly good diversity and richness with respect to species composition with low concentration of dominance suggesting a good species composition. The tree species are particularly noteworthy showing luxuriant growth with good diversity. The shrub layer also shows good diversity. The ground cover vegetation, however, shows poor representation compared to other vegetation types.

Figures 5.7 (a-p) Distribution of taxa in various forest types in Darjiling Hills

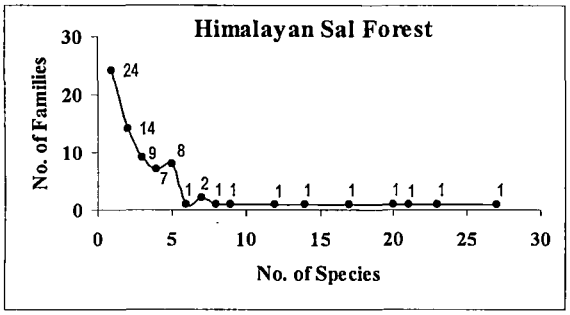


Fig 5.7a Distribution of species and families in Himalayan Sal Forests

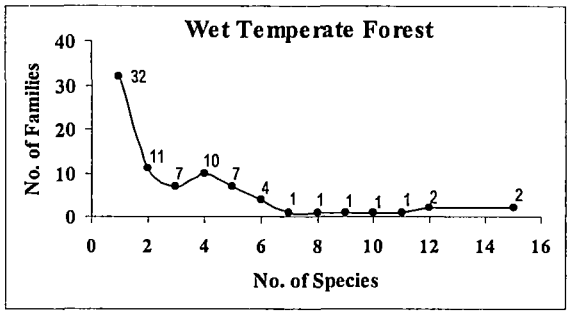


Fig 5.7b Distribution of species and families in Wet Temperate Forests

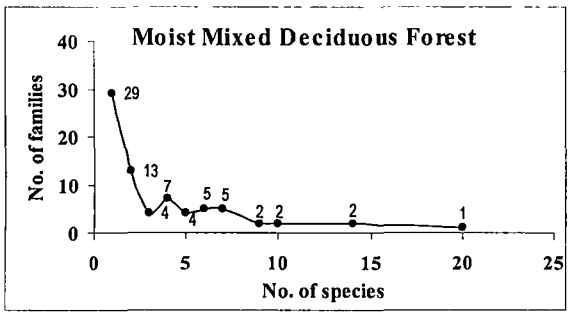


Fig 5.7c Distribution of species and families in Moist Mixed Deciduous Forests

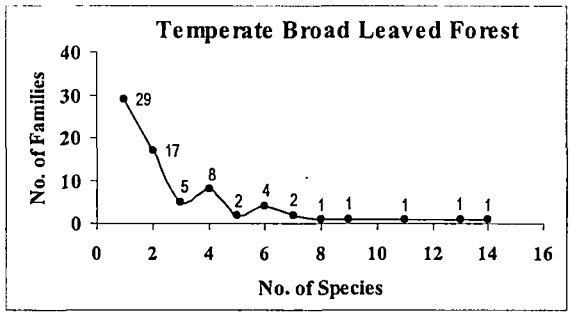


Fig 5.7d Distribution of species and families in Temperate Broad Leaved Forests

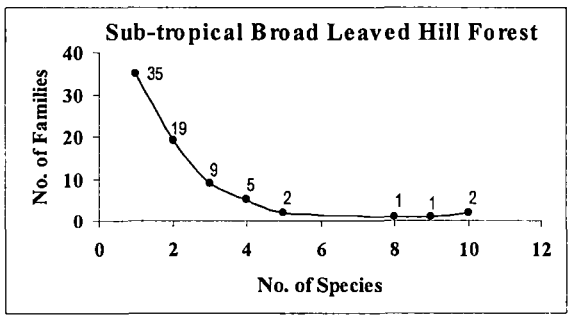


Fig 5.7e Distribution of species and families in Sub-Tropical Broad Leaved Hill Forests

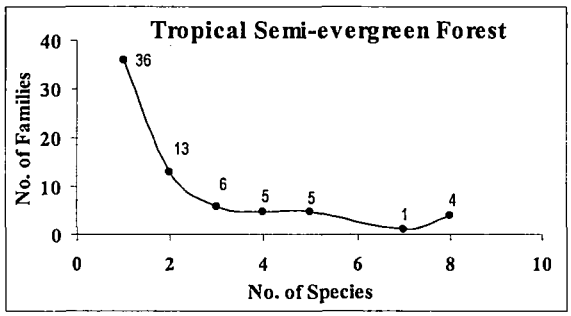


Fig 5.7f Distribution of species and families in Tropical Semi-evergreen Forests

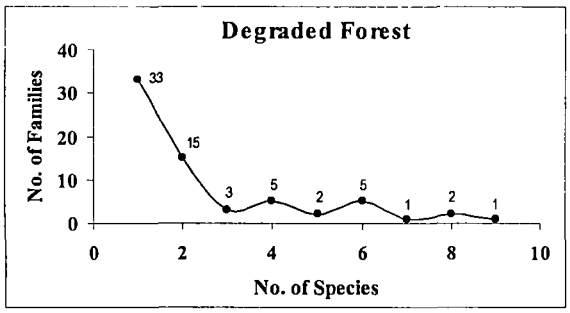


Fig 5.7g Distribution of species and families in Degraded Forests

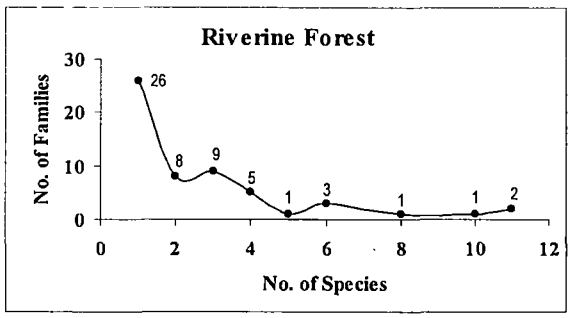


Fig 5.7h Distribution of species and families in Riverine Forests

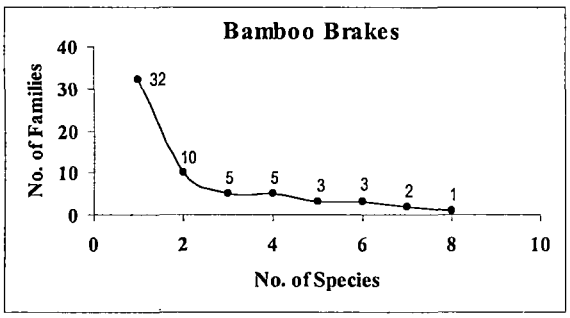


Fig 5.7i Distribution of species and families in Bamboo Brakes

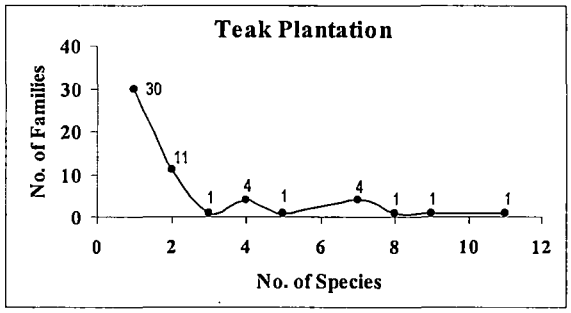


Fig 5.7j Distribution of species and families in Teak Plantation

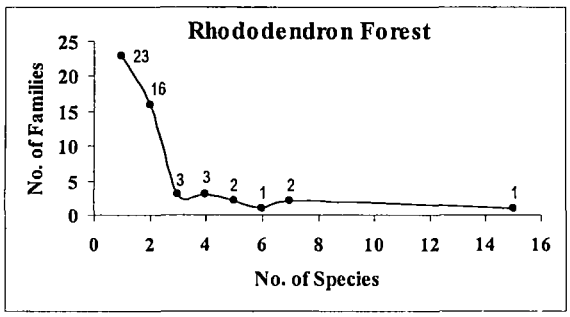


Fig 5.7k Distribution of species and families in *Rhododendron* Forests

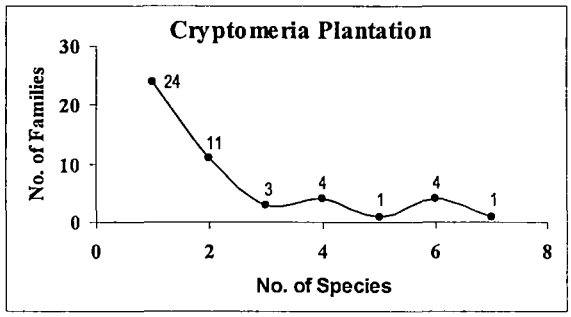


Fig 5.7l Distribution of species and families in *Cryptomeria* Plantation

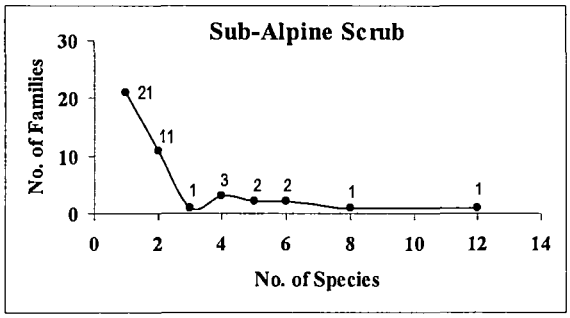


Fig 5.7m Distribution of species and families in Sub-Alpine Scrub

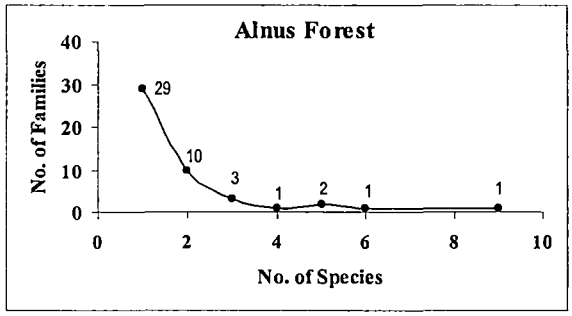


Fig 5.7n Distribution of species and families in *Alnus* Forests

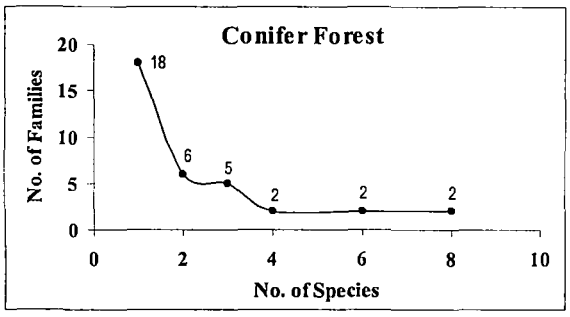


Fig 5.7o Distribution of species and families in Conifer Forests

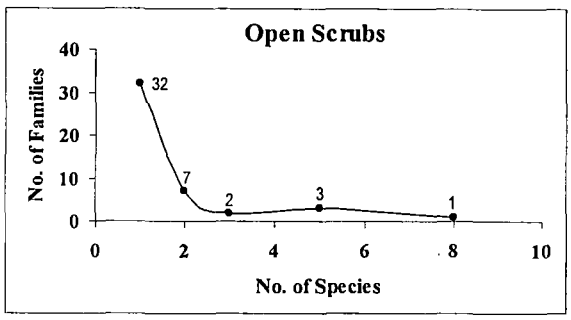


Fig 5.7p Distribution of species and families in Open Scrub

5.2.5 Sub-Tropical Broad Leaved Forests

Six sample plots were laid in this forest type covering 0.24 ha. A total of 167 species distributed in 140 genera and 74 families have been recorded (Table 5.3b). Tree layer constitutes 60 species, shrub and herb layer comprise 62 and 78 species each (Table 5.3a). In this forest type 940 individuals were counted of which, 172 stands were for trees. The tree density was calculated to be 716.67 individuals/ha and the basal area has been found out to be 52.64 m^2/ha (Table 5.4). Family-wise representation showed highest number of species for Euphorbiaceae (10 spp), Urticaceae (10 spp), Acanthaceae (9 spp) and Moraceae (8 spp). There are at least 39 families having 2 or more species and 35 families with a single species (Fig 5.7e).

The forest shows *Schima wallichii* (DC.) Korthals as a prominent species with an IVI score of 46.06 in which RDm contributes 25.98 followed by RD (16.28) and RF (3.80), however, with respect to abundance; it shows a Frequency of 50% only. Density for the species was found out to be 116.67 per hectare, which is quite high. *Bombax ceiba* L. is another species having high IVI score of 25.72, where RDm is significantly high with 23.72 and very low RF (1.27) and RD (1.16). The Frequency of *Bombax ceiba* was only 16.67%. High IVI value is due to high value of BA, which is reflected from the RDm value. This is also supported by low Density value of only 8.33 per hectare. In middle canopy, species like *Ostodes paniculata* Blume, [IVI = 22.86; F = 50%] *Brassaiopsis hainla* (D.Don) Seemann [IVI = 18.71; F = 50%] are some of the commonly occurring species in this forest type (Annexure I, Table 5). These two middle canopy species also shows high Density of 83.33 and 91.67 individuals/ha. Shrub layer constitutes an important component of this vegetation. *Boehmeria macrophylla* Hornemann Var *scabrela* (Roxburgh) Long,

Dendrocnide sinuata (Blume) Chew and *Clerodendrum viscosum* Ventenat are some of the important species in shrub layer (Annexure II, Table 5). In herb layer, *Oplismenus burmanii* (Retzius) P. Beauvois *Polystichium lentum* (D. Don) Moore and *Elatostema obtusum* Weddell are some of the important species in this layer (Annexure III, Table 5).

This forest type exhibits highest *Shannon-Weiner index* value for diversity of 4.51 for the vegetation, values for tree layer is 3.45, shrub layer interestingly recorded highest diversity value of 3.70 in this forest type and for herb layer the value was 1.13 (Fig 5.3). The vegetation is represented by a uniform distribution of large numbers of species in the shrub layer; many of them are tree sapling. This indirectly hints to a considerable influence by anthropogenic activities. Herb layer shows a poor diversity. *Simpson's index* of dominance for this forest has been determined to be lowest for the vegetation with 0.02, for tree layer the value was 0.06, 0.03 and 0.001 for shrub and herb layers respectively (Fig 5.4). The values for different tiers show that the vegetation is very heterogeneous. *Menhinick's index* of species richness shows highest value for this forest type. Value calculated is 5.48 for the vegetation, 4.57 for tree layer, 3.40 for shrub layer and 3.31 for herb layer (Fig 5.5). However, this trend is not seen in *Margalef's index* value shows 24.39 for the vegetation, 11.46 for tree layer, 10.50 for shrub layer and 12.83 for herb layer (Fig 5.6).

This vegetation shows very high species diversity and richness with low concentration of dominance suggesting a very heterogeneous nature. Most notable of the three layers is the shrub layer, which has high diversity value.

5.2.6 Wet Temperate Forests

A total of 22 sample plots were laid covering an area 0.88 ha in this forest type. Total number of species encountered was 273 species distributed among 171 genera and 80 families (Table 5.3b). Tree layer recorded 44 species, whereas, in shrub layer 76 species and in herb layer 179 species were recorded (Table 5.3a). A total of 9020 individuals were counted and the number of tree species individuals constituted 518. The tree density for the forest was calculated to be 588.64 individuals/ha and the basal area was 82.37 m^2/ha (Table 5.4). The highest number of species was recorded for Orchidaceae (15 spp) and Rosaceae (15 spp). Other families having high species includes Urticaceae (12 spp),

Asteraceae (12 spp), Lauraceae (11 spp) and Rubiaceae (10 spp). There are at least 48 families having 2 or more species and 32 families with a single species (Fig 5.7b).

Lithocarpus pachyphylla (Kurz) Rehder is the dominant species. They are prominently seen throughout this forest type. It shows highest IVI score of 57.52 in which RDm contributes 35.08 followed by RF (11.43) and RD (11.00). The species shows ubiquitous distribution with 72.73% Frequency and a Density of 64.77 individuals/ha. Other important associates include *Quercus oxydon* Miquel [IVI = 37.09; F = 45.46%] and *Symplocos caudata* G. Don [IVI = 25.23; F = 59.09%] and *Symplocos theifolia* D. Don [IVI = 24.39; F = 31.82%]. *Symplocos caudata* G. Don and *Symplocos theifolia* D. Don also shows high Density of 87.50 and 102.27 individuals/ha. The forest type is dominated by the Buk-Oak association that is reflected from high percentage (44%) of total IVI value for the forest type. (Annexure I, Table 6). In the shrub layer, important species includes *Arundinaria racemosa* Munro that forms dense brakes, *Smilax rigida* Wallich ex Kunth, *Symplocos glomerata* Clarke are some of the important species in this layer (Annexure II, Table 6). In the herb layer important species includes *Cyperus squarrosus* L., *Peracarpa carnosa* (Wallich) Hook. f. and Thomson, *Cautleya spicata* (Smith) Baker, *Ainsliaea aptera* DC., and *Ophiopogon intermedius* D. Don etc are some of the important species in this layer (Annexure III, Table 6).

Shannon-Weiner index of diversity has been found out to be fairly good with 4.06 for the vegetation; for tree layer it is 2.89, 2.21 for shrub layer and 5.86 for the herb layer (Fig 5.3). Cold and humid climatic condition has favoured the development of rich ground cover vegetation in this zone; the shrub layer is rather poor in species occurrence as can be seen from its diversity value. There are less tree species in this forest type compared to their lower hill counterpart as is reflected in their diversity and richness value. Concentration of dominance (*Simpson's index*) is comparatively low except for shrub layers. It is 0.05 for the vegetation, 0.09 for tree layer, 0.25 for shrub layer and 0.08 for herb layer (Fig 5.4). *Menhinick's index* of species richness is also fairly good with 2.94 being calculated for the vegetation, 1.93 for tree layer, 1.33 for shrub layer and 2.77 for the herb layer (Fig 5.5). The forest exhibits a good *Margalef's index* of species richness. It is 30.53 for the vegetation 6.88 for tree layer, 9.28 for shrub layer and 22.98 for herb layer (Fig 5.6).

The forest type is also highly heterogeneous in nature with good species diversity but low species richness and low species concentration. The forest type is particularly rich in ground cover vegetation; tree and shrub layers are rather poor in species composition.

5.2.7 Temperate Broad Leaved Forests

In this type, 9 sample plot covering 0.36 ha were laid. A total of 213 species were recorded, which are distributed among 138 genera and 72 families (Table 5.3b). Tree layer recorded 35 species from this forest type, whereas for shrub and herb layer comprised of 45 and 116 species respectively (Table 5.3a). The total of 5631 individuals was counted of which 199 individuals were tree species. Tree density was calculated to be 552.78 individuals/ha and the total basal area was found to be 97.64 m^2/ha, which is comparatively higher than other forest types (Table 5.4). Highest number of species was recorded for Urticaceae (14 spp) followed by Rosaceae (13 spp), Asteraceae (11 spp), Lauraceae (9 spp) and Rubiaceae (8 spp). There are at least 43 families having 2 or more species and 29 families with a single species (Fig 5.7d).

Floristically this forest is similar to Wet Temperate Forest in species composition where *Lithocarpus pachyphylla* (Kurz) Rehder is the prominent species contributing an IVI value of 57.11 in which RDm accounts to 34.29 followed by RD (13.07) and RF (9.76). The species shows ubiquitous distribution with a Frequency of 88.89% and a Density of 72.22 individuals/ha. *Acer campbellii* Hiern [IVI = 24.34; F = 66.67] and *Rhododendron grande* Wight [IVI = 24.14; F = 77.78] are some of the important species of this forest type that shows regular occurrence with a Density of 30.56 and 55.56 individuals/ha. (Annexure I, Table 7). *Arundinaria racemosa* Munro dominates the shrub layer. Other important species of this layer are *Pilea scripta* (D. Don) Weddell, *Sarcococca hookeriana* Baillon, *Viburnum erubescens* DC. and *Smilax rigida* Wallich ex Kunth (Annexure II, Table 7). In the herb layer *Elatostema obtusum* Weddell, *Pilea symmeria* Weddell and *Persicaria chinensis* (L.) H. Gross are prominent (Annexure III, Table 7).

Shannon-Weiner index of diversity for this forest is fairly good with 3.99 for the vegetation, for tree layer it is 3.08, shrub layer 2.16 and for herb layer it is 3.26 (Fig 5.3). Here too like the Wet Temperate Forests, the ground cover vegetation is rich compared to

tree and shrub layers. Tree layer has a good diversity; the shrub layer is poor in species composition. *Simpson's index* shows low value of dominance except for shrub layer. It is 0.05 for the forest type, 0.06 for tree layer, 0.22 for shrub and 0.08 for herb layers (Fig 5.4). *Menhinick's index* for species richness was found to be moderate with 2.87 for the forest type, for tree species it is 2.48, for shrub it is 1.13 and for herb layer it is 2.16 (Fig 5.5). *Margalef's index* for richness shows 24.78 for the forest type, 6.42 for tree, 5.97; for shrub and 14.54 for the herb layer (Fig 5.6). The species richness is good for the ground cover vegetation.

The forest type is fairly good in species diversity and richness with low concentration of dominance. Herb layer is particularly rich in species diversity and richness. Tree layer also shows fairly good species richness but species belonging to shrub layer shows high abundance of one or few species as reflected in their concentration of dominance values.

5.2.8 *Alnus* Forests

In this forest types 9 sample plots were laid covering 0.36 ha. A total number of 87 species under 80 genera and 47 families have been recorded (Table 5.3b). Tree accounts for a mere 12 species with 106 individuals. Shrub and herb layer comprises 23 and 48 species respectively (Table 5.3a). Density of trees is determined at 294.44 individuals/ha; lowest among all forest types. Basal area has been calculated at 50.17 m^2/ha (Table 5.4). The highest number of species was recorded for Asteraceae (9 spp) followed by Poaceae (6 spp), Lamiaceae (5 spp) and Urticaceae (5 spp). There are at least 18 families having 2 or more species and 29 families with a single species (Fig 5.7n).

Bulk of the tree layer is composed of *Alnus nepalensis* D. Don which alone contributes an IVI score of 132.74; where RDm has a share of 77.57 followed by RF (33.33) and RD (21.84) (Annexure I, Table 8). The species shows 100% Frequency and a considerably higher Density of 158.33 individuals/ha. In the shrub layer, *Eupatorium adenophorum* Sprengel, *Thysanolaena maxima* (Roxburgh) Kuntze and *Leucosceptrum canum* Smith are some of the important species in this layer (Annexure II, Table 8). While *Oplismenus compositus* (L.) P. Beauvois, *Persicaria chinensis* (L.) H. Gross and *Commelina benghalensis* L. are some of the important species in the herb layer (Annexure III, Table 8).

Shannon-Weiner index for species diversity was found to be low with 3.14 for the vegetation, for tree layer it is 1.38; shrub and herb layers recorded a values of 2.22 and 2.09, respectively (Fig 5.3). Low species diversity value for tree layer is due to almost pure stand of *Alnus nepalensis*. Shrub layer shows high diversity compared to tree and herb layers. However, concentration of dominance is comparatively low for the vegetation with 0.08; high for the tree layer with 0.37, for shrub it is 0.19 and for herb layer it is 0.07 (Fig 5.4). *Menhinick's index* shows low species richness for this forest type with 1.40, for tree layer it is 1.17, 1.09 for shrub layer and herb layer shows the lowest value of 1.05 (Fig 5.5). *Similarly Margalef's index* also shows poor species richness with 10.70 for the forest type, 2.36 for tree layer, 3.61 for shrub layer and 6.34 for the herb layer (Fig 5.6)

The forest type shows a mixed diversity trend where shrubs show high species diversity; whereas, herb layer shows good species richness and tree layer showing low diversity and richness.

5.2.9 Conifer Forests

Three sample plots were laid in this forest type and 2462 individuals were recorded. A total of 81 species belonging to 61 genera and 35 families (Table 5.3b) have been registered from this forest type. Tree layer comprised of only 9 species with 106 stands. Shrub and herb layer recorded 17 and 49 species respectively (Table 5.3a). Tree density for this forest was 883.33 individuals/ha, which is highest among various forests in Darjiling hills. The total basal area calculated was 100.42 m^2/ha (Table 5.4). Family-wise representation showed highest number of species for Orchidaceae (8 spp), followed by Rosaceae (8 spp), Ericaceae (6 spp) and Convallariaceae (6 spp). There are at least 17 families having 2 or more species and 18 families with a single species (Fig 5.7o).

The forest type is dominated by *Rhododendron arboreum* Smith and *Abies densa* Miller *Rhododendron arboreum* Smith exhibited the highest IVI score of 92.95 in which RDm contributed 38.88 followed by RD (38.68) and RF (15.38). The species showed high Frequency of 66.67% and a very high Density of 341.67 individuals/ha. *Abies densa* Miller show an IVI score of 80.56 where RDm is 32.15 followed by RD (33.02) and RF (15.38). This species also shows high Frequency of 66.67% and a good Density of 291.67 individuals/ha. *Tsuga dumosa* (D. Don) Eichler [IVI = 41.31; F = 41.31%] is another

equally important species of this forest type. The species have high Density of 75 individuals/ha (Annexure I, Table 9). Like other forest types from high altitude, the shrub layer shows high preponderance of *Arundinaria racemosa* Munro. *Daphne bholua* D.Don also frequent occurrence in this layer (Annexure II, Table 9). In herb layer important species includes *Bistrota emodi* (Meisner) Hara, *Elatostema sessilis* L., *Cyperus squarrosus* L. etc with good abundance (Annexure III, Table 9).

Shannon-Weiner index for species diversity was calculated to be 3.18 for the forest type, 1.57 for tree layer 1.79 for shrub layer, which is the lowest value among all forests, and 2.01 for the herb layer (Fig 5.3). Like rest of the vegetation of high altitude, ground cover vegetation is rich in species diversity. Shrub layer also shows moderate to low species diversity. *Simpson's index* calculated for the vegetation shows 0.08 for the forest type, 0.28 for tree layer, which is significantly higher, and for herb layer it is 0.048 (Fig 5.4). Concentration of dominance for the forest is highest for shrub layer. The ground cover shows heterogeneous species distribution reflected by their low dominance value. *Menhinick's index* of species richness shows poor value where species richness for the forest type is 1.63. Values for tree, shrub and herb layers show 0.87, 1.19 and 1.11 respectively (Fig 5.5). *Margalef's index* for species richness shows similarity with that of *Menhinick's index* where the index value is lowest for herb layer with 6.33, it is 10.24 for the forest type, 1.72 for tree layer and for shrub it is 3.37 (Fig 5.6).

The Temperate – Sub-alpine location of this vegetation has supported few tree and shrub species leading to poor species diversity and richness. The ground cover vegetation though having good scores is not impressive in comparison to other forest types in this climatic zone.

5.2.10 Sub-Alpine Scrub

In this vegetation type 22 sample plots of 5 × 5 m were laid covering a total area of 0.55 ha. A total of 100 species have been recorded belonging to 76 genera and 42 families (Table 5.3b). The numbers of individuals encountered in this vegetation were 5884. Because of very few scattered and stunted growth of tree species in this vegetation, they were considered in the shrub layer. No separate study on tree species has been carried due to this reason. In the shrub layer 35 species and in herb layer 71 species were recorded

(Table 5.3a). Family-wise representation showed highest number of species for Rosaceae (12 spp) followed by Asteraceae (8 spp), Gentianaceae (6 spp) and Ranunculaceae (6 spp). There are at least 21 families having 2 or more species and 21 families with a single species (Fig 5.7m).

Important shrub species of this vegetation includes *Arundinaria racemosa* Munro and *Daphne bholua* D. Don. These species show ubiquitous distribution in this vegetation (Annexure II, Table 10). In the herb layer *Iris clarkei* Hook. f., *Saxifraga gageana* W.W. Smith and *Fragaria nubicola* (Hook. f.) Lacaita are some of the important species having good abundance (Annexure III, Table 10).

Shannon-Weiner index for species diversity among different forest type shows good diversity with 3.58 for the vegetation; moderate for shrub layer with 2.08, however, it showed highest value of 4.49 for herb layer (Fig 5.3). Most interestingly, concentration of dominance (*Simpson's index*) was also found to be highest for herb layer compared to other forest types with 0.144. The dominance value was low for overall vegetation with 0.05 and high for shrub layer with 0.20 (Fig 5.4). *Menhinick's index* shows poor species richness for the vegetation with 1.34, which again is the least. Shrub and herb layer is also poor showing a value of 1.11 and 1.08 respectively (Fig 5.5). *Margalef's index* also shows a similar trend, where species richness is lowest for the vegetation with 9.33, for shrub it is 4.17 and for herb layer it is 6.84 (Fig 5.6).

This vegetation being highly disturbed by various biotic and natural forces, and is therefore poor in species diversity and richness. Trees are almost absent; shrubs are scanty. This has led to the development of rich ground cover vegetation.

5.2.11 Bamboo Brakes

In this forest type 12 sample plots were laid covering an area of 0.48 ha. A total of 142 species with 2282 individuals have been recorded belonging to 118 genera and 61 families (Table 5.3b). Tree species comprise of 41 species with 1104 individuals of which, only 103 stands are of woody dicotyledonous plants, rest 1001 individuals are of *Dendrocalamus hamiltonii* Munro. Shrub and herb layers recorded 55 and 84 species respectively (Table 5.3a). Tree density for this forest type was calculated to be 2333 individuals/ha (for all

species); 214.6 individuals/ha for the woody species and the total basal area was determined at 23.64 m^2/ha for the vegetation (Table 5.4). Highest number of species was recorded for Euphorbiaceae (8 spp) followed by Lauraceae (7 spp), Verbenaceae (7 spp), Acanthaceae (6 spp), Rubiaceae (6 spp), and Urticaceae (6 spp). There are at least 29 families having 2 or more species and 32 families with a single species (Fig 5.7i).

This forest type is dominated by *Dendrocalamus hamiltonii* Munro with an IVI score of 139.38 in which RD contributes to 90.67 followed by RDm (33.9) and RF (14.82). The species shows 100% Frequency and a Density of 2085.42 individuals/ha. Few aggressive tree species shows regular occurrence. Important species that almost occurs along with Bamboo Brakes are *Schima wallichii* (DC.) Korthals with an IVI score of 23.59 in which RDm contributes highest of 19.16 followed by RF (3.70) and RD (0.73). This species however, shows low Frequency of 25% and Density of 16.67 individuals/ha. *Bombax ceiba* L. [IVI = 18.18] shows higher occurrence with 66.67% Frequency with a Density of 33.33 individuals/ha. (Annexure I, Table 10). Shrub layer constitutes an important component of this vegetation. *Clerodendrum viscosum* Ventenat is the most important species followed by *Strobilanthes auriculata* Nees, *Pilea scripta* (D. Don) Weddell and *Eupatorium odoratum* L. are some of the important species in this vegetation (Annexure II, Table 11). In the herb layer *Oplismenus burmanii* (Retzius) P. Beauvois, *Ageratum conyzoides* L. and *Dicanthium annulatum* (Forsskal) Stapf are some of the important species in this vegetation (Annexure III, Table 11).

Species diversity (*Shannon-Weiner index*) in this forest has been calculated to be least with 3.00, for tree layer it is 0.61, shrub layer shows good diversity with 3.15 and the herb layer with moderate species diversity of 2.04 (Fig 5.3). Dense bamboo brakes have prevented normal growth and development of other tree species. Elimination of bigger trees created open space, where large number of shrubby species has successfully established, moreover, saplings have also contributed to high diversity in this layer. Concentration of dominance (*Simpson's index*) shows high values of the vegetation and the tree layer. The vegetation shows highest concentration value of 0.21 among different forest types. Tree layer recorded the highest value of 0.82, thereby indicating highly homogeneous nature of the tree layer brought about by *Dendrocalamus hamiltonii* Munro. The trend however, is not seen in the shrub and the herb layer, each with low score of 0.07 and 0.013 respectively

(Fig 5.4). *Menhinick's index* for species richness shows moderate richness with 2.97 for the vegetation, 1.23 for tree layer, 2.23 for shrub layer and 2.16 for herb layer (Fig 5.5). *Margalef's index* also shows a similar trend with 18.2 for all species, 5.71 for tree species, 8.4 for shrub and 11.33 for herbs (Fig 5.6).

This forest type has resulted from clearing of forests that have developed almost pure stand of *Dendrocalamus hamiltonii* and are homogeneous, leading to low species diversity and richness. Ample space created by various factors in this forest has led to growth and development of large number of shrub and herb species, which is reflected by their diversity values.

5.2.12 *Rhododendron* Forests

In this forest type 5 sample plots were laid covering 0.2 ha. Altogether 2600 individuals belonging to 121 species under 92 genera and 51 families have been recorded (Table 5.3b). There are 19 species in the tree layer with 122 stands. Shrub and herb layers recorded 22 and 82 species respectively (Table 5.3a). The tree density was 610 individuals/ha. Total basal area was calculated to be 82.67 m^2/ha (Table 5.4). Family-wise representation showed high number of species for Rosaceae (15 spp), Asteraceae (7 spp), Ericaceae (7 spp), and Urticaceae (6 spp). There are at least 28 families having 2 or more species and 23 families with a single species (Fig 5.7k).

Most prominent species in this forest type is *Rhododendron arboreum* Smith with an IVI value of 138.54 in which RDm accounts for 72.91 followed by RD (50.00) and RF (15.63). The species shows 100% Frequency and high Density of 305 individuals/ha. *Rhododendron falconeri* Hook. f. [IVI = 21.90; F = 20%] and *Lithocarpus pachyphylla* (Kurz) Rehder [IVI = 18.21; F = 40%] are important associates with a Density of 70 and 25 individuals/ha (Annexure I, Table 11). Like rest of the vegetation from high altitude *Arundinaria racemosa* Munro is the prominent species followed by *Viburnum erubescens* DC. and *Rubus thomsonii* Focke in shrub layer for this forest type and constitutes important component of this layer (Annexure II, Table 12). Whereas, *Cyperus squarrosus* L., *Fragaria rubiginosa* Lacaita and *Gaultheria nummularioides* D. Don are some of the important species of ground cover (Annexure III, Table 12).

Species diversity (*Shannon-Weiner index*) for this forest has been found to be moderate with 3.86 for the vegetation, 1.98 for tree layer, 1.90 for shrub layer and 2.28 for the herb layer (Fig 5.3). Like rest of the forest types from upper hills, ground cover vegetation shows good diversity compared to other layers. Tree and shrub layers show low diversity. Concentration of dominance was 0.04 for the vegetation, 0.28 for tree layer, 0.22 for shrub layer, which is higher in these layers and 0.015 for the herb layer (Fig 5.4). *Menhinick's index* of species richness was found to be 2.39 for the vegetation, 1.72 for tree layer, 0.83 for shrub, lowest among different forest types and for herb layer the value was 1.99 (Fig 5.5). Similarly, *Margalef's index* shows similar trend with 15.39 for the vegetation, 3.75 for tree layer, for shrub layer it was 3.21 and finally for herb layer it is 10.89 (Fig 5.6).

The forest type is moderate in species diversity and richness. Like all the high altitude vegetation, this forest type shows good diversity for ground vegetation. Tree and shrub layer shows low diversity and richness.

5.2.13 Open Scrub

Five sample plots of 5 × 5 m size were laid in this vegetation. A total of 3101 individuals belonging to 75 species under 69 genera and 45 families have been recorded (Table 5.3b). Because of very few scattered tree species, study of tree layer is not included; however, these trees have been treated under shrub layer as has been done in Sub-alpine Scrub vegetation. Altogether 25 species in shrub and 55 species in herb layers were recorded from this vegetation (Table 5.3a). Family-wise representation showed high number of species for Asteraceae (8 spp), Cyperaceae (5 spp), Poaceae (5 spp), and Rubiaceae (5 spp). There are at least 13 families having 2 or more species and 32 families with a single species (Fig 5.7p).

This vegetation is dominated by *Eupatorium adenophorum* Sprengel *Aconogonon molle* (Meisner) Reichenbach, *Osbeckia stellata* Ker-Gawler, *Dichroa febrifuga* Loureiro are some of the important species of this vegetation with good abundance (Annexure II, Table 13). Whereas, *Erigeron karvinskianus* DC., *Chamabainia cuspidata* Wight, *Poa annua* L. are important species in the herb layer (Annexure III, Table 13).

Species diversity (*Shannon-Weiner index*) was found 3.13 for the vegetation, 1.93 for shrub layer and 2.61 for the herb layer (Fig 5.3). Concentration of dominance has been calculated to be 0.07 for the vegetation, 0.27 for shrub layer and 0.065 for herb layer (Fig 5.4). *Menhinick's index* of species richness was found to be lowest for the vegetation with 1.34, whereas shrub and herb layers too exhibited poor richness with 1.11 and 1.08 respectively (Fig 5.5). *Margalef's index* showed similar trend with 9.33 for the vegetation, which is the lowest value, shrub layer with 4.17 and for the herb layer it was 6.84 (Fig 5.6).

This vegetation is moderate in species diversity but poor in species richness. Few species in shrub layer show clear dominance. Herb layer showed rich species diversity and richness.

5.2.14 Teak Plantations

Eleven sample plots were laid in this vegetation covering 0.44 ha. A total of 5693 individuals were recorded belonging to 132 species distributed in 110 genera and 54 families (Table 5.3b). 19 species of trees with 152 individuals were recorded from the tree layer, 53 species in shrub and 68 species in herb layer (Table 5.3a). Tree density was calculated to be 345.45 individuals/ha and the total basal area was calculated at 36.51 m^2/ha (Table 5.4). Family-wise representation showed high number of species for Fabaceae (11 spp), Orchidaceae (9 spp) and Acanthaceae (8 spp). There are at least 24 families having 2 or more species and 30 families with a single species (Fig 5.7j).

Tectona grandis L.f. forms bulk of the vegetation contributing more than one half of IVI score with 175.33 in which RDm contributes 82.84 followed by RD (69.08) and RF (23.40). The species shows high Density of 238.64 individuals/ha. *Bombax ceiba* L. [IVI = 23.77; F = 36.36%] is another important species in this vegetation (Annexure I, Table 12). But they show poor occurrence as can be seen from the Density value. The high IVI score is due to high BA for the species. In the shrub layer, importance species includes *Coffea bengalensis* Schultes, *Eupatorium odoratum* L. and *Clerodendrum viscosum* Ventenat (Annexure II, Table 14). *Globba racemosa* Smith, *Coffea bengalensis* Schultes and *Auxonopus compresus* (Sw.) P. Beauvois makes up an important component in the herb layer (Annexure III, Table 14).

Shannon-Weiner index for species diversity calculated for this type shows 3.17, for tree layer it is 1.41, for shrub layer it is 1.96 and for herb layer, it is 2.29 (Fig 5.3). *Simpson's index* for concentration of dominance shows 0.01 for the plantation forest, higher for tree layer with 0.49, 0.29 for shrub layer and 0.075 for herb layer (Fig 5.4). *Menhinick's index* of species richness shows lower value for this forest with 1.76, for tree layer it is 1.54, 1.08 for shrub layer and 1.43 for the herb layer (Fig 5.5). A similar trend is observed in *Margalef's index* with 15.27 for the vegetation, 3.58 for tree layer, 6.67 for shrub layer and 8.77 for the herb layer (Fig 5.6).

High concentration of Teak species (*Tectona grandis*) has a direct influence in the species diversity and richness as reflected by its low value. The ground cover vegetation shows comparatively good diversity and richness.

5.2.15 *Cryptomeria* Plantations

In this plantation forest 4 quadrates were laid. A total of 1905 individuals belonging to 107 species distributed in 82 genera and 48 families were recorded (Table 5.3b). Tree comprises of a mere 6 species with 106 stands, shrub and herb layers comprises 29 and 60 species respectively (Table 5.3a). The tree density for was calculated at 767 individduals/ha. Total basal area was found to be 64.53 m^2/ha (Table 5.4) for this forest. Family-wise representation showed high number of species for Asteraceae (7 spp), Lamiaceae (6 spp), Poaceae (6 spp), Rosaceae (6 spp) and Urticaceae (6 spp). There are at least 24 families having 2 or more species and 24 families with a single species (Fig 5.7l).

The IVI value for *Cryptomeria japonica* (L.f.) D. Don is calculated to be 236.09 in which RDm contributed 99.78 followed by RD (91.87) and RF (44.44) (Annexure I, Table 13). This species shows very high Density of 706.25 of the total 768.75 individuals/ha. In the shrub layer, *Strobilanthes echinata* Nees, *Eurya acuminata* DC. and *Rubus moluccanus* L. are some of the important species of this vegetation (Annexure II, Table 15). In the herb layer, important species includes *Elatostema sessilis* Forster, *Oplismenus compositus* (L.) P. Beauvois and *Cyperus cyperoides* (Retzius) Kuntze for this vegetation (Annexure III, Table 15).

Species diversity (*Shannon-Weiner index*) for the plantation forest has been calculated to be 3.86. Diversity value calculated for various layers shows 0.40 for tree layer, lowest among forest types. Shrub layer recorded fairly good diversity with 2.62 and for herb layer it is 1.78 (Fig 5.3). This plantation forest exhibited low concentration of dominance with 0.03. However, tree layer recorded 0.85; highest dominance for the vegetation, which is in conformity with low species diversity. Shrub and herb layers show moderate dominance with 0.11 and 0.010 respectively (Fig 5.4). *Menhinick's index* of species richness was calculated to be moderate for the forest with 2.50; tree layer recorded lowest value for the forest with 0.54, for shrub and herb layers it is 1.64 and 1.86 respectively (Fig 5.5). *Margalef's index* shows similar trend with 14.30 for the vegetation, lowest for tree layer of 1.04, for shrub layer it is 4.87 and for herb layer it is 9.21 (Fig 5.6).

Highly homogeneous nature of this forest with *Cryptomeria japonica* contributing 2/3rd of IVI value for vegetation is the reason for low species diversity and richness, which is reflected in its high dominance. The ground cover vegetation was rich in species composition; shrub layer is poorly represented.

5.2.16 Degraded Forests

In this forest type 9 sample plots were laid covering 0.36 ha. A total of 2855 individuals belonging to 164 species distributed in 125 genera and 67 families (Table 5.3b) have been recorded. There are 31 species of trees, 44 species of shrubs and 53 species of herbs in the vegetation (Table 5.3a). 699 individuals were registered from the tree layer of these only 69 individuals belong to dicotyledonous tree-species; rest 623 individuals are of *Dendrocalamus hamiltonii*. The tree density in this forest type is found to be 2389.386 individuals/ha including bamboos and 271.43 individuals/ha for the woody species. Total basal area, one of the lowest for the forest type has been recorded from this vegetation. It is calculated to be 25.82 m^2/ha (Table 5.4). Highest number of species was recorded for Acanthaceae (9 spp) followed by Euphorbiaceae (8 spp), Poaceae (8 spp) and Fabaceae (7 spp). There are at least 34 families having 2 or more species and 33 families with a single species (Fig 5.7g).

Dendrocalamus hamiltonii Munro have extensively invaded the available spaces in this forest type which is reflected by its high IVI score of 137.31 in which RD contributes

89.13 followed by RDm (35.45) and RF (12.73). The species shows 100% Frequency and a Density of 2225 individuals/ha. Woody species having high importance value is *Bauhinia purpurea* L. [IVI = 27.18; F = 14.29%]. Among the Bamboo Brakes, some resistant species with frequent occurrence includes *Heteropanax fragrans* Seemann [IVI = 11.90; F = 71.43%], *Schima wallichii* (DC.) Korthals [IVI = 10.21; F = 57.14%] etc. (Annexure I, Table 14). In shrub layer, *Clerodendrum viscosum* Ventenat, *Sauropus androgynous* (L.) Merrill, *Soriudeia madagascarensis* DC. and *Desmodium motorium* (Houttyn) Merrill are some important species (Annexure II, Table 16). All these species shows a good abundance in this vegetation type. In the herb layer *Dicanthium annulatum* (Forsskal) Stapf, *Strobilanthes auriculata* Nees and *Dicliptera bupleuroides* Nees are some of the important components of this vegetation (Annexure III, Table 16).

Shannon-Weiner index for species diversity for the vegetation was calculated to be 3.85, 0.66 for tree layer, 2.93 for shrub layer and 1.05 for herb layer (Fig 5.3). Concentration of dominance for this forest type was 0.06; high dominance was recorded for tree layer with 0.80, but shrub and herb layers show low value with 0.09 and 0.004, respectively (Fig 5.4). Species richness (*Menhinick's index*) for this forest type is found to be 3.10; 1.17 for tree layer, 1.77 for shrub layer and 2.07 for herb layer (Fig 5.5). Similarly, *Margalef's index* has been calculated to be 20.72 for the vegetation, 4.58 for tree, 6.70 for shrub and 8.23 for herb layers (Fig 5.6).

Despite being disturbed, the vegetation shows moderate value for species diversity and richness, however, the tree layer is poor as has been reflected by different diversity indices. The ground cover vegetation is rich and the shrub layer also shows good representation.

5.3 Similarity index

Comparison between different forest types was done to understand their phyto-sociological affinities and overall similarity among these vegetation types (Table 5.6). Permutation combinations for sixteen forests show greater heterogeneity among high altitude vegetations, whereas lower hills are more homogeneous and similar. Among the 120 different combinations, 43 pairs show species similarity above 40%. Seven forest types from lower hills are sharing moderate to high percentage of common species with 3 or more vegetations thereby indicating a homogeneous nature; whereas, species similarity

shared by the vegetations of upper hills are less in number indicating greater heterogeneity. However, three pairs from upper hills and two pairs from the lower hills shows high similarity percentage (>50%). Similarity between the upper and lower hills shows very low or insignificant values. A wide difference in altitude, climate, and geomorphic features of the upper hill with lower hills has brought about significant difference in their species composition, which is evident from poor (low) similarity percentage values between vegetations from these two ecological zones.

Wet Temperate Forests shows highest similarity with Temperate Broad Leaved Forests where 79.98% of species are common to both forest types. However, owing to the difference in the spectral signature, these two forests have been segregated into two distinct types, otherwise these vegetations are same. Although Temperate Broad Leaved Forest recorded highest species similarity with Conifer Forests, Sub-Alpine Scrub and *Cryptomeria* Plantation, but the values are not significant. These forest types share 28.35%, 36.43% and 34.78% common species respectively. Sub-Alpine Scrub shares 67.86% similar species with *Rhododendron* Forests; it also shows good similarity with Open Scrub with 50.35% species. *Rhododendron* Forests also shows good similarity with Temperate Broad Leaved Forests with 47.79%, moderate with Wet Temperate Forests and Conifer Forest with 36.58% and 37.43% similar species respectively. Among the lower hill forests, Himalayan Sal Forests shows 65.31% similarity with Moist Mixed Deciduous Forest. Both these forest types show good similarity with Riverine Forests, Bamboo Brakes, Teak Plantations and Degraded Forests ranging from 36.81 – 43.20%. Bamboo Brakes shows high similarity with Degraded Forest having 60.68% common species. Tropical Semi-evergreen Forests shows moderate to high species similarity with Moist Mixed Deciduous Forests, Sub-Tropical Broad Leaved Hill Forests and with Bamboo Brakes sharing 47.86%, 41.01% and 42.73% respectively.

Bamboo Brakes show an interesting feature; it shares high number of species with other forest types of lower hills (Tropical Semi-evergreen Forests, Himalayan Sal Forests, Moist Mixed Deciduous Forest, Riverine Forests and Sub-Tropical Broad Leaved Hill Forests and Degraded Forests) with more than 40%. More tolerant coloniser species with greater ecological amplitude already existing in the adjacent forests may have invaded this vegetation leading to high common species. Himalayan Sal Forests, Moist Mixed

Deciduous Forests and Riverine Forests also show homogeneous species composition, sharing high number of species, with at least 5 other forest types from the lower hills. The close proximity of these forests having similar climatic and edaphic conditions are responsible for such high similarity value. Sub-Tropical Broad Leaved Hill Forests is another forest type showing moderate similarity with both lower and the upper hills of Darjiling. Though this forest type does not show very high similarity value, but it shares good number of common species from both ecological zones. This is the reason why this zone has high species diversity and richness.

Plate 1

Different forest types found in Darjiling Hills

Semi-evergreen Forest

Moist Mixed Deciduous Forest

Himalayan Sal Forest

Sub-Tropical Broad Leaved Hill Forest

Wet Temperate Forest

Conifer Forest in SNP

Plate 2

Different forest types found in Darjiling Hills

Rhododendron forest in full bloom in SNP

Sub-Alpine Scrub in SNP

Degraded Forest

Teak Plantation

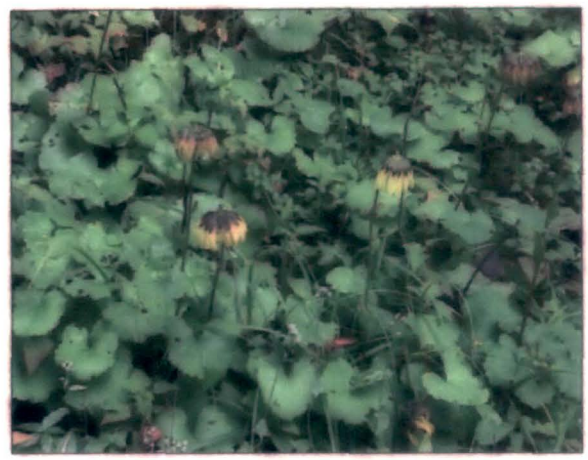
Cryptomeria plantation

Alnus Forest

Plate 3

Endemic plants found in Darjiling Hills

Chirita macrophylla Wallich



Cremanthodium reniforme (DC.) Bentham

Codonopsis affinis Hook. f. & Thomson

Didymocaprus podocarpus Clarke

Arisaema griffithii Schott

Cardiocranium giganteum (Wall.) Makino

Calanthe manii Hook. f.

Plate 4

Medicinal plants of Darjiling Hills

Panax pseudogensin Wall. var *angustifolia* (Burkill) Li.

Aconitum bisma (Hamilton) Rapaics

Polygonatum cirrhifolium (Wall.) Royle

Phlogacanthus thyrsiformis (Hardw.) Mabberley

Mahonia nepaulensis DC.

Hydrocotyl nepalensis Hook.f.

Sida acuta Burman f.

Costus speciosus (J. Konig) Smith

Plate 5

Interesting plants of Darjiling hills

Androsae sermentosa mat in Singalila National Park

Corallodiscus lanuginosus (DC.) B.L. Burtt in Siri Khola (SNP)

Dicentra paucinervia Stern an endemic species from SNP

Monotropa uniflora Linn. from Ramam forest (SNP)

Stemona tuberosa Lour. Recorded for the first time in Darjiling district from Mahananda WLS

Pedicularis furfuracea Bentham endemic species from SNP

Table 5.6: Similarity index of various forest types in Darjiling Hills

TSE	100															
HS	30.19	100														
MMD	47.86	65.32	100													
Riv	29.5	41.94	42.78	100												
STBL	41.01	27.44	30.08	26.95	100											
WT	5.06	6.54	4.49	4.75	13.37	100										
TBL	4.83	5.36	7.30	5.03	11.60	79.98	100									
Aln	14.17	9.16	12.46	10.44	22.41	17.06	14.79	100								
Con	0.00	0.00	0.00	0.00	0.81	24.30	28.35	4.79	100							
SAS	0.74	0.00	0.00	0.79	3.76	28.06	36.43	8.65	32.91	100						
BB	42.73	43.20	41.71	43.21	39.07	8.82	9.15	25.09	0.00	2.35	100					
Rho	0.69	0.00	0.00	0.73	2.80	36.58	47.79	6.83	37.43	67.86	2.79	100				
OS	1.66	2.56	4.15	0.00	3.33	24.68	22.14	24.32	15.07	50.35	4.70	22.47	100			
Tpl	27.27	40.85	40.12	46.75	20.51	2.96	3.51	11.37	0.94	0.85	36.59	0.79	0.96	100		
Cpl	4.44	6.24	5.45	6.32	12.26	30.95	34.78	22.35	11.70	26.14	8.31	27.59	26.99	4.22	100	
Deg	32.39	42.00	36.81	43.24	29.86	4.63	5.44	12.61	0.00	0.00	60.68	0.00	2.52	39.68	4.51	100
Forest Types	**TSE**	**HS**	**MMD**	**Riv**	**STBL**	**WT**	**TBL**	**Aln**	**Con**	**SAS**	**BB**	**Rho**	**OS**	**Tpl**	**Cpl**	**Deg**

TSE: Tropical Semi-evergreen Forests; **HS**: Himalayan Sal Forests; **MMD**: Moist Mixed Deciduous Forests; **Riv**: Riverine Forests; **STBL**: Sub-Tropical Broad Leaved Forests; **WT**: Wet Temperate forests; **TBL**: Temperate Broad Leaved Forests; **Aln**: *Alnus* Forests; **Con**: Conifer Forests; **SAS**: Sub-Alpine Scurb; **BB**: Bamboo Brakes; **Rho**: *Rhododendron* Forests; **OS**: Open Scrub; **Tpl**: Teak Plantation; **Cpl**: *Cryptomeria* Plantation; **Deg**: Degraded Forests

5.4 Endemism

The extent of endemicity of plant species reflects originality of flora for a region. The flora of Darjiling hills has good representation of its indigenous flora *vis-a-avis* endemic species. A total of 126 endemic species have been recorded from the hills during present exploration, out of the known 479 species of endemics for this region (Bhujel and Das 2002; Das 1995, 2004) (Annexure IV). Their vegetation type-wise distribution is shown in Table 5.7. Among these forest-types, higher altitude vegetations in particular, have been found to be very rich in endemic species. Temperate Broad Leaved and Wet Temperate Forests houses 40 each endemic species accounting to 18.78% and 14.65 % of the flora of these forests respectively. Even forest types (insert a few names of forest types) having smaller area, showed the presence of high percentage of endemic species. Conifer Forests, *Rhododendron* Forests, Sub-Alpine Scrub and Open Scrub have fairly good number with 19, 20, 15 and 8 species accounting to 23.46%, 16.53%, 15% and 10.67%, respectively, of their flora. Comparatively the lower hill is vegetations are poor in occurrence of endemic species. Forests with large area coverage like Moist Mixed Deciduous Forests, Tropical Semi-evergreen Forests, Himalayan Sal, Sub-Tropical Broad Leaved Hill Forests, have been found to house moderate number of endemic species with 23, 21, 21 and 18 species accounting to 8.65%, 13.04%, 6.60% and 10.78% respectively. Forests like Bamboo Brakes, Teak Plantations, *Cryptomeria* Plantations, Riverine Forests and Degraded Forests have fewer endemics with 12, 9, 10; 7 and 11 species respectively. On the other hand, *Alnus* Forests had only one endemic species. Percentage distribution of endemic species in different forest is shown in the Fig: 5.8

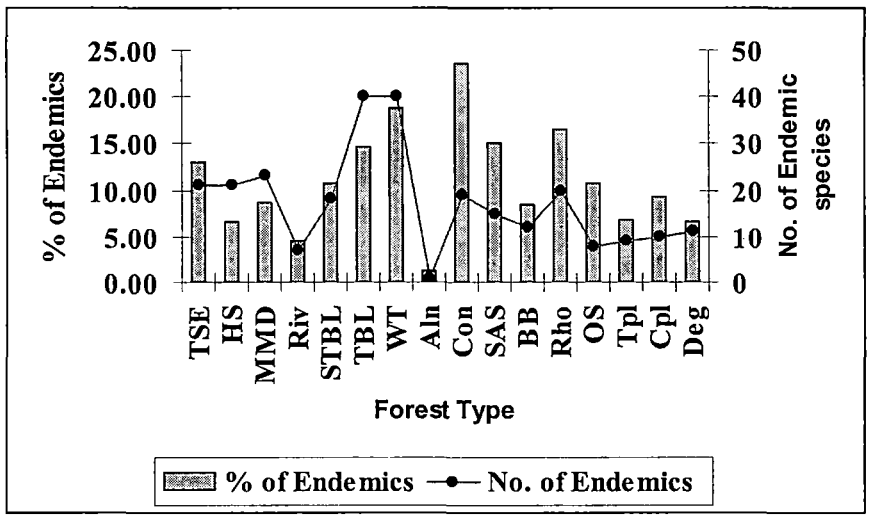


Fig 5.8 Line graph showing the percentage of endemic species in different forest types

Table 5.7 Number of endemic species found in the Darjiling Hills

Sl. No.	Forest Type	Total Species	Endemic Species	% of Endemics
1	Tropical Semi-evergreen Forests	161	21	13.04
2	Himalayan Sal Forests	318	21	5.97
3	Moist Mixed Deciduous Forests	266	23	8.65
4	Riverine Forests	167	7	4.19
5	Sub-Tropical Broad Leaved Forests	152	18	11.18
6	Wet Temperate Forests	273	40	14.29
7	Temperate Broad Leaved Forests	213	40	17.37
8	*Alnus* Forests	87	1	1.15
9	Conifer Forests	81	19	22.22
10	Sub-Alpine Scrub	100	15	14.00
11	Bamboo Brakes	142	12	7.04
12	*Rhododendron* Forests	121	20	16.53
13	Open Scrub	75	8	10.67
14	Teak Plantations	132	9	6.06
15	*Cryptomeria* Plantations	107	10	9.35
16	Degraded Forests	164	11	6.10

5.5 Medicinal plants

A total of 236 species out of 300 medicinal plants reported from the Darjiling Hills (Bhattacharjee, 2001; Rai, 2002, Das and Mandal, 2003) have been recorded in the present study. These medicinal plant species belonging to all life forms have been recorded with their uses and distribution from different forest types and has been presented in Annexure V. These plants are used for treatment of myriad illness, viz. cold and cough, diarrhoea, dysentery, toothache, headache, stomach problem, bleeding gums, cuts and wound and veterinary medication etc. Some of them includes: *Aconitum violaceum* Jacquemont ex Stapf, *Alstonia scholaris* (L.) R. Brown, *Astilbe rivularis* D. Don, *Dichroa febrifuga* Loureiro, *Euphorbia hirta* L., *Holarrhena pubescens* (Buchnan-Hamilton) G. Don, *Rhododendron arboretum* Smith, *Rhus semialata* Murray, *Woodfordia fructicosa* (L.) Kurz, etc. Some of the plant species are sources of potent chemicals used for treating chronic diseases like jaundice, asthma, bronchitis, rheumatic pain, leprosy, gastritis etc. these includes: *Bassia butyracea* Roxburgh, *Berberis asiatica* Roxburgh, *Callicarpa arborea* Roxburgh, *Clerodendrum colebrookeanum* Walper, *Gynocardia odorata* R. Brown, *Vernonia cinerea* (L.) Lessing etc. Some of the species like *Berberis aristata* DC., *Betula utilis* D. Don, *Clematis Buchanania* DC., *Hemidesmus indicus* (L.) Schultes, *Lyonia ovalifolia* (Wallich) Drude, *Sida rhombifolia* L. etc. are also effective in preventing and curing various diseases caused by bacterial, viral and fungal infection. Many of these

species like *Artemisia indica* Willdenow, *Bauhinia vahlii* Wight and Arnott, *Dioscorea deltoidea* Wallich ex Kunth, *Dioscorea prazeri* Prain and Burkill, *Entada rheedii* Sprengel, *Polygonatum verticillatum* (L.) Allioni, *Syzygium cumini* (L.) Skeels are used for promoting general health and are taken as health tonics, aphrodisiacs and post natal health care. Yet some species shows anti-cancerous activities like *Aristolochia platanifolia* Duchartre, *Berberis asiatica* Roxburgh, *Bridelia retusa* (L.) Sprengel, *Curcuma aromatica* Salisbury, *Tetrastigma serrulatum* (Roxburgh) Planchon etc.

Comparison of vegetation-wise occurrence of medicinal plant species exhibited an interesting result. The medicinal plant content for different forest types ranged between 10 - 93 species. Vegetation in lower hills of the district contained high number of medicinal species than their high altitude counterparts (Table 5.8). Himalayan Sal Forests shows highest number of 97 species (29.25%) followed by Moist Mixed Deciduous Forests with 87 species (32.71%), Bamboo Brakes with 75 species (52.82%). Teak Plantations, though having low diversity contributes 51 species is the second highest contributor of medicinal plant resource with 38.64%. This is followed by Sub-Tropical Broad Leaved Hill Forests and Riverine Forests each recorded 61 and 55 species constituting 36.53% and 36.18 % respectively. *Alnus* Forests interestingly contributes 35.63% of medicinal plant sources. Percentage of occurrence of medicinal plant species is shown in Fig 5.9. On the other hand, in higher altitude Wet Temperate Forest recorded highest number of 38 species (13.92%), Temperate Broad Leaved Forests with 27 species (12.68%). Open Scrub with 20 species contributes 26.67%, followed by Sub-alpine Scrub, *Cryptomeria* Plantation and *Rhododendron* Forests with 20, 18 and 19 accounts to 18%, 17.76% and 15.70 % respectively. Conifer Forests recorded the least of 10 species accounting to 12.35%. More extensive survey work with chemical testing need to be carried out for the high altitude plants to know their medicinal property.

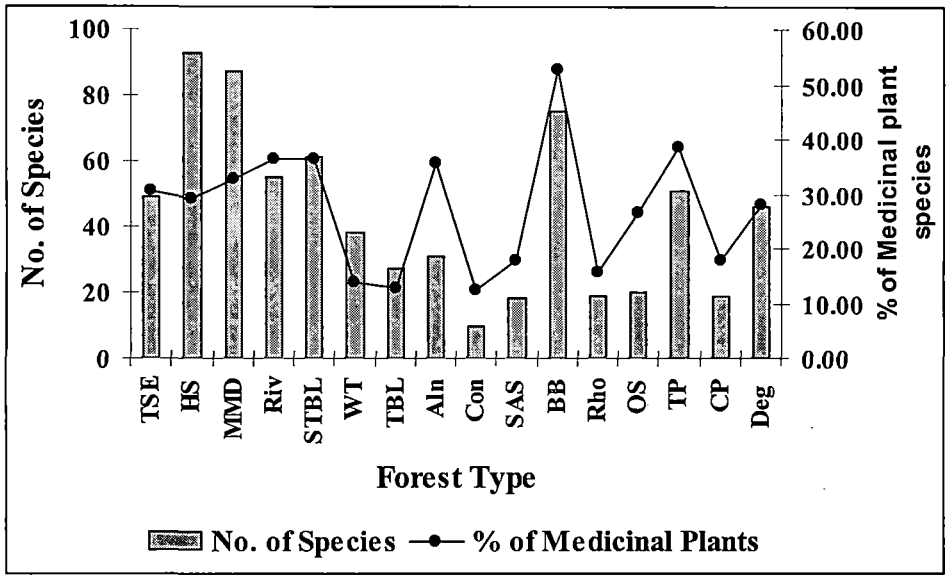


Fig 5.9: Percentage of distribution of medicinal plant species in different forest types

Table 5.8: Number of medicinal plants occurring in various forest types

Sl. No.	Forest types	Total Species	No. of Medicinal species	%
1	Tropical Semi-evergreen Forests	161	49	30.43
2	Himalayan Sal Forests	318	93	29.25
3	Moist Mixed Deciduous Forests	266	87	32.71
4	Riverine forests	152	55	36.18
5	Sub-Tropical Broad Leaved Hill Forests	167	61	36.53
6	Wet temperate Forests	273	38	13.92
7	Temperate Broad Leaved Forests	213	27	12.68
8	*Alnus* Forests	87	31	35.63
9	Conifer Forests	81	10	12.35
10	Sub-alpine scrub	100	18	18.00
11	Bamboo Brakes	142	75	52.82
12	*Rhododendron* Forests	121	19	15.70
13	Open scrub	75	20	26.67
14	Teak plantations	132	51	38.64
15	*Cryptomeria* plantations	107	19	17.76
16	Degraded Forests	164	46	28.05

5. 6 Girth class distribution

Girth size of an individual in vegetation gives indirect clue to the degree of its interaction with different biotic factors and consequently reflects the health of forest. Individuals in higher girth class indicate a mature forest whereas higher number in lower girth size is indicative of developing vegetation, which is of secondary nature. Different individuals encountered in the above mentioned forests have been grouped into five girth-classes as (i)

<50 cm, (ii) 51-100 cm, (iii) 101-150 cm, (iv) 151-200 cm and (v) >200 cm. Distribution of individuals in these GBH classes shows a gradual decreasing pattern from lower to higher GBH group, except for plantation forests. This type of pattern in the forest ecosystem is particularly so due to different age as pointed out by Spies and Turner (1999), where the proportion of various classes across a landscape and over time is one of the fundamental characteristics of the vegetation mosaic. A total of 3072 individuals were encountered during sampling. Number of individuals of tree species recorded in 14 forest types ranged from 82 – 641. Total number of individuals or stands and their distribution in different girth class is provided in Table 5.9. Highest proportion of stands in the <50 cm group was recorded for *Sub-Tropical Broad Leaved Hill Forest* where 98 stands accounted for 60.5% in this class. This is followed by *Moist Mixed Deciduous Forest* with 194 stands accounting to 57.6%. *Degraded Forests* also have a high proportion of individuals in this class with 43 stands (excluding bamboos) accounting to 56.1%. *Himalayan Sal Forests* with 323 of 641 individuals is the next forest type, where the individuals in lower girth class constitute 50.4%. From the higher altitude only *Wet temperate forest* showed high number of individuals in this class with 261 of 517 individuals accounting for 50.5%. These values suggest developing nature of these vegetations. *Wet Temperate Forest* however, is not the same case. High number of individuals in lower GBH is due to the large number of middle canopy species, which is evident from Table 6 of Annexure I.

Some forests have high percentage of individuals in girth class above 100 cm particularly of plantation forests and of high altitude vegetation. Notable among them are *Rhododendron Forests* with 57 of 122 accounting to 46.7% followed by *Conifer Forests* with 47 of 102 individuals accounting to 44.3%, *Temperate Broad Leaved Forests* with 84 of 200 accounting for 42.0%. *Alnus Forests* shows 67 of 106 accounting for 63.2% and *Teak Plantation* with 88 of 154 accounts to 57.1% in this GBH class.

Table 5.9 Number of individuals in different girth size class

Sl. No.	Forest Types	<50 cm	100 cm	150 cm	200 cm	>200 cm
1	Tropical Semi-evergreen Forests	106	70	22	13	13
2	Himalayan Sal Forests	323	146	75	52	45
3	Moist Mixed Deciduous Forests	194	60	30	26	27
4	Riverine Forests	71	57	24	16	16
5	Sub-Tropical Broad Leaved Hill Forests	98	40	9	6	9
6	Wet Temperate Forests	261	114	49	32	61
7	Temperate Broad Leaved Forests	70	46	21	24	39
8	*Alnus* Forests	35	4	11	44	12
9	Conifer Forests	23	36	27	14	6
10	Sub-Alpine Scrub	-	-	-	-	-
11	Bamboo Brakes	58	18	24	18	4
12	*Rhododendron* Forests	24	41	33	13	11
13	Open scrub	-	-	-	-	-
14	Teak Plantations	49	17	61	21	6
15	*Cryptomeria* Plantation	56	32	15	7	5
16	Degraded Forests	46	23	4	3	6

5.6 Landscape analysis

5.6.1 Mask size analysis

The hills of Darjiling have a very complex topography. For landscape analysis use of a unit mask size did not yield better interpretability for certain landscape parameters. Different mask sizes were used that best suits the parameters and explains the landscape characteristics. Hence optimum mask sizes for different parameters were considered separately for final incorporation. Four mask sizes have been used depending upon the suitability for each parameter for interpreting respective parameters. Minimum mask size was determined at 250 m × 250 m and a maximum of 1000m × 1000m. Use of different mask sizes and observations on the effect are given in Table 5.10

Table 5. 10: Mask size sensitivity for different landscape parameters

	Fragmentation	Patchiness	Biotic Buffer	Porosity	Interspersion	Juxtaposition	Disturbance Map Remarks
Map 1	500	500	250	1000	1500	1000	Predictable map
Map 2	500	500	250	1000	1000	750	No apparent difference
Map 3	500	500	250	500	1000	750	Better than the other three maps
Map 4	500	500	250	500	500	500	Buffering distinct not suitable for interpretation

5.6.2 Fragmentation

Fragmentation image obtained shows three levels (Fig 5.10). It has been observed from analysis that the fragmentation level increases with the increased number of non-forest classes. Statistical analysis shows that 1056.48.22 km^2 accounting to 47.42% are pure non-forest excluding rivers/ water bodies and the rejected class (Clouds and Shadow). This is indicative of highly fragmented landscape. This is corroborated by the result that 396.35 km^2 constituting 17.79% of the total hill area are under medium to high level of fragmentation. It accounts to 36.20% of the total forests cover and therefore is significantly fragmented. The area statistics for fragmentation has been provided in Table 5.11.

The area statistics on fragmentation image show 37.69 km^2 and 358.66 km^2 (1.69% and 16.10%) of the forests under high to moderate level of fragmentation and are particularly discernible along forest fringes where village settlements with extensive human activities are taking place. Road sides also show high level of fragmentation. High level of fragmentation is visible in forests of Rammam, Srikhola area in the eastern part of Singalila National Park, Kurseong-Mahaldiram, Singbulli and Tindharia areas in the Kurseong sub-division. In the Kalimpong subdivision high level of fragmentation is visible in reserve forests of Suruk-Samtar, Lolaygoan, Pala, Singi and Samalbong areas. Gokh and Sukhia Pokhria in Darjiling sub-division show large area under high level of fragmentation. Forests along national highway 31A in the Teesta Valley also show high level of fragmentation. Moderate or medium level of fragmentation is visible all along the mid-elevation regions, indicating considerable biotic interference. Closer examination of the fragmentation map revealed that Sub-tropical Broad Leaved Hill Forests are heavily affected and are vulnerable to various anthropogenic pressures being located near the human settlements.

Table 5.11: Area statistics of Fragmentation image

Sl. No.	Levels of Fragmentation	Area (km^2)	% area
1	Low	698.66	31.36
2	Moderate	358.66	16.10
3	High	37.69	1.69
4	Rivers/ water bodies	39.90	1.79
5	Clouds and shadow	36.75	1.65
6	Non-forests	1056.48	47.42
	Total	**2228.13**	**100**

FRAGMENTATION MAP OF DARJILING HILLS

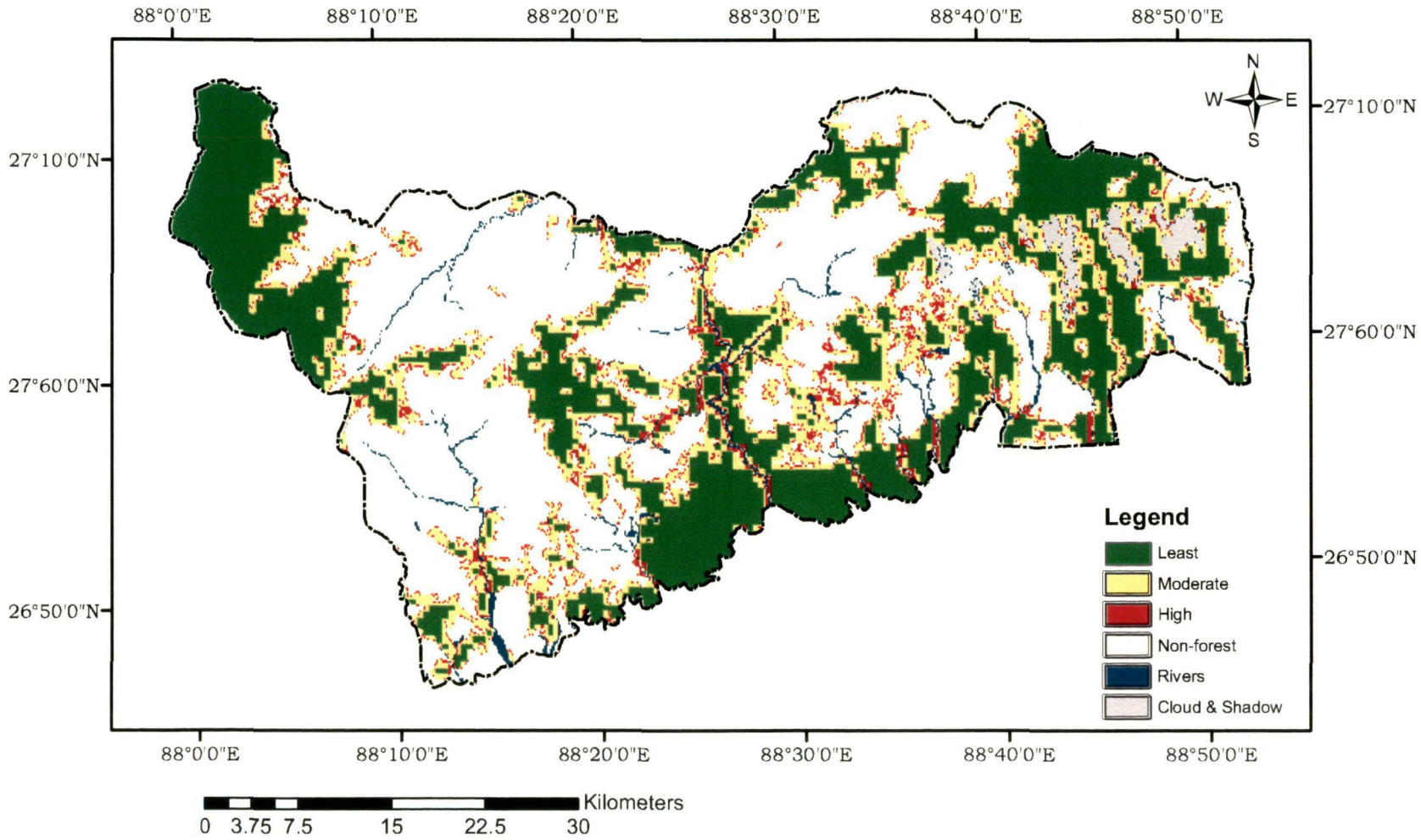


Fig. 5.10

5.6.2 Patchiness

Patchiness is the measurement of density of patches. Patchiness is a common and ubiquitous phenomenon in a forested landscape that reflects its dynamic nature and is a fundamental characteristic of plant communities (Gurevitch *et al.*, 2002). High patchiness index is indicative of its diverse life forms and consequently high degree of dispersion among different vegetation types. Various levels of patchiness in the landscape reflect a mosaic of soil types, topographic conditions, microclimate and successional stages resulting from disturbance. In the present study the non-forest has, however, been taken out of the patch study and only forest land has been considered. Fig 5.11 shows patchiness map of Darjiling hills.

The patchiness image shows a large number of patches scattered non-uniformly throughout the forested landscape. A total of 953.39 km^2 constituting 42.79% of the total hill area falls under low level of patchiness. This however, accounts to 90.18% of the total forest area, thereby indicating more or less homogenous vegetation. Only 130.86 km^2 (5.87%) falls under moderate and 10.76 km^2 (0.48 %) of the forests come under high level of patchiness (Table 5.12). The patchiness image reveals high patchiness along the fringes/ edges of the forested areas, whereas interior of larger forests those are away from human habitations showed low level of patchiness. Large parts of interior or the core region of the forest in the lower hills and the Neora Valley National Park shows low level of patchiness thereby showing great degree of association and hence stable vegetation. Singalila National Park, Senchal Wildlife Sanctuary and reserve forests along the Teesta, however, show maximum number of patches. Higher heterogeneity in these areas has been one of the determinants for higher biodiversity.

Table 5.12: Area statistic of Patchiness image

Sl. No.	Levels of Patchiness	Area (km^2)	% area
1	Low	953.39	42.79
2	Moderate	130.86	5.87
3	High	10.76	0.48
4	Rivers/ water bodies	39.90	1.79
5	Clouds and shadow	36.75	1.65
6	Non-forests	1056.48	47.42
	Total	**2228.13**	**100**

PATCHINESS MAP OF DARJILING HILLS

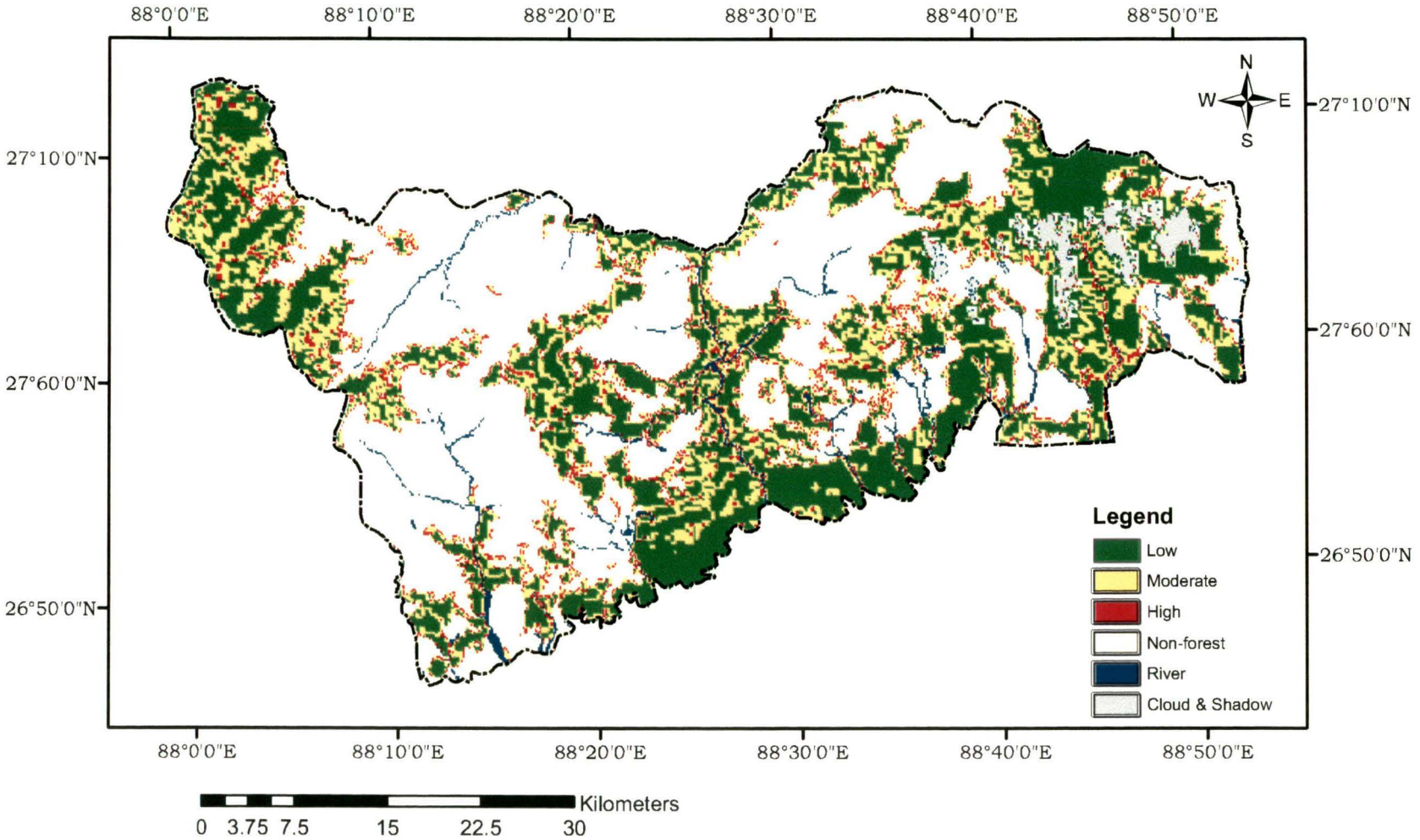


Fig. 5.11

POROSITY MAP OF MOIST MIXED DECIDUOUS FOREST IN DARJILING HILLS

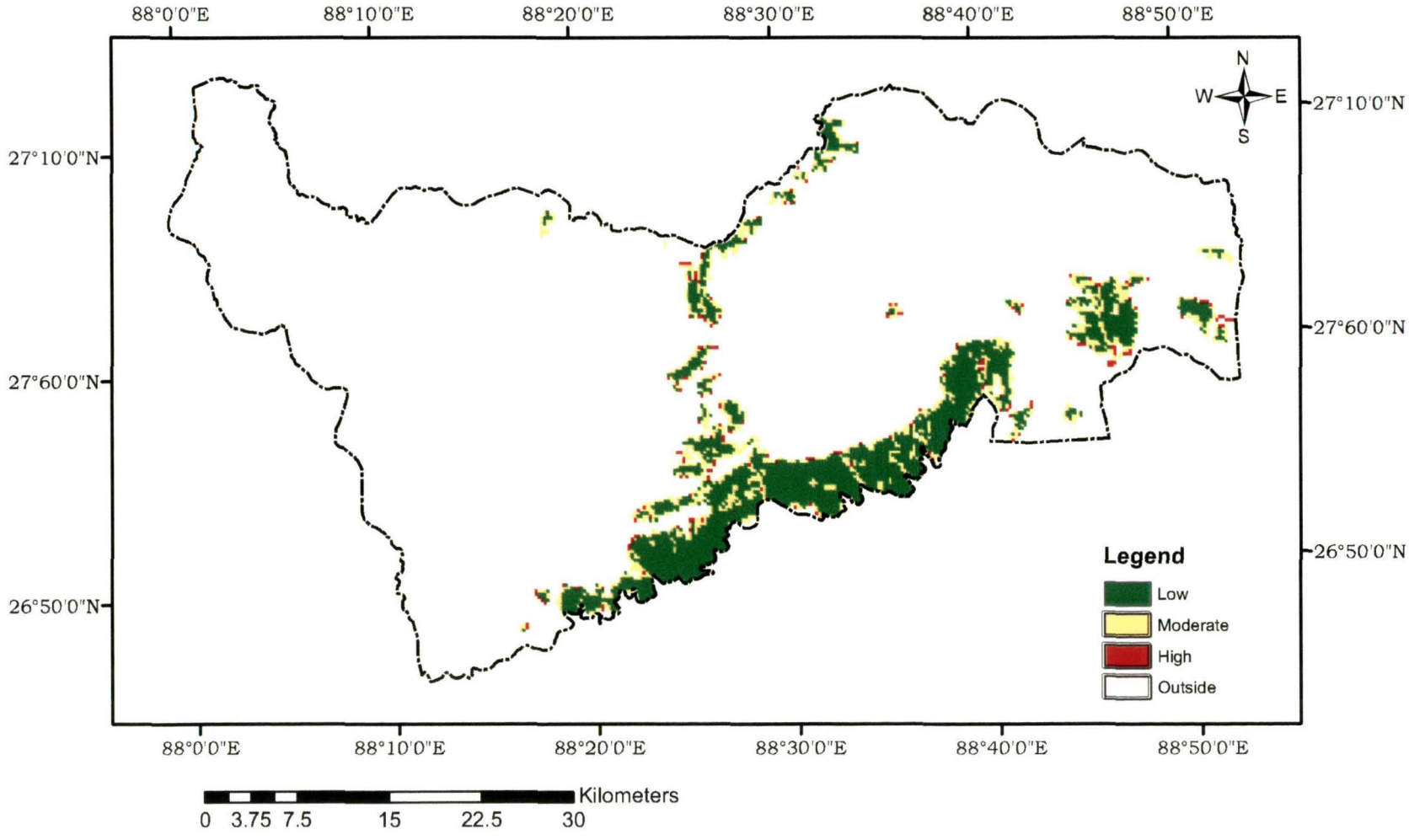


Fig. 5.12a

POROSITY MAP OF SUB-TROPICAL BROAD LEAVED HILL FOREST IN DARJILING HILLS

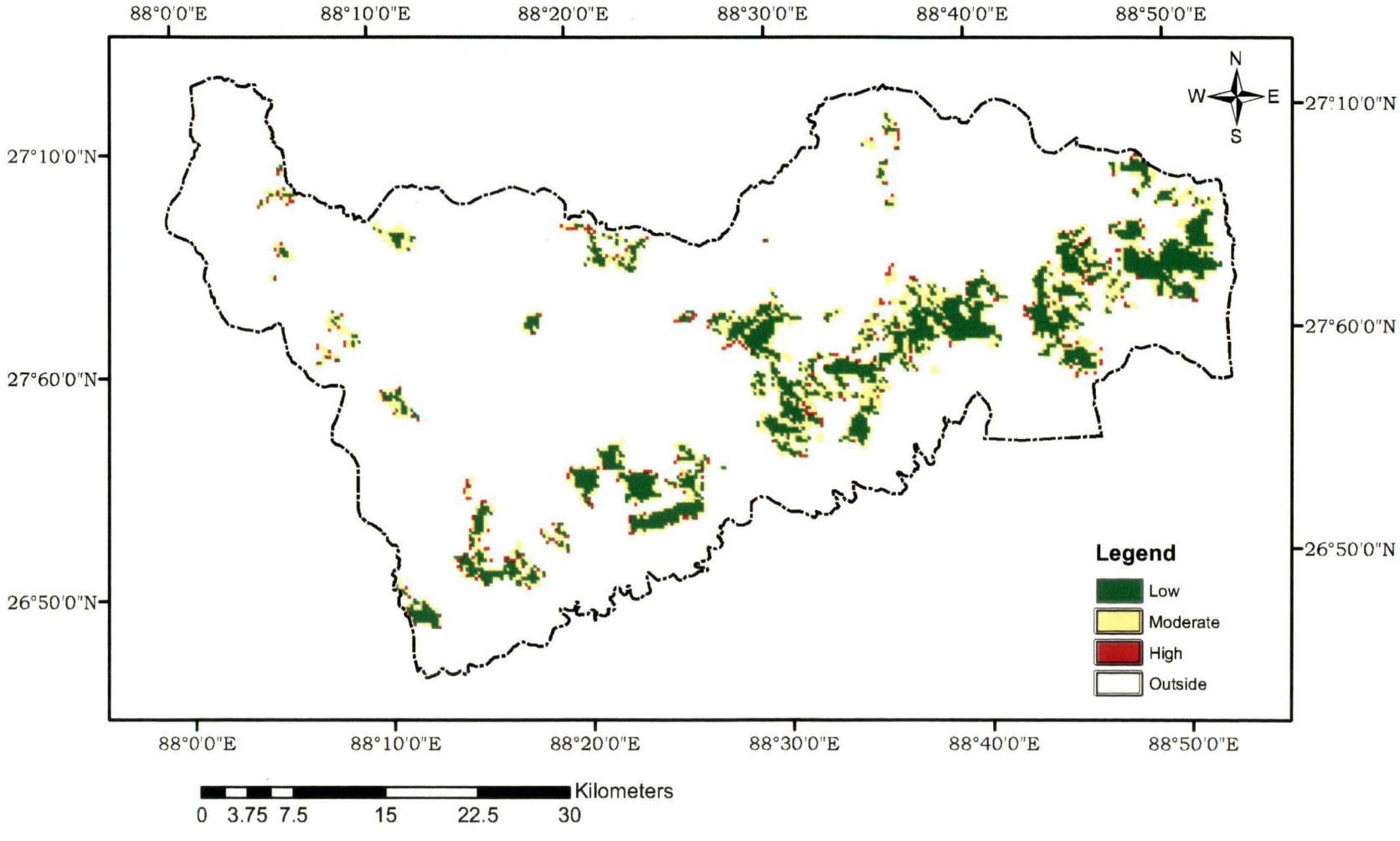


Fig. 5.12b

POROSITY MAP OF WET TEMPERATE FOREST IN DARJILING HILLS

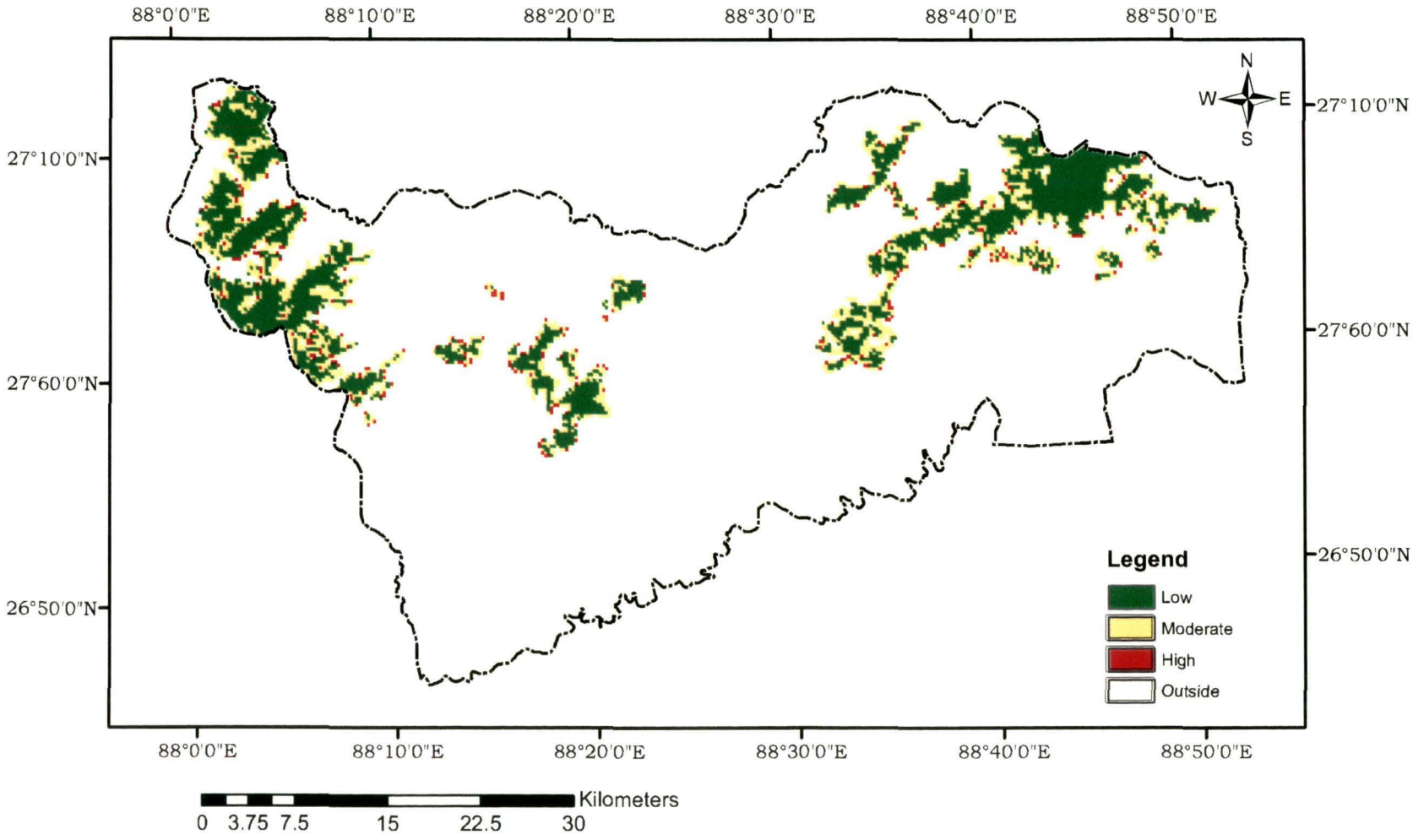


Fig. 5.12c

INTERSPERSION MAP OF DARJILING HILLS

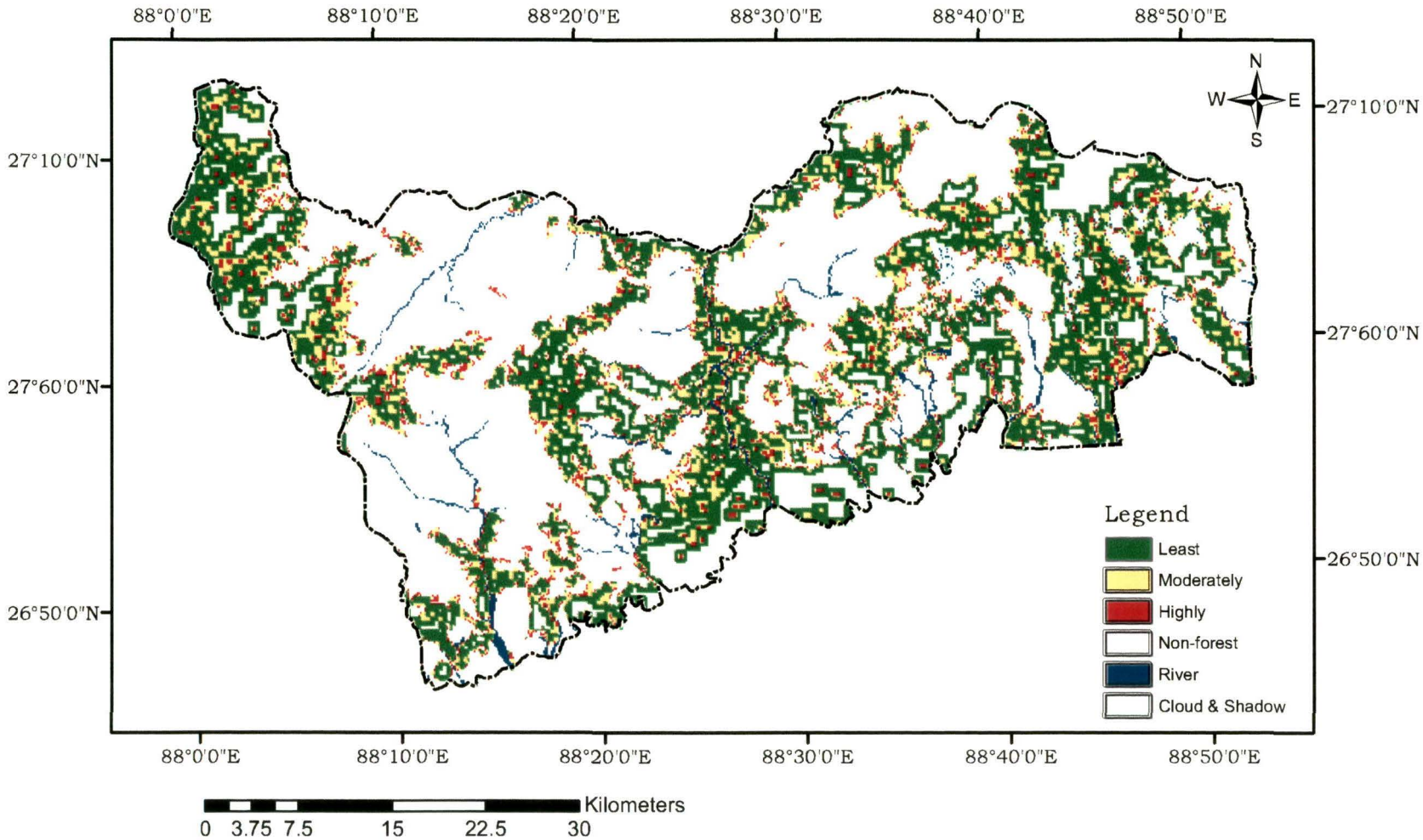


Fig. 5.13

5.6.3 Porosity

Porosity image (Figs. 5.12 a, b and c) of three dominant phenological types viz. Wet Temperate Forests, Sub-Tropical Broad Leaved Hill Forests and Moist Mixed Deciduous Forests from three altitudinal zones was taken to study porosity in the Darjiling hills (Table 5.13). These three forests alone covers 730.08 km^2 and together constitutes 66.67% of the total forest cover of Darjiling hills. Major part (65.36%) of Moist Mixed Deciduous Forests are non porous thereby indicating a homogeneous and non-fragmented nature of this forest, whereas, 30.38% and 4.26% of the total forest type is under moderate and high level of porosity. This figure indicates that the vegetation is undergoing a process of degradation. In Sub-Tropical Broad Leaved Hill Forests, a total of 110.94 km^2 accounting to 49.23% of this vegetation is under low porosity level, 44.94% and 5.83% are under moderate and high level of porosity. High level of porosity of the forest type is indicative of disturbed forest brought about by anthropogenic activities and natural disturbances. There is every likely chance of this forest being wiped out in near future. Similarly, Wet Temperate Forests also shows good porosity with 35.92% and 5.18% of this vegetation under moderate and high level. However, in this case, large number of different forest patches scattered throughout the region may be accounted for higher porosity value.

Table 5.13: Area statistics of Porosity image of three dominant phenological types

Sl. No.	Levels of Porosity	Moist Mixed Deciduous Forests		Sub-Tropical Broad Leaved Hill Forests		Wet Temperate Forests	
		Area (km^2)	% area	Area (km^2)	% area	Area (km^2)	% area
1	Low	145.27	6.52	110.94	4.98	166.39	7.47
2	Moderate	67.54	3.03	101.26	4.54	101.45	4.55
3	High	9.47	0.43	13.13	0.59	14.63	0.66
4	Outside	1969.1	88.37	1966.05	88.24	1908.91	85.67
5	Clouds and Shadow	36.75	1.65	36.75	1.65	36.75	1.65
	Total	**2228.13**	**100**	**2228.13**	**100**	**2228.13**	**100**

5.6.4 Interspersion

Interspersion image obtained show little or no interspersion for 821.01 km^2 (36.85%) of the total hill area (Fig 5.13). This indicates that the dispersal ability of the central class is low i.e. influence of neighbouring cover types is much more, which has led to the suppression of the central class. The spatial intermixing of all classes was not uniform.

Only 207.09 km^2 (9.29%) and 66.91 km^2 (3.0%) of constitute moderate and high level of interspersion. This can be related to simultaneous access to different cover types and species number found on the border between land cover types (Lyon, 1983). Area statistic of interspersion of the Darjiling hills is shown in Table 5.14.

Table 5.14: Area statistics of Interspersion image

Sl. No.	Levels of interspersion	Area (km^2)	% area
1	Low	821.01	36.85
2	Moderate	207.09	9.29
3	High	66.91	3.00
4	River/ water body	39.90	1.79
5	Cloud and shadow	36.75	1.65
6	Non-forest	1056.48	47.42
	Total	**2228.13**	**100**

5.6.5 Juxtaposition

Juxtaposition is the measure of relative importance of adjacency and proximity of various habitat types. It also indicates the connectivity of areas of similar vegetation types.

The area statistic of the Juxtaposition image (Table 5.15) shows maximum percentage of area under high to very high level of adjacency thereby indicating better interaction among patches of different types. The juxtaposition image (Fig 5.14) obtained reveals that Moist Mixed Deciduous Forests has high interaction with Himalayan Sal Forests followed by Sub-Tropical Broad Leaved Forests. The wet temperate vegetation also shows high interaction with temperate broad leaved forest in the upper hills. Similarly, low level of juxtaposition is observed in *Cryptomeria* plantation and open scrub vegetation.

Table 5.15: Area statistics of Juxtaposition image

Sl. No.	Levels of Juxtaposition	Area (km^2)	% area
1	Low	266.96	11.98
2	Moderate	220.28	9.89
3	High	272.12	12.21
4	Very high	335.65	15.06
5	Rivers/ water bodies	39.90	1.79
6	Clouds and shadow	36.75	1.65
7	Non-forest	1056.48	47.42
	Total	**2228.13**	**100**

JUXTAPOSITION MAP OF DARJILING HILLS

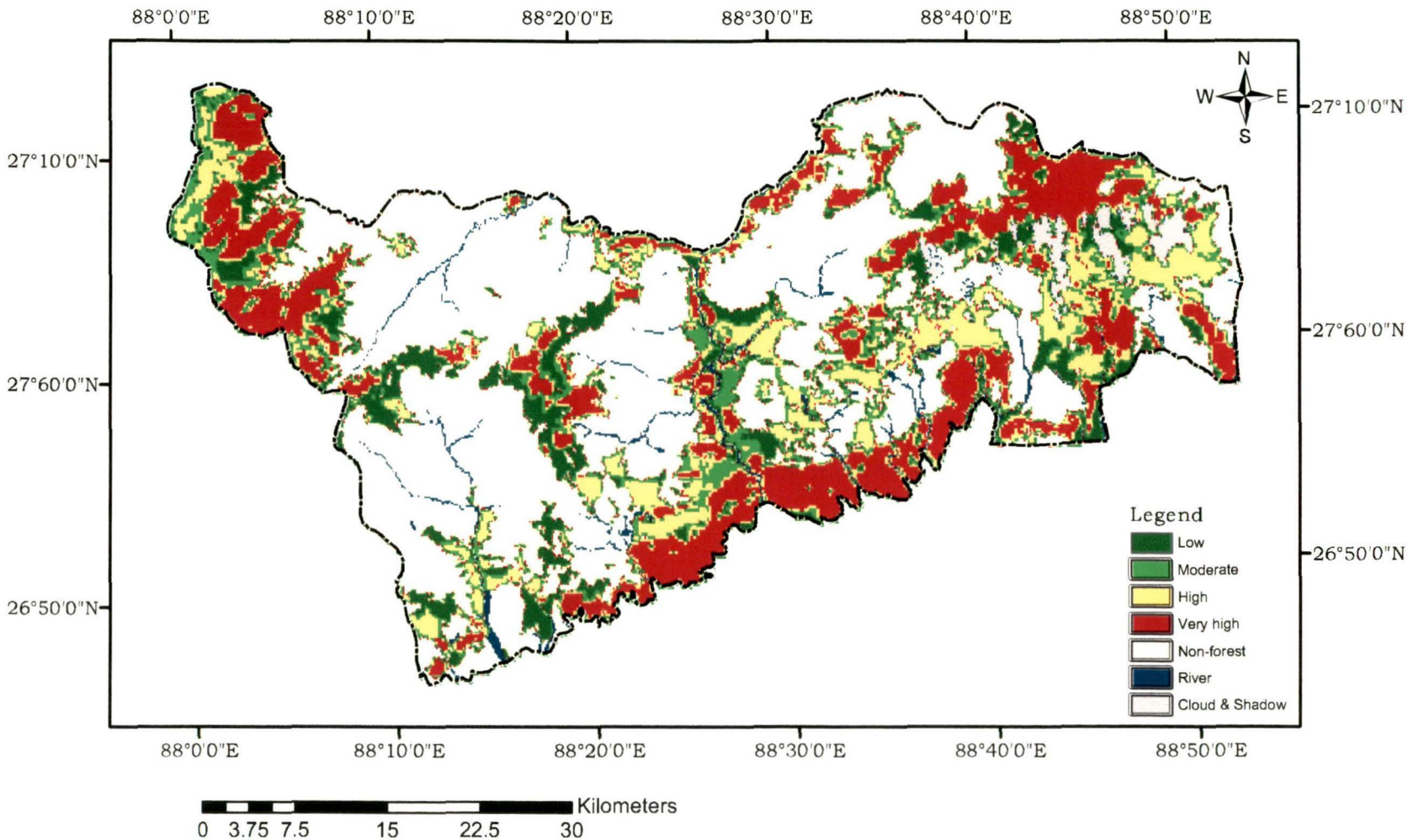


Fig. 5.14

5.7 Disturbance Index

Six parameters viz. fragmentation, biotic buffer, patchiness, porosity, interspersion and juxtaposition were considered for deriving the disturbance index (DI), an interactive weightage for individual parameters based on different gradient level. All other parameters were assigned positive weightages as they are directly proportional to disturbance. But for juxtaposition, reverse weightage were given as it is inversely proportional to disturbance. DI was computed by adopting a linear combination of the defined parameters on the basis of probabilistic weightage.

Disturbance index image (Fig 5.16) obtained recorded three levels of gradient i.e. low, moderate and high levels. Low levels of disturbance were characterized by low level of fragmentation, patchiness, porosity, interspersion, high level of juxtaposition and increased distance from the sources of biotic disturbances. The study area shows high level of disturbance, with 430.69 km^2 constituting 19.33% of the total hill area. Another 232.11 km^2 (10.42% of the total hill) show moderate level of disturbance. A total of 432.21 km^2 constituting 19.40% of the study area shows low or little disturbance (Table 5.16). High level of disturbance was observed along the forest fringes near human habitation, along roads and near dry river beds which acted as trails/ paths. Interior of the forest in all the three elevations showed low/ very less disturbance. The disturbance image reveals that the entire mid elevation region (1000 – 2100 m) to be highly disturbed. Protected forests (2 National Parks and 2 Wildlife Sanctuaries) too are not alien to its effect. Among the protected areas Senchal Wildlife Sanctuary is the badly affected one. Other three too show significant level of disturbance along the landscape. The entire landscape is now tending towards increased levels of disturbance due to increased biotic interferences.

Table 5.16: Area statistics of Disturbance image of Darjiling Hills

Sl. No.	Levels of Disturbance	Area (km^2)	% area
1	Low	432.21	19.40
2	Moderate	232.11	10.42
3	High	430.69	19.33
4	Rivers/ water bodies	39.90	1.79
5	Clouds and shadow	36.75	1.65
6	Non-forest	1056.48	47.42
	Total	**2228.13**	**100**

BIOTIC BUFFER MAP OF DARJILING HILLS

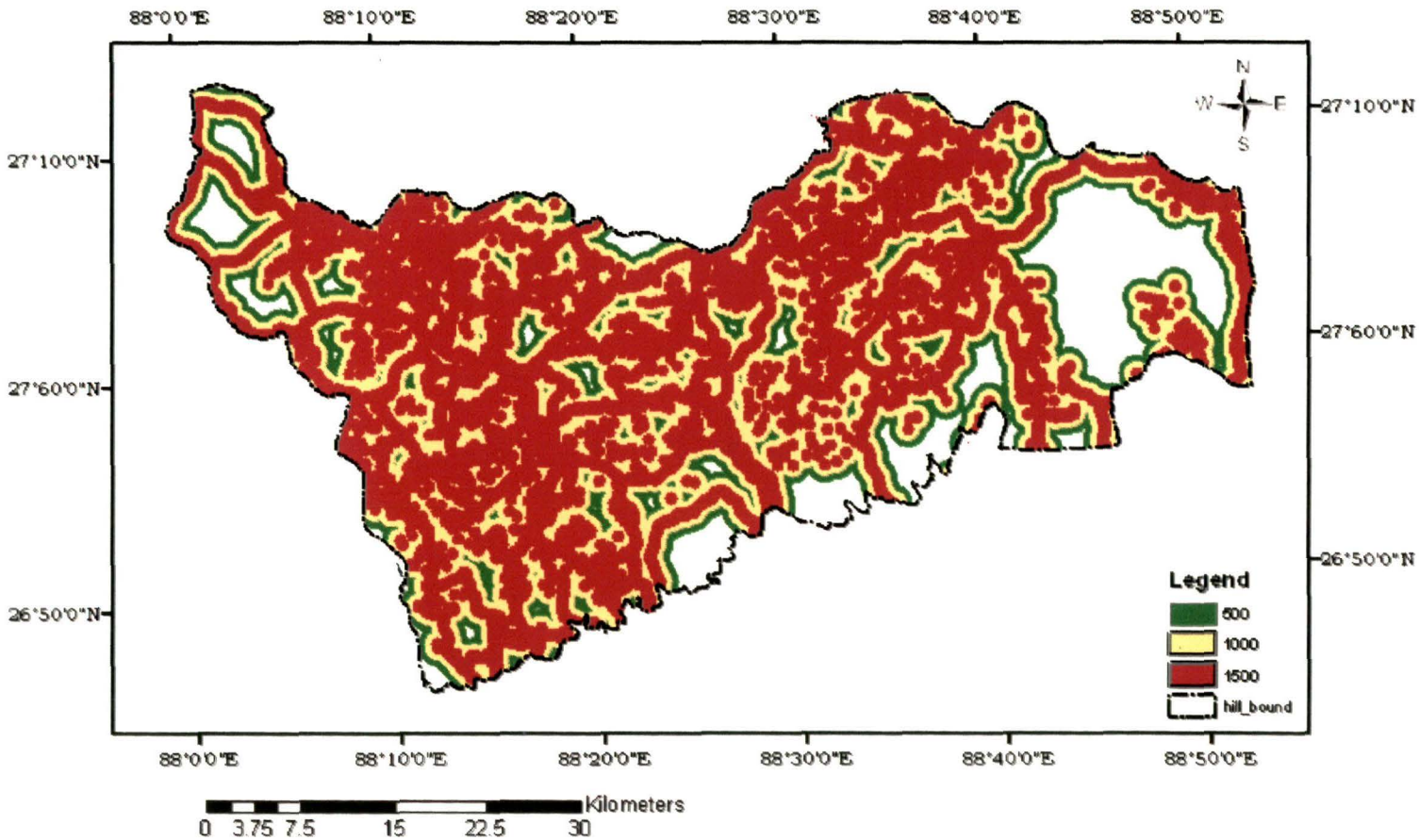


Fig. 5.15

DISTURBANCE INDEX MAP OF DARJILING HILLS

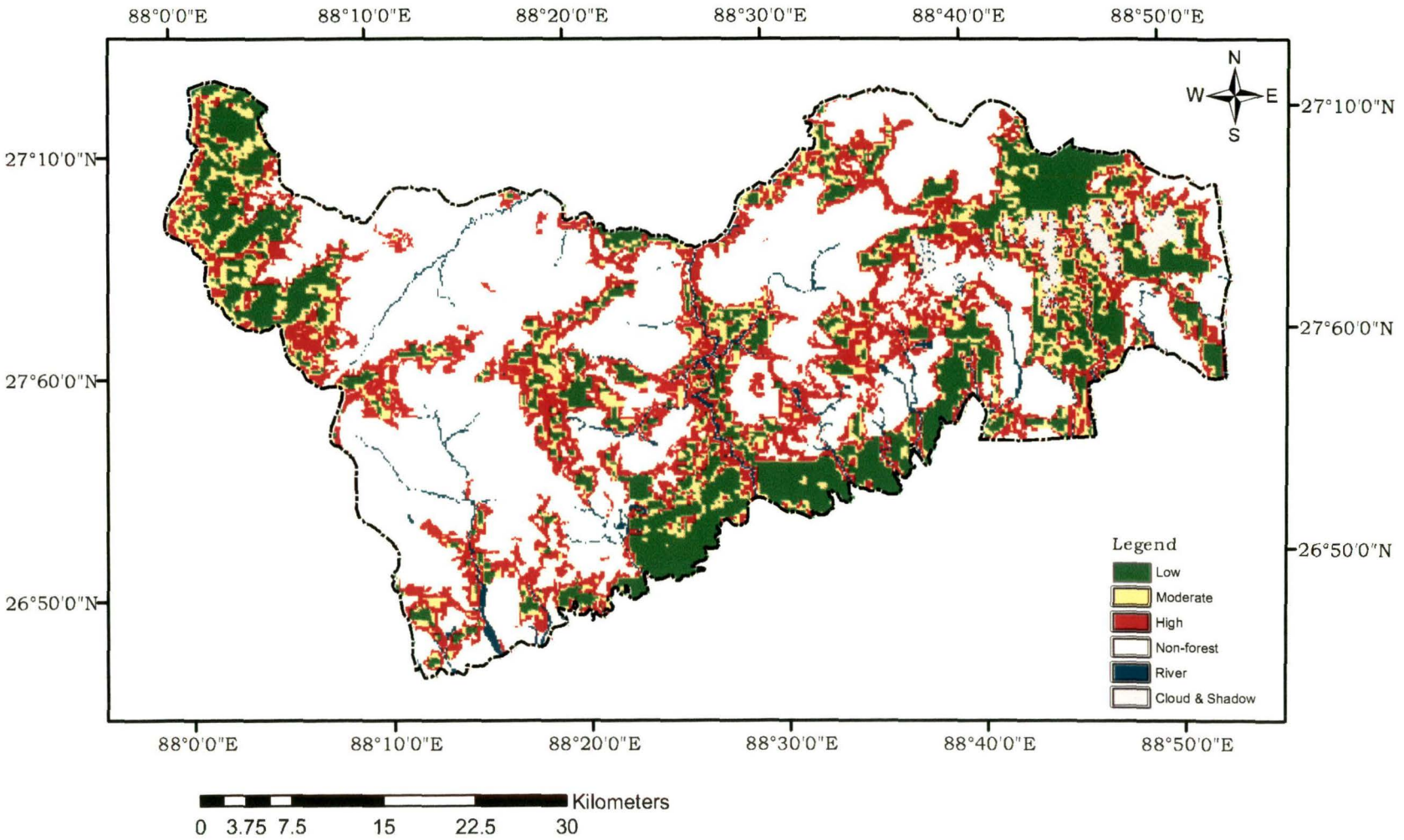


Fig 5.16

5.8 Biological richness modelling

Biological richness is a function of disturbance index, terrain complexity, species richness, and biodiversity value and ecosystem uniqueness. Interactive values for these functions are fed to simulate a biological richness map.

5.8.1 Disturbance index

Disturbance map is one of the important parameters for biological richness map generation. It has an inverse relation with the biological richness of an area. Thus, highly disturbed areas are assigned minimum weights and least disturbed area with maximum value for biological richness modelling. Different levels of disturbance in the Darjiling hills are shown in disturbance index map (Fig. 5.16). Weightage assigned to different levels of disturbance are provided in Table 4.6.

5.8.2 Terrain complexity

Topography is regarded as one of the important parameters/ functions in determining biological resource of an area. Digital elevation model (DEM) generated from SRTM data at 100m intervals was scaled at 4 levels of complexity. It was observed that the terrain complexity increases with increasing altitude. However, in the lower elevation, areas along river Teesta showed complex terrain. Abrupt rise in elevation from the river bed and numerous hills on both side of the river is responsible in the complexity of terrain. Weights assigned to terrain complexity are provided in.Table 4.6.

5.8.3 Species richness

Forest-wise field data was subjected to species richness (*Shannon-Weiner Index*) calculation. The normalised values for each of these vegetations were then fed in SPLAM. Species richness map generated was subsequently recoded to 4 levels of richness. Higher weights were assigned to higher species richness and *vice versa* (Table 4.6)

5.8.4 Biodiversity value

Total importance value of a species based on economic, ethical and ecological uses calculated for each forest type was used as one of the important parameters to generate biodiversity map. Biodiversity value for all forest types were calculated and then subjected to linear weight assignment for deriving biological richness map.

5.8.5 Ecosystem uniqueness

This is one of the parameters that directly extracted from the field data used in simulating the biological richness modelling. A total of 126 species of endemics were found to occur in various forest types in the Darjiling hills. Apart from the endemics, 8 species categorised in the IUCN red data book and 10 species of exotic species have been recorded from the study area. Temperate Broad Leaved and Wet Temperate Forests harbour highest endemic species, each with 40 species (Table 5.17). List of endemic species of Darjiling hills is provided in Annexure IV.

Table 5.17: Normalised values assigned to parameters determining the Ecosystem Uniqueness

Sl. No.	Forest Types	Endemic species	Represent-ativeness	Ecosystem uniqueness
1	Tropical Semi-evergreen Forest	5	2	4
2	Himalayan Sal	5	6	6
3	Moist Mixed Deciduous Forest	6	6	7
4	Riverine Forest	2	6	4
5	Sub-Tropical Broad Leaved Hill Forest	4	2	3
6	Wet Temperate Forest	10	6	8
7	Temperate Broad Leaved Forest	10	8	10
8	*Alnus* Forest	1	2	2
9	Conifer Forest	5	10	8
10	Sub-Alpine Scrub	4	10	8
11	Bamboo Brakes	3	2	3
12	Rhododendron Forest	5	10	8
13	Open Scrub	2	6	4
14	Teak Plantation	2	6	4
15	*Cryptomeria* Plantation	3	6	5
16	Degraded Forest	3	8	6

Number of endemic species occurring within Eastern Himalayas, endangered and exotic species was checked using various literatures to see the representativeness of the forest types, which were later used to determine uniqueness of each forest. Each of these endemic species was categorised based on their distributional extent as local endemics covering only Darjiling hills, Darjiling-Sikkim Himalayas and the Eastern Himalaya. Weights were assigned in descending order from the local endemics to the most cosmopolitan species. Similarly, ecosystem with higher number of endangered species was assigned higher

weightage and those having higher number of exotic species were assigned low weightage. All these three parameters were then normalised into a 10 point value which is fed to simulate an ecosystem uniqueness map. The map so obtained was recoded to 4 levels with increased weights from low to very high level (Table 5.18)

Table 5.18: Normalised value assigned for Biological Richness model

Sl. No.	Forest Types	Ecosystem uniqueness	Species richness	Biodiversit values
1	Tropical Semi-evergreen Forest	4	9	5
2	Himalayan Sal	6	9	10
3	Moist Mixed Deciduous Forest	7	9	8
4	Riverine Forest	4	8	5
5	Sub-Tropical Broad Leaved Hill Forest	3	10	5
6	Wet Temperate Forest	8	9	9
7	Temperate Broad Leaved Forest	10	9	7
8	*Alnus* Forest	2	7	3
9	Conifer Forest	8	7	3
10	Sub-Alpine Scrub	8	8	3
11	Bamboo Brakes	3	7	4
12	Rhododendron Forest	8	8	4
13	Open Scrub	4	7	2
14	Teak Plantation	4	7	4
15	*Cryptomeria* Plantation	5	8	4
16	Degraded Forest	6	8	5

Table 5.19: Area statistics of Biological Richness image of Darjiling Hills

Sl. No.	Levels of Biological richness	Area (km^2)	% area
1	Indicator	33.87	1.52
2	Low	61.38	2.75
3	Moderate	304.98	13.69
4	High	463.57	20.81
5	Very high	231.21	10.38
6	River/ water body	39.90	1.79
7	Cloud and shadow	36.75	1.65
8	Non-forest	1056.48	47.42
	Total	**2228.13**	**100**

BIOLOGICAL RICHNESS MAP OF DARJILING HILLS

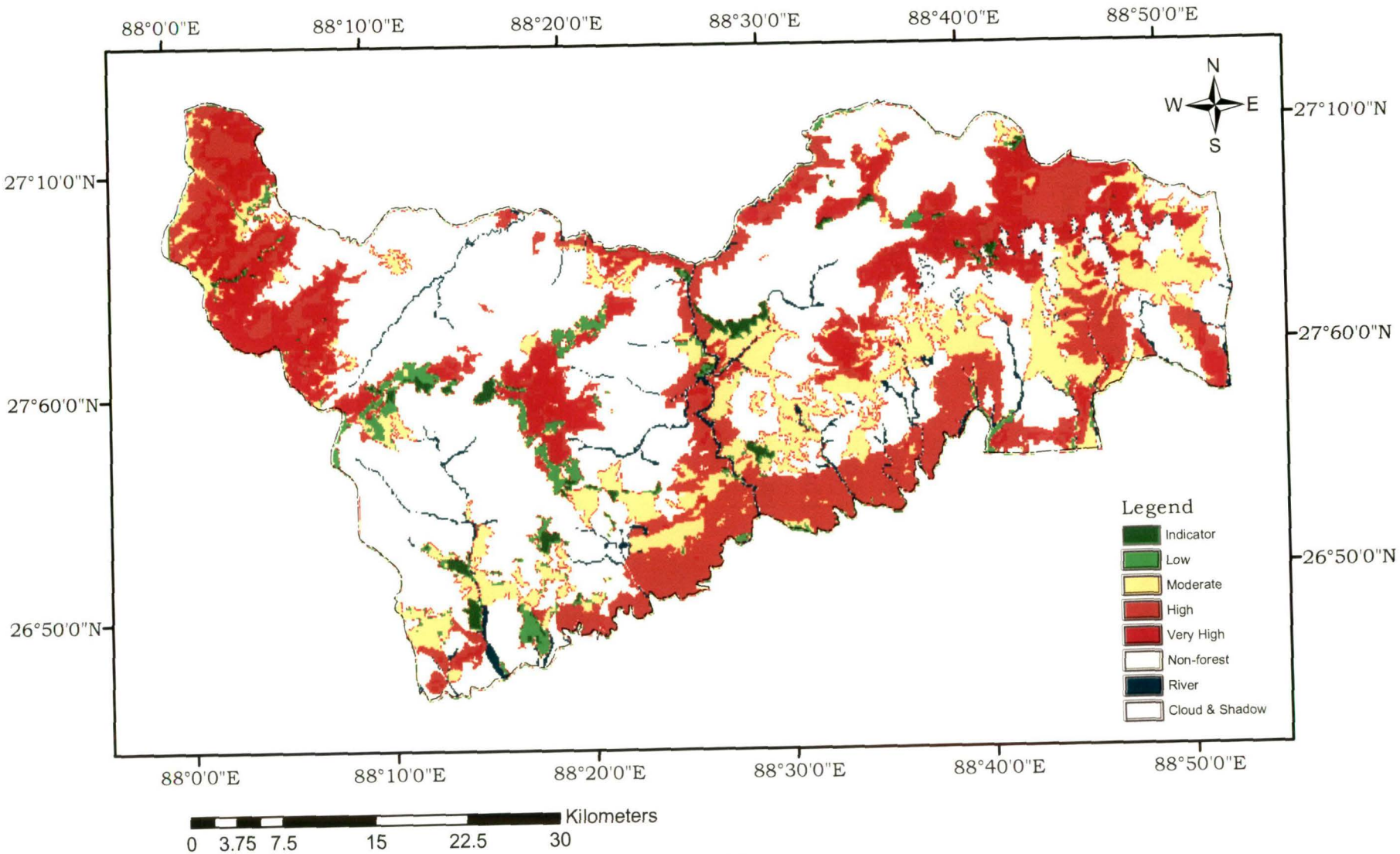


Fig.5.17

5.8.6 Biological Richness

Biological richness is the function of species richness, ecosystem uniqueness, biodiversity value, terrain complexity and disturbance index. These landscape parameters along with the interactive weightage, derived from the ground truth data have been subjected to biological richness modeling in deriving the Biological richness map for Darjiling hills. The biodiversity richness map (Fig 5.17) obtained indicated a high level of biological richness through out Darjiling hills. A total of 231.21 km^2 accounting to 10.38% of the hills show very high level of biological richness, 463.57km^2 (20.81%) under high level, 304.98 km^2 (13.69%) shows moderate and with only 61.38 km^2 (2.75%) showing low biological richness. The area statistics for the biological richness map is shown in Table 5.19. The Temperate Broad Leaved Forests in higher elevation and Himalayan Sal Forests in the foothills show the highest biological richness followed by Wet Temperate Forests, Moist Mixed Deciduous Forests. Sub-Tropical Broad Leaved Hill Forests, however, shows moderate richness. Degraded Forests, Open Scrub and plantation forests showed least to low biological richness.