A STUDY ON THE VEGETATION OF SHIVALIKS AND OUTER HIMALAYA IN DEHRA DUN DISTRICT, UTTAR PRADESH

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by

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DEDICATED

to

MY BELOVED PARENTS

Late Smt. Govindi Devi & Late Shri S.S. Bhainsora

whose infallible love and care provided

initial stimulus

to take up this work

भारतीय वन्यजीव संस्थान
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CERTIFICATE

This is to certify that the Ph. D. dissertation titled A STUDY ON THE VEGETATION OF SHIVALIKS AND OUTER HIMALAYA IN DEHRA DUN DISTRICT, UTTAR PRADESH is based on the original work done by Shri N.S. Bhainsora during 1992 - 1994 under my supervision. The work presented in the thesis has not formed basis for award of any degree, diploma or any other title. I have great pleasure in forwarding the thesis for the award of Doctor of Philosophy in Wildlife Science (Botany) from Saurashtra University.

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2. Sal (*Shorea robusta*), a commercially important tree, is considered as climax species in this tract and has been studied extensively. However, there is a paucity of information on the overall conservation status and regeneration of forests in this area. Therefore present study was undertaken with the following objectives: i) to study the structure and composition of the woody vegetation (tree and shrub layer) along the gradients of

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altitude and human use in Shivaliks and outer Himalaya, ii) to study the species diversity and human-animal use patterns in various zones, and iii) to assess and compare the regeneration status of Sal and associated tree species in the Shivaliks and outer Himalaya.

3. The study was conducted within about 500 km^2 area in the lower parts of Dehra Dun district, Uttar Pradesh (29^0 57' to 31^0 20' N lat and 77^0 35' to 79^0 20' E long). The study area also included parts of western Rajaji National Park, westerns Shivalik Forest Division, forests in Doon Valley, protected forest patches adjacent to Wildlife Institute of India (WII), Indian Military Academy (IMA), Forest Research Institute (FRI), Upper parts of Rajpur, Malsi and mine reclamation sites near Mussoorie.

4. The study area was stratified into three zones viz. Shivaliks, Doon Valley and Outer Himalaya. In each zone random rectangular plots of 20 m x 5 m i.e. 100 m^2 were laid. The rectangular plot was selected because it was found more efficient for sampling the patchy vegetation in a very undulating topography. The plot size was determined using species area curve method. The tree

and shrub species along with their number were recorded within each plot. For tree species, girth at breast height (GBH), height, disturbance type (cut, lopped, etc.) were recorded. For regeneration study of Sal, *Anogeissus latifolia* and *Pinus roxburghii*, their saplings were recorded within each plot. Other abiotic factors such as topography, soil moisture, texture, slope class, presence of domestic livestock and wild animal dung were also recorded in each plot.

5. In all, 256 plots were laid within the study area. Data were analyzed using PC - XTcomputers and statistical packages such as TWINSPAN and SPSS. Species diversity, community composition, Importance Value Index (IVI)which is a cumulative index of Relative Frequency (RF), Relative Density (RD) and Relative Dominance (RDom), similarity Index and Maturity Index were calculated to characterize the communities of all the zones.

6. TWINSPANanalysis gave 17 communities within the entire study area. Critical review of all identified community types reveal that only about 10 were distinctly identifiable in the field. Others, represented in only few plots, were transitional and man

influenced types. Diversity Index of tree species for Shivaliks, Doon Valley and Outer Himalaya were H = 2.15, 1.39 and 0.43 respectively. Based on the number of shrub species per unit area, Doon Valley was richest. Sorenson's Similarity Index showed that Shivaliks and Doon Valley were most dissimilar (Similarity Index = 45.85 %) where as Doon Valley and Outer Himalaya had maximum similarity (55.04 %). Absence of *Anogeissus latifolia* in the outer Himalaya and Doon Valley marked the differences from the tree associations of Shivaliks.

7. The outer Himalayan zone showed best regeneration of Sal as indicated by high density of Sal saplings (46 $\pm$ 12.08/ 100m^2) compared with Doon Valley (21. $\pm$ 4.22 per 100 m^2) and Shivaliks (14 $\pm$ 3.64/100 $m2^2$). There was no correlation between tree canopy cover and sal saplings in all the zones. But there was a strong correlation between shrub cover and sal seedlings r= 0.29 P= 0.007. Both the shrub cover and tree canopy cover showed negative correlation (r= - 0.18 P= <0.005 and r= - 0.12 P= 0.05) with *Anogeissus* saplings respectively.

8. Maturity Index (MI), indicative of early and late successional

stages of the forests, showed that Sal forests of Doon Valley was more mature compared to both Shivaliks and Outer Himalaya.

9. Importance Value Index (IVI) values of Sal were 262.92, 232.86 and 83.86 in Outer Himalaya, Doon Valley and Shivaliks respectively. Individual sites within larger strata varied considerably in terms of IVI values e.g. Chandrabani in Doon valley showed highest IVI value (288.62) perhaps, due to site conditions and past silvicultural practices.

10. *Lantana camara* dominated the shrub layer in all the three zones wherever canopy had been opened by lopping and cutting of trees. Though this exotic shrub gave protection to the Sal saplings, but overall diversity of shrubs and trees was reduced greatly in such areas.

11. Influence of topography, aspect, soil, and other biotic factors have been discussed in detail. It was found that altitude within 350 - 1200 m asl had less influence on vegetation compared to terrain and topography. Conservation implications of these findings have been discussed in detail. The conservation issues

1.0 GENERAL INTRODUCTION

Vegetation is one of the major geographical features of almost all parts of earth's surface on which depends the existence of all animal life including human beings. As such, it is one of the most important of all subjects for ecological investigations because the careful analysis of vegetation reveals useful information about other components of the ecosystem (Daubenmire 1963). Most of the studies proceed from the description of vegetation in the field to the subsequent analysis of these records in the laboratory. The descriptions of vegetation are generally based on physiognomic characters which are easily measurable in the field. Most of the studies on vegetation are directed towards the intrinsic values or practical importance for conservation and human use. A few areas which require description and analysis of vegetation are (i) Environmental Impact Assessment, (ii) Habitat surveys and evaluation, (iii) Collection of baseline data for long term vegetation monitoring, (iv) Biodiversity (plant) studies, and (v) Studies on animal-habitat interactions. Thus traditional plant ecologists as well as environmental and wildlife ecologists study various parameters of vegetation for any of the above reasons (Greig-Smith 1983, Bonham 1989).

and suggestions for better management of the forests are given.

12. The Chapters in the thesis include general introduction, the study area, detailed literature review on the Sal and subtropical vegetation, material and methods, results, general discussion, and references. Figures, tables and plates are given wherever appropriate.

1.1. ECOLOGICAL CONSIDERATIONS :

In nature plant communities occur in repeating groups of associated species. They are best described by noting the identity and growth form of the most abundant species, the target species and the most characteristic of a particular community. That is, the community is not described by simply listing all the species which comprise it. Instead, a community is characterised by detailing those species which most contribute to its unique structure and composition (Mueller-Dombois and Ellenberg, 1974).

It is well established fact that biogeographical location, climate, geology and dominant herbivores influence the vegetation of a region. Today, however, most of the natural ecosystems have been heavily altered by man. More particularly so in densely populated and developing countries like India. As India has barely ca 18% of the geographical area under forest cover of which only half is supposedly undisturbed (with more than 50% canopy cover), it is very important to keep track of natural vegetation patches, wherever they have escaped man's greedy eyes. In India, conservationists and various government organisations have time and again stressed the need for conserving the flora and fauna in various geographical regions (Gadgil 1992, 1994

and Panwar 1994). Recently, a biogeography based protected area network has been proposed by the Wildlife Institute of India (Rodgers and Panwar, 1988) which proposes about 5.6% of the country's geographic area under protected area network i.e. 147 national parks and over 600 wildlife sanctuaries. This report takes into account the biological attributes not only in the context of biogeographic and physical environment but also in relation to the interspersion of human habitation. Of the various biogeographic zones and protected areas suggested in the report, the Upper Gangetic Plains (7A) and Himalayan belt (2B) interphase is most interesting. The former i.e. Upper Gangetic plains is India's most fertile and heavily populated belt while the latter is geologically young, tectonically active, and ecologically diverse zone. Between these two zones lies the Shivalik range which represents characteristics of both the biogeographic zones.

Shivaliks, one of the most recent hill ranges of the world, are even more fragile ecosystems than Himalayas. They occupy about 40,000 km^2. area in northern India, of which only roughly 2,000 km^2. area has been brought under the present protected area net work. Important protected area being Rajaji and Corbett national parks in the foot hills of Uttar Pradesh Himalaya. Thus the 5% area of Shivaliks which falls under the protected area network alone cannot conserve

the whole range of flora and fauna which have evolved in the region. Since, majority of the land is under the human influence, it is essential to see the trends of human use and conditions of these forests so as to predict the future course the vegetation is likely to take and plan a comprehensive conservation strategy.

The Shivalik belt along with the intersecting river valleys (Doons) form a very fertile belt in north India, popularly known as Bhabar tract. In this belt Sal (*Shorea robusta*) is regarded as a climax species of forest succession, which occurs in pure stands or in varying degree of association with miscellaneous species such as *Anogeissus latifolia*, *Buchanania lanzan*, *Lagerstroomia parviflora*, *Odgenia dalbergioides*, *Terminalia tomentosa* Syn. *T.alata* and *Bauhinia* species (Osmaston 1928, Puri *et al* 1989). Towards higher Shivalik slopes and outer Himalaya Sal is replaced by Chir pine (*Pinus roxburghii*) on frequently burnt slopes while Banj oak (*Quercus leucotrichophora*) replaces both the species on moist slopes of Himalaya above 1500 m asl.

Extensive cultivation, industrial and township development in the Bhabar and Tarai belts, livestock grazing, lopping and the collection by local people and *Gujjars*, (a pastoral community) has led to degradation of forests, and wildlife habitats. Most of the forests show the signs of weed proliferation (in the form of Lantana

use gradients in Shivaliks and outer Himalayas. The two "Tension" zones of Sal, viz. outer and inner boundaries of Shivaliks and *Doon* have been compared. It is hoped that the information on the status, structure and composition of the forests in the various zones will be useful in (i) updating the current knowledge on the Sal biology, and (ii) understanding the successional trends in outer and inner distribution range of Sal. The results will also be valuable for landuse and conservation planning in this area. The major objectives of the study are as follows:

1) To study the structure and composition of the woody vegetation (Tree and Shrub layer) along the gradients of altitude and human use in Shivaliks and outer Himalaya.

2) To study the species diversity and human-animal use patterns in various zones.

3) To assess and compare the regeneration status of Sal and associated tree species in the Shivaliks and outer Himalaya.

The Thesis includes seven Chapters i.e. General introduction,

and *Parthenium* patches), and poor regeneration of trees. Though, some part of the forest along with its fauna in this area have been legally protected in two protected areas i.e. Rajaji and Corbett National Parks, the former continues to suffer from encroachment and biomass removal by man. Thus, the Sal and its associated species grow in a varied landuse and habitat regimes in this area. There is a paucity of information on the conservation status, regeneration and current level of pressure on these forests.

Above ecological considerations and range of ecological conditions indicated by the natural vegetation along the Bhabar tract have prompted this study. The forest vegetation around Dehradun (Uttar Pradesh) which represents the sharp ecological boundaries i.e. Shivaliks, the Doon valley and outer Himalaya along the climatic and human use gradients warrants a comparative study on the aspects mentioned above. Therefore, this study was initiated in the year 1992 with the following aims and objectives.

1.2 AIMS AND OBJECTIVES :

The present study aims at investigating the regeneration status of the Sal and its associated species along the altitudinal and human

The study area, Literature review, Methods, Results, General Discussion, and References. Broad ecological considerations and objectives discussed in this chapter (Ch.1) are followed by a detailed description of the study area which includes geology, soil, climate and general vegetation types. This is followed by field and analytical methods. The figures, plates, tables and graphs referred in the text, are given at appropriate places.

2.0 THE STUDY AREA

The study was conducted in Dehradun district, which lies in the North-western part of Uttar Pradesh state, India with 29°57' to 31°20' N latitudes and 77°35'to 79°20' E longitudes (Fig.2.1). It is a small district of 3099 km^2 area with a population of 10,07,532 (1991 census) and varying geographical and altitudinal ranges. The district is well known for its scenic beauty and moderate climate. Northern part of the district is mountainous everywhere over 1500 m above sea level (asl). High ranges of Himalaya rise over 2800 m and rivers like Yamuna and Tons have cut deep valleys in between. Thus, there are numerous watersheds, spurs, valleys and escarpments. The southern part is an undulating plain with watershed distinctly marked in the middle about 750 m asl, where on the east-west direction land slopes steeply down to a little over 350 m. This plain (Doon valley) drains partly into the Yamuna in the west and partly into the Ganges in the east. The Tons, Yamuna, Ganges and Song are perennial rivers while the others are mostly dry except in the rainy seasons. The Doon is made up of alluvial soil but along the river erosion has cut the banks and removed the much of top fertile soil. The district is bounded in the

south by the Shivalik range of hills, about 850 m asl in height.

The administrative boundaries of Dehradun district are with Uttarkashi district in north and Tehri Garhwal district in east, Sirmor district of Himachal Pradesh in west and Haridwar and Saharanpur districts in south. The district has 7 towns Dehradun being the largest with the population of about 5,00,000. Mussoorie and Chakrata are the popular hill resorts.

The climate of the district is mid-latitude monsoon type with rainfall mostly from mid June to mid September. The rainfall is heavy in all places of the district e.g. 212 cm in Dehradun, 245 cm in Mussoorie and 205 cm in Chakrata. In winter there is a little precipitation about 15 cm, which is in the form of snow in higher altitudes. The plain region is hot in summer. The day's maximum temperature is 38°C and minimum 4°C. However, in recent years summer temperature in Dehradun has soared as high as 41°C.

On account of high rainfall and moderate temperature there is a rich natural vegetation in the district. On lands higher than 1500 m coniferous forests of Chir pine (*Pinus roxburghii*) and Deodar (*Cedrus deodara*) and oak forests occur, while lower down deciduous forests of Sal (*Shorea robusta*) and other trees are found still covering a considerable area (E.Van Es 1974).

In the past heavy lumbering was done around Dehradun on commercial scale and timber for buildings, furniture and railway sleepers were extracted (Sharma 1965). Collection of minor forest products such as medicinal herbs, grasses for ropes and paper, bark for tannin, honey and dye stuffs was also common till recent decades. Owing to a very diverse climatic and topographic features the district is very rich in flora and fauna.

2.1 THE INTENSIVE STUDY AREA

The intensive study area lies in the lower part of Dehradun district in a south to north direction starting from Mohand (Dist. Saharanpur) to outskirts of Mussoorie hill town. The study area also includes a part of Rajaji National Park (RNP) along its western boundary which is partially occupied by Gujjars, a semi nomadic pastoral community. The following ecological zones can be distinguished in the study area:

2.1.1. The Shivaliks

This zone forms the southernmost part of the Himalaya just above the Indo-Gangetic plains. It is also known as sub-Himalayan

zone. Structurally, this belt is characterized by broad open folds with increasing evidence of greater deformation as reverse faults in the northern limit close to the 'Main Boundary Fault' (MBF). This zone is characterized by conglomerates, sand stone and clay beds of Tertiary age. Variation in lithological attributes indicates that the sediments were deposited in various sub-environments of fluvial systems since Pleistocene epoch. The Shivaliks were known to ancient Indian geographers as 'MAINAKPARVAT'(Law 1944). These are the long chains of narrow and low hills about 700-1320 m, running almost parallel to the Himalaya. At places, the Shivaliks and lower Himalayan ranges are separated by longitudinal structural valleys which are called Doons or Dun valleys. (Fig.2.2).

In the Shivalik range the study was conducted from Mohand (300 m) and adjacent part of RNP in Saharanpur district, 30 Km south of Dehradun town. In this area, several seasonal springs and deep ravines intersect the Shivalik hills. The Delhi-Dehradun highway which separates Rajaji National Park from the Shivalik forest Division was selected as baseline for laying the transects on either side of the forest. Important sampling sites in Shivaliks include Mohand, Western part of Rajaji NP, Mohand pass and higher reaches of Karuapani and Asarori forests.

2.1.2. The Doon Valley

This is an open valley enclosed by the Shivalik hills and outer Himalaya. It can be called an irregular parallelogram with its longer axis lying almost NW to SE direction. The town of Dehradun is situated in the central part of the valley which is now home of about 5,00,000 people. The valley lies between latitudes 29°55' to 30°30', and longitudes 77°35' to 78°24'. It is the terminus of Haridwar-Dehradun line of Northern railway. It is at 682 m above asl, and is situated on the crest of a low ridge that extends from Mohand pass to Rajpur and forms the water parting between Ganges and Yamuna. The important torrents of the town are Bindal and Rispana raus (Rau = local name for seasonal river which remains dry for most part of the year), both originate from outer ridges of the Himalaya.

The Doon valley has remarkable heterogeneity in its natural environment. There are several interesting places which are important from the floristic, geological and religious view points. Important botanical sites include Chandrabani, Karuapani lower areas, New Forest (FRI) and Indian Military Academy (IMA) complex and vicinity, Raipur forest, Mothuranwala swamp, etc. More than 60% area in the Doon valley has come under human habitation or cultivation. About

10-15% area is occupied by the natural and seminatural forests which were sampled during the course of this study. The valley happens to be the home of a special variety of Basmati rice (*Oryza sativa*) and Litchi (*Litchi chinensis*) which are famous all over the world. Due to developmental activities, more and more agricultural area is being converted into concrete jungles leading to low production of above crops.

The New Forest and adjacent areas of natural vegetation are located in the west of Dehradun Town and extend to the Tons river. Other sampling site, Rajpur, lies at the foot of Himalaya about 10 km from Dehradun on the way to Mussoorie. Its highest elevation is 990 m asl. In addition, an important area has been recently developed towards Shivaliks on way to Saharanpur from Dehradun i.e. Wildlife Institute of India campus, Chandrabani. In and around this institute a large patch of natural vegetation has been protected which was also sampled.

2.1.3. The Outer Himalaya

As we ascend from Dehradun to Mussoorie (outer Himalaya) and leave the alluvial plain, the more stable sedimentary rocks are

is diversified by two isolated hills, the southern Nagsidh which is an offshoot of the Shivaliks, and northern Kalanga which is an outlier of the Himalaya. Both are divided from their parental ranges by rivers. River Suswa separates Nagsidh from the Shivaliks and Song disconnects Kalanga from the Himalaya.

Western Doon is bounded on the north by water parting of the lower Himalayan range on the northwest by Yamuna. It is more open valley when compared to Eastern Doon, and lower slopes of Himalaya rise at a more gentle gradient. It comprises four well defined tracts.

i) The river tract that comprises the land to the east of Dehra-Asarori road around the source of Suswa and the Shelving land on both sides of the river, Asan from its source to its confluence with Yamuna.

ii) The uplands on the rest of the ridge where the town of Dehradun is located.

iii) A similar triangle of rich land at the northwestern extremity of the district irrigated by the Katapathar canal, and

encountered. All the areas above 1400 m. asl towards Mussoorie fall under outer Himalayan belt.

This belt is characterized by shales, quartzite, and conglomerates. At places there are limestone deposits which have been heavily quarried till recently leading to soil erosion and removal of forest cover. Very few natural vegetation patches are found in this zone. Important sampling sites in this zone were Malsi, Rajpur higher range, Sahansahi Ashram, Jorigaon etc. With the increasing environmental awareness among various social workers such as Friends of the Doon, The Save Mussoorie Society and Eco-Task Force of the Indian Army have been able to restore the land stability and natural vegetation in this zone to some extent.

2.2. TOPOGRAPHY

The Doon valley is divisible into two natural zones, Eastern Doon and Western Doon. Eastern Doon is bounded on the north-east by the outer scarp of Himalaya and Chandana rao from Tehri Garhwal, on the south-east by Ganges, on the south west by the Shivaliks and on the north-west by Sukh rao and Rispana rao. It has fewer sloping plateaus because of the abrupt rise of Himalaya. The central part of the valley

iv) The sub montane tract between ii and iii and north of the riverine land fringing the Asan river. This tract comprises a series of parallel plateaux slope down gently towards Asan on the southern side. The summits area occupied by villages and irrigated terraced fields. The beds of torrents are converted into rice fields irrigated by small canals opened from the upper course of torrents. The eastern Doon is drained by Asan and its tributaries.

2.3 GEOLOGY AND SOIL

Dehradun belongs to the tectonic group and consists of lower and upper Tertiary rocks and sedimentary river deposits of the Shivalik system, which comprises sand stones, grits, conglomerates, psendoconglomerates, silt and clays. The river beds consist of water borne debris of granite core of Himalaya with scattered conglomerate boulders, calcareous tuffs, small rounded stones, loose river gravel and sand. The soil type is alluvial and highly fertile (Gupta 1954, 1960).

In outer Himalaya adjacent to Dehradun the huge and thickly deposited formations of argillaceous rocks are found, which are mixed with some quartzite and lime stones. It consists of mostly massive

lime stone, a few grits and shales, slates and schists (Valdia 1980).

In Shivaliks the crest of these hills are generally made up of hard conglomerates whereas the lower slopes are formed by softer sand stones which disintegrates more rapidly and the slopes wear down sooner to an acute angle. The Shivaliks and Doon valley are separated from the rocks of lower Himalaya by the Main Boundary Thrust. (Wadia 1967, Negi, 1984). Due to these geological features the alluvial plains of Dehradun valley is rich in soil fertility and well suited for Agriculture. Characteristics of soil in Doon valley at different depths are given in Table 2.1.

2.4 CLIMATE

The Doon valley, is well guarded from heat waves and dust storms of the plains from the south and cold waves of interior Himalaya from the north, as it is bounded by Shivaliks on the south and outer Himalaya on the north. The climate of Dehradun is relatively temperate with rainfall chiefly confined to the monsoon season. Climate of southern shivaliks e.g. Mohand, etc. relatively drier and warmer.

2.4.1 Temperature

May and June are the hottest months (40-41°C) and December and January are coldest when the temperature reaches about the freezing point. The extremes i.e. higher and lower are more pronounced in outer and inner parts of the study area, respectively. Generally the temperature increases February onwards and decreases gradually July onwards. The mean monthly temperature of the study area is given in Fig.2.4.1.

2.4.2 Rainfall

The Southeast monsoon strikes the valley in the mid-June, and bursts unabated from July onwards till the middle or even the end of September. The subsequent period i.e. October-November, generally called 'retreating monsoon', characterized by a few or no showers at all, marks the beginning of cold season. The north-east monsoon sweeps the valley through January and February bringing in occasional showers often accompanied by hail. The period from March to mid-June constitutes the hot season characterized by the absence of rainfall. The annual average rainfall is approximately 200 cm to 212

cm. Table 2.4.2 gives the variation in the temperature and rainfall within the study area.

2.4.3 Wind

During first half of the monsoon, the wind usually blows southwest to northwest and is often accompanied by torrential rains. In the second half of the monsoon, winds are nearly normal. The summer season especially May and June, experiences thunder storms accompanied by squalls of considerable velocity. The relative humidity of the study area is shown in Fig.2.4.3.

2.5 THE VEGETATION

The vegetation of the study area can be broadly classified into following categories (Plates *I* to *XIV*).

2.5.1 The Sal Forests

Traditionally the vegetation of south and north facing slopes of Shivaliks have been categorized as Dry Shivalik Sal (5B/c/a) and Moist

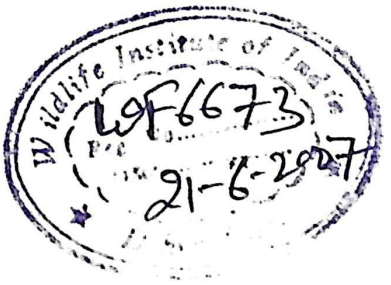
associated species are laden with various species of grasses e.g. *Chrysopogon fulvus*, *Desmostachya bipinnata*, *Heteropogon contortus*, *Neyraudia arundinacea*, etc. The steeper slopes are covered by Bhabar grass (*Eulaliopsis binata*) which is frequently harvested by local people for making ropes and brooms.

2.5.4. River banks and alluvial terraces

These categories are mainly founded in the southern slopes of Shivaliks characterized by scattered trees of *Acacia catechu* and *Dalbergia sissoo* in association with *Zizyphus mauritiana*, *Cordia myxa*, etc.

2.5.5. Degraded scrub vegetation.

Areas close to human habitation, *Gujjar Deras* (camps) and lime stone quarries are characterized by sparse tree cover and dense thickets of *Lantana* and other shrubs.



2.6 FAUNA

Lower part of the study area adjacent to Rajaji National Park is rich in animal diversity. Notable among them are Asiatic elephant (*Elephas maximus*), spotted deer (*Cervus axis*), barking deer (*Muntiacus muntjack*), Sambar (*Cervus unicolor*), Porcupine (*Hystrix indica*), wild boar (*Sus scrofa*), common langur (*Presbytis entellus*) and rhesus macaque (*Macaca mulata*). Non-forested and open grassy slopes and woodlands are occupied by goral (*Nemorhaedus goral*). Among carnivores tiger (*Panthera tigris*), leopard (*Panthera pardus*), Jackal (*Canis aureus*), Himalayan yellow throated martin (*Martes flavigula*) are occasional. Prominent avifauna of this region include the pea fowl (*Pavo cristatus*), red jungle fowl (*Gallus gallus*), Kalij pheasant (*Lophura leuco melana*), a variety of babblers, warblers and flycatchers. The area is rich in a large number of altitudinally migrant species which come from the higher Himalaya during the winter season and others from the peninsular India during summer (Rawat and Panwar 1990).

Table 2.3 : Soil Characteristics in various Sal forests of Doon Valley, Dehra Dun (Source Joshi 1980).

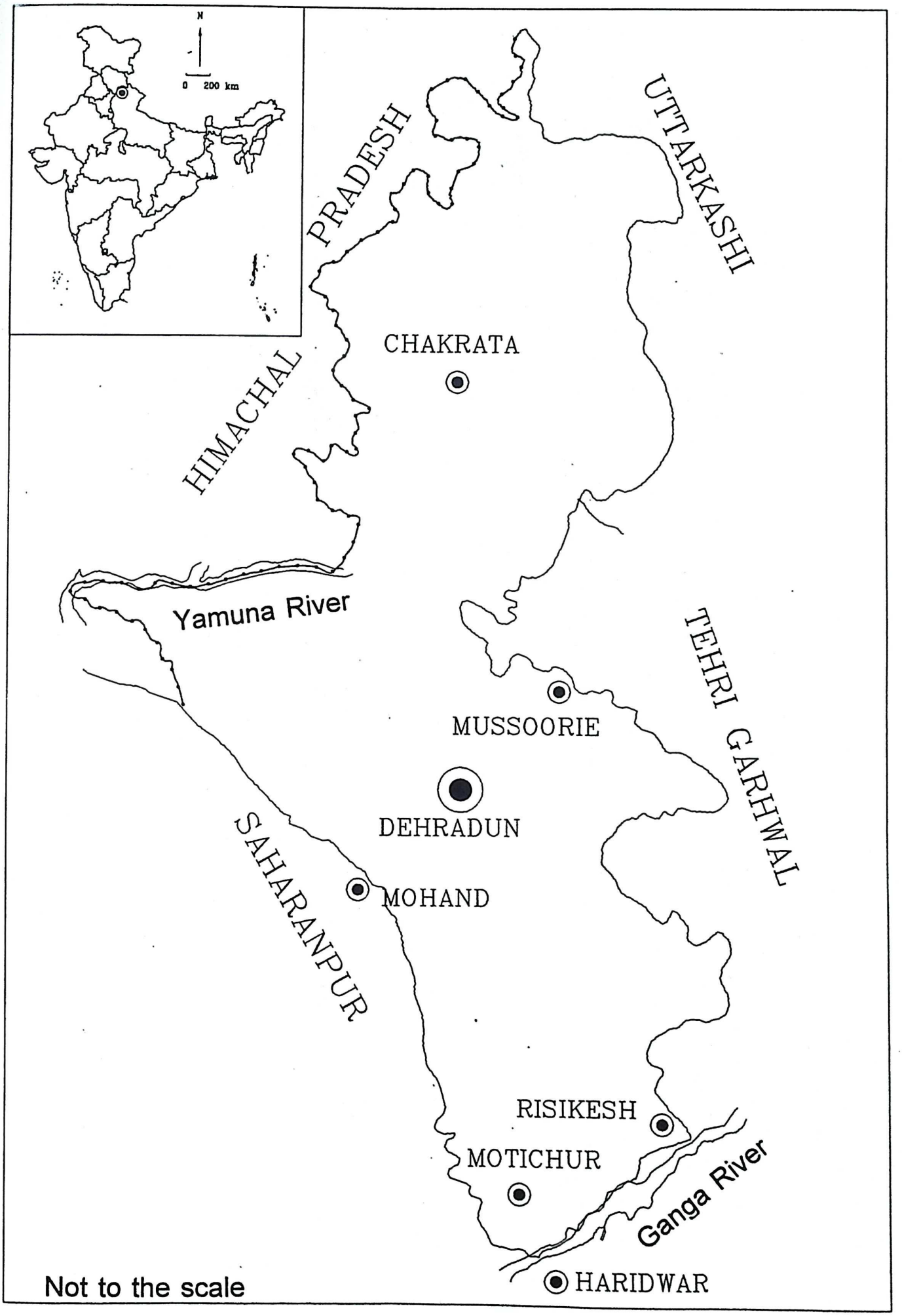
Location, Altitude & Soil type	Mechanical composition %						pH
	Depth (cm)	Coarse sand	Fine sand	Silt	Clay	WHC*	
1. Betbani (457 m) Brown	0-15	35.5	47.6	9.6	1.6	31.1	6.2
	25-60	35.0	44.6	12.5	5.0	28.4	6.4
2. Lachhiwala (610 m) Alluvium	0-15	5.8	25.3	56.6	10.9	40.7	6.2
	15-33	10.5	34.2	39.3	10.9	39.1	6.1
3. Asarori (650 m) Alluvium	0-15	-	-	-	-	36.43	5.85

* WHC = Water Holding Capacity.

Table.2.4.2 : Temperature and rainfall variation in the study area.

Climatic Zone	Mean Ann temp. (^{0}c)	Mean Max temp. (^{0}c) (June)	Mean Max temp. (^{0}c) (Jan)	Mean Ann. rain fall (cm)
Outer Himalaya Temperate Zone (1200 - 1800 m)	18.9	27.2	11.1	298
Doon Valley Subtropical (600 - 900 m)	21.1	29.4	13.3	212
Shivaliks Subtropical (300 - 500 m)	22.4	31.0	14.0	150

Fig. 2.1 Map showing location and details of Dehra Dun district.



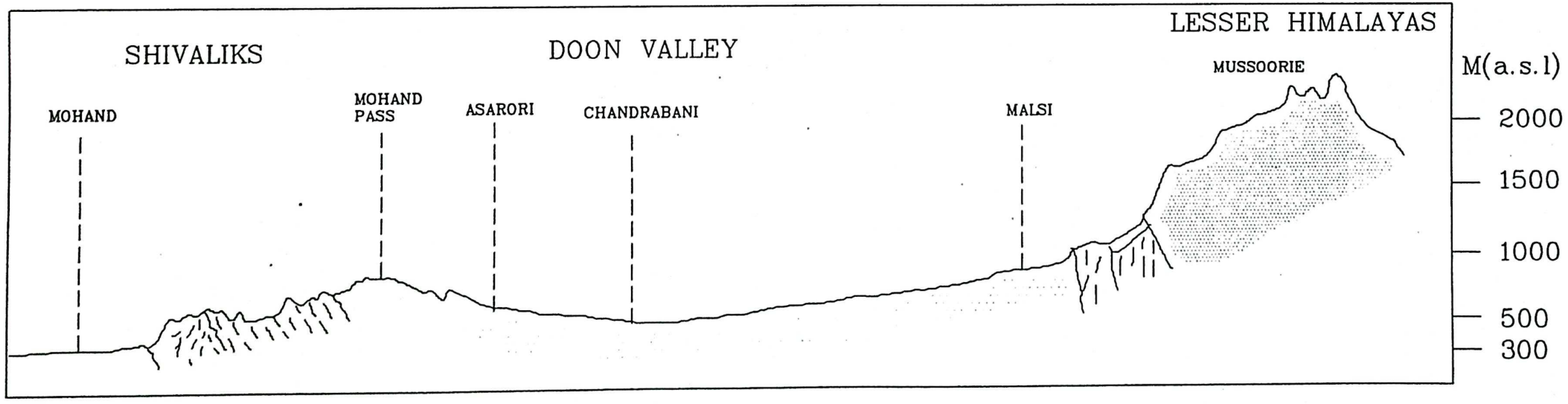
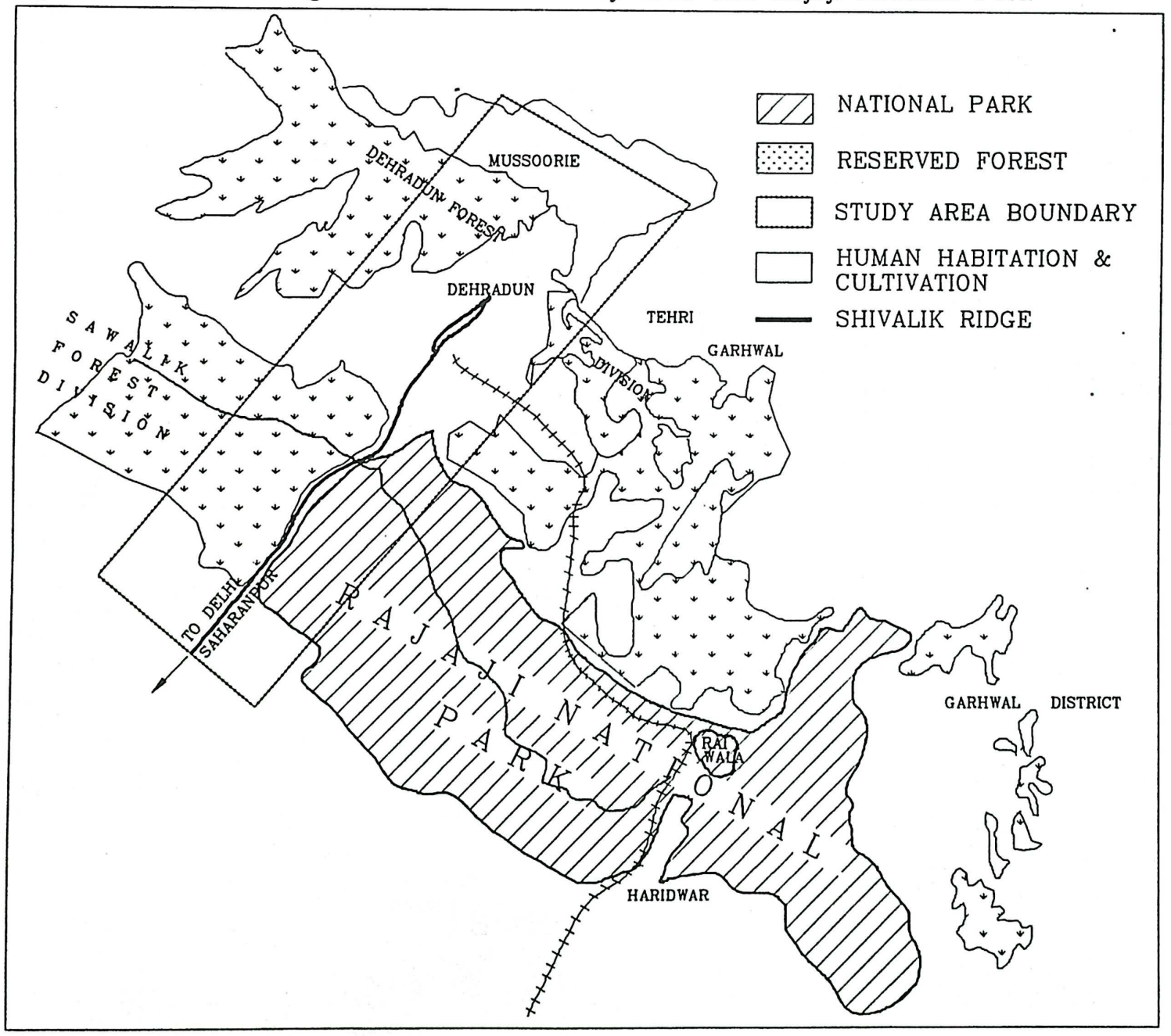


Fig: 2.2 : Cross-section at right angle to the Doon Valley showing topography of the study area.

Fig: 2.3 : Map Showing Location of the study area and Rajaji National Park



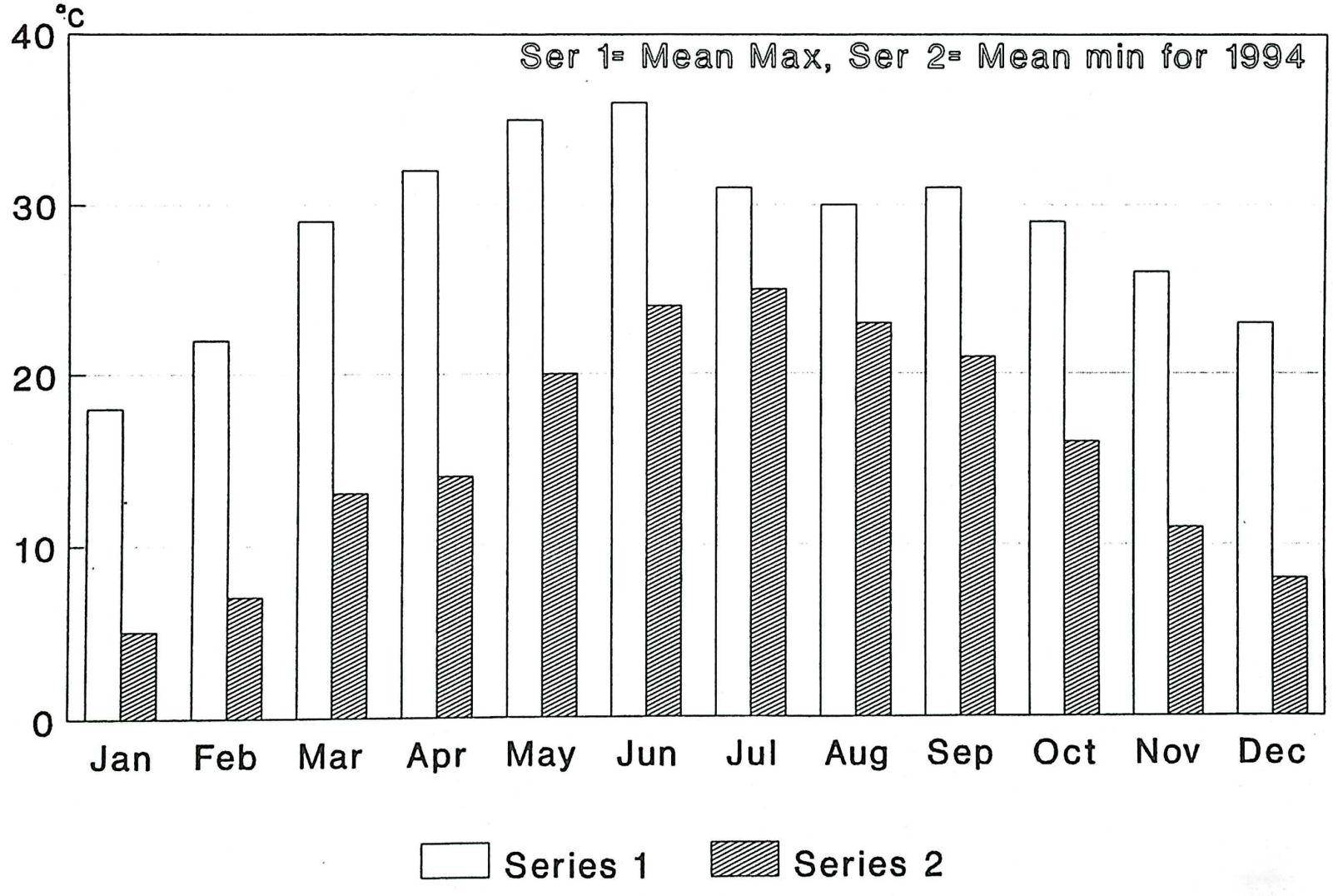


Fig 2.4.1: Mean (Max. & Min.) monthly temp. in Dehra Dunt

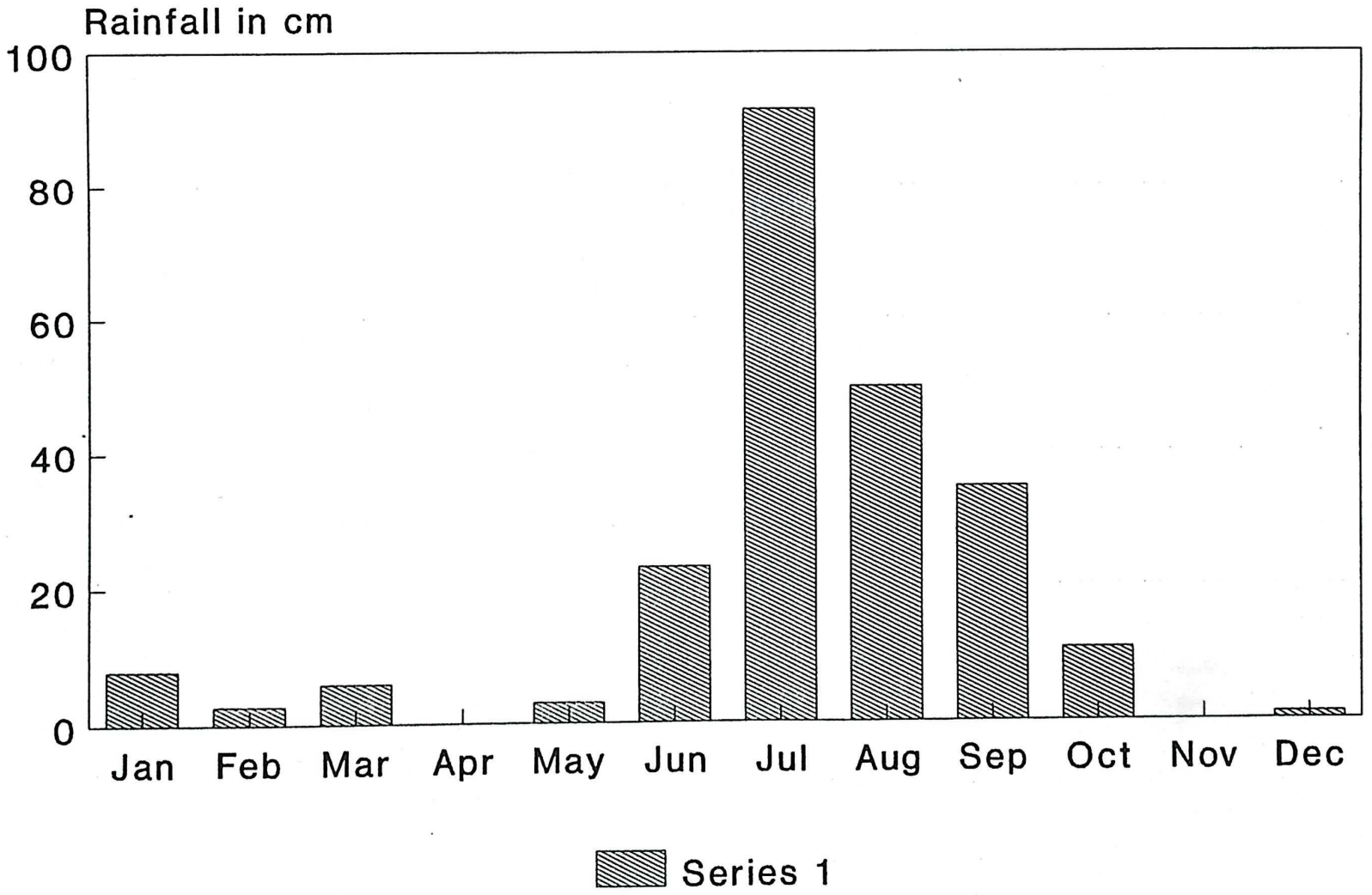


Fig 2.4.2: Mean monthly rainfall (cm) in Dehra Dun

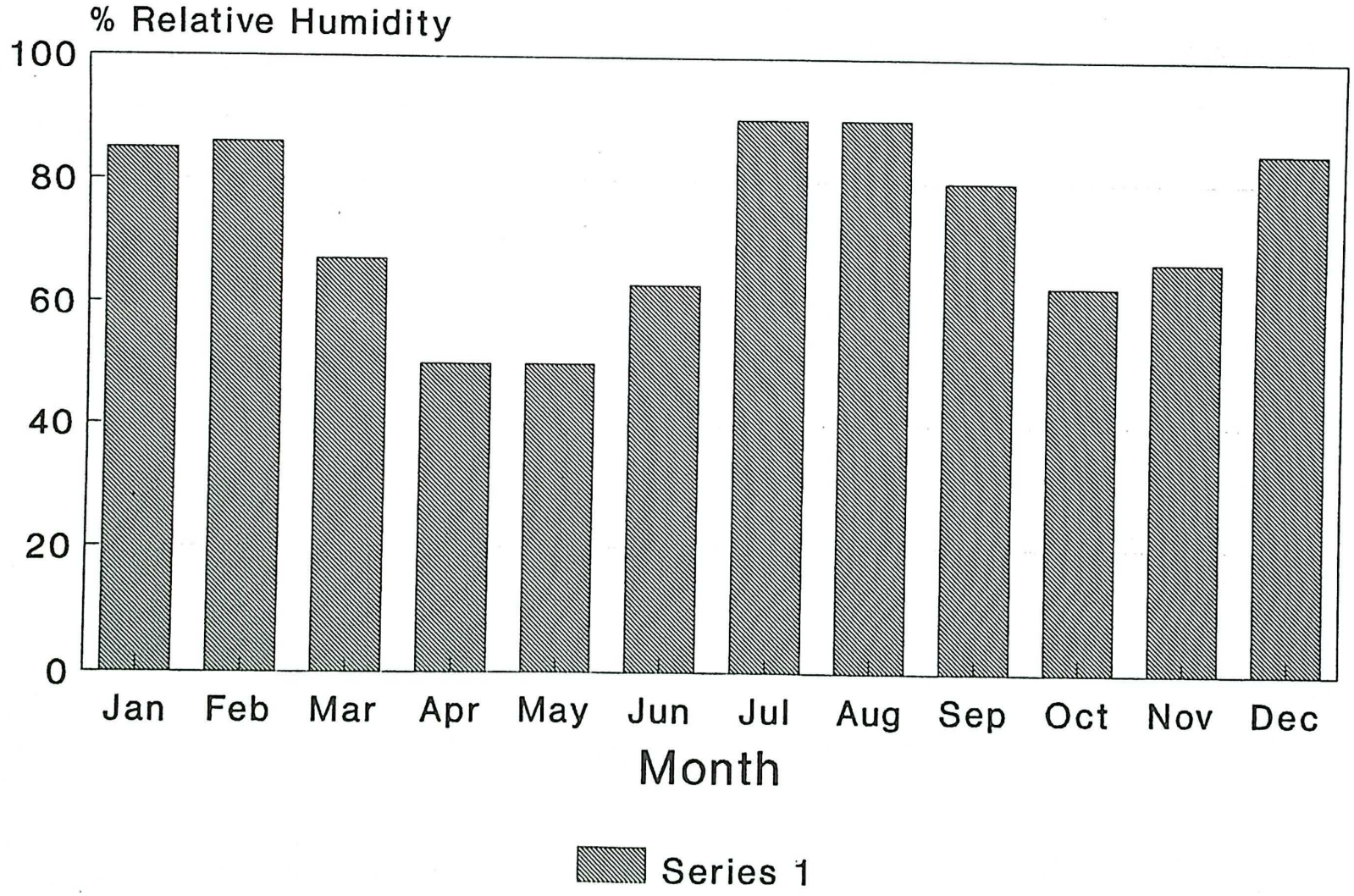


Fig 2.4.3: % Relative Humidity in Doon Valley during 1994

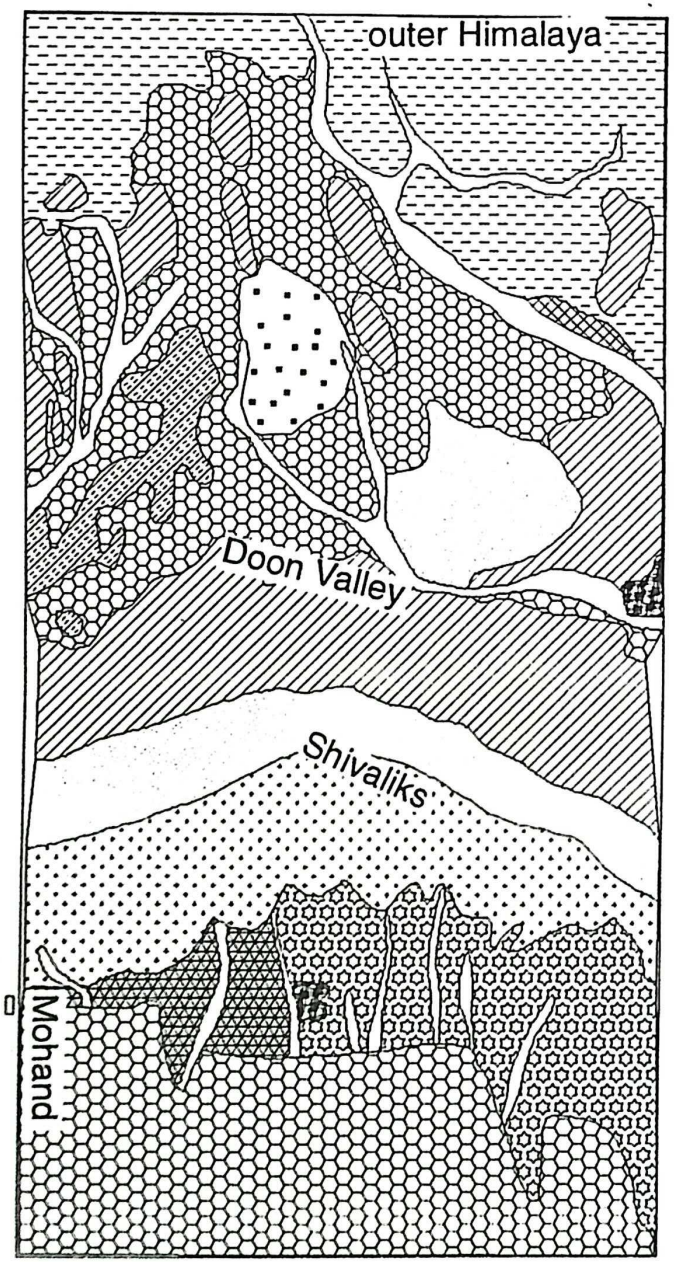


Fig. 3.3: Vegetation map of the study area as interpreted from remote sensing data by E. Van Es (1975) **scale 1 : 250 000**

- Mixed Deciduous Hill Forest
- Cultivation
- Dry Deciduous Forest
- Riverine Forest
- Tea Gardens and Orchards
- Moist Deciduous Forest (Sal)
- Himalayan Subtropical Scrub
- Plantation
- Dry Deciduous Forest (Plains)
- Mixed Forest with Plantation
- River Bed
- Township (Dehra Dun)

N

3.0 LITERATURE REVIEW

The forests of outer hills in Dehradun district adjoining Shivaliks and outer Himalaya have been studied piecemeal since the beginning of this century. Perhaps, George King (1871) was the first forester to survey the vegetation of this region. Numerous floristic and descriptive accounts of the vegetation exist scattered in the literature. However, there has been hardly any attempt to synthesize the past studies. The following account gives an overview of the past studies conducted in the forests of the study area and its adjacent tracts. The review is confined to the subtropical belt in the Bhabar along with a brief account on the ecology and distribution of the climax species of the area i.e. Sal (*Shorea robusta*).

3.1 PHYSIOGNOMY

Puri *et.al.* (1989) give a brief account of the physiognomic types of the forest vegetation around Bhabar tract of Uttar Pradesh. These have been named as monsoon forests, i.e. *Shorea-Bauhinia* formation (Kenoyer, 1921); Bhabar forests, Sal forest, or miscellaneous forest

(Smythies, 1921); Sub deciduous forests of Sal, Bhabar and Tarai sal, miscellaneous low hill deciduous forest; *Shorea-Anogeissus*-pine association (Osmaston, 1922, 1927); monsoon forests of *Shorea robusta*, upper monsoon forest (Dudgeon and Kenoyer, 1925); *Shorea robusta* forest, mixed monsoon forest, winter deciduous monsoon forest, winter deciduous mixed forest, tropical monsoon forest (Heske, 1929); Dry sal, and moist sal forest (Champion, 1933, 1936); Northern tropical dry deciduous forest and northern tropical moist deciduous forest (Champion and Seth, 1968); Tropical deciduous forest and dry and moist sal forest (Schweinfurth, 1957). Singh, J.S. and Singh, S.P. (1987) categorise these forests under sub-mountain broadleaf summer-deciduous forest formation. Thus, different authors have given different names to these forests keeping physiognomy and community types in view.

3.2 VEGETATION COMMUNITIES

Most of the vegetation cover in the study area is physiognomically forest, and have been broadly described in Champion & Seth's (1968) 'Forest types of India'. This work reviews the several descriptive accounts of the Sal (*Shorea robusta*) forests of

Dehradun Shivaliks. Since then several studies were conducted on the vegetation of this area. The frequency of such studies were due to wide spread concern by foresters over poor regeneration of sal. Rodgers *et.al.* (1990) reviewed the ecological studies conducted in the Rajaji National Park.

There has, however, been no thorough quantitative study of the communities by either forestry or academic ecologists except for herbaceous vegetation e.g., Krishnaswami *et. al.*(1954). Despite the existence of long term records in stock maps, compartment records, preservation plots etc. The less commercially important non-sal forests have received much less attention except continued interest in the biologically interesting swamp forests of Mothuranwala which has cleared been now, and Golatappar (Kanjilal 1901, Som Deva and Srivastava, 1978). Similarly, a few studies exist on the oak forests of Uttar Pradesh Hills but from very higher altitudes (e.g. Gupta and Singh 1962, Negi 1979, Negi and Gupta 1987, Pangtey *et.al.* 1989, Saxena *et.al.* 1978.

According to Puri *et.al.* (1989), the following variations can be well marked on different edaphic formations around Shivaliks and outer Himalaya:

1) Conglomerate type, constituting an open type of mixed deciduous forest composed of *Shorea robusta-Anogeissus latifolia*, *Anogeissus latifolia-Terminalia*, *Terminalia-Shorea* and *Pinus roxburghii-Anogeissus* community on scarp slopes and dip with higher proportions of sal.

2) Clay type, composed of *Shorea robusta-Syzygium cumini*, *Shorea-Terminalia tomentosa*, *Shorea-Ougeinia* communities distributed according to the level of the soil moisture, organic matter and exchangeable calcium.

3) Alluvial type on freshly laid alluvium *Acacia-Dalbergia* community occurs on gravely soil, on finely divided soil with clay and silt *Trewia-Holoptelia-Bombax* community is commonly found.

Scarp slopes in outer Himalaya are dry and vegetation consists of *Acacia catechu*, *Emblica officinalis*, *Nyctanthes arbor-tristris*, *Colebrookia oppositifolia*, *Rhus cotinus*, *Rhus parviflora*, *Euphorbia royleana*, *Carissa carandas*, *Woodfordia fruticosa* and *Adhatoda vasica* while the dip slopes are moist and have a luxuriant vegetation.

Above communities are distributed upto about 1400 m till the *Pinus roxburghii* forests replaces them in the outer Himalaya where *Quercus leucotrichophora* a climax species in temperate belt, has been pushed into the river valleys and damp places. A continuous zone of *Pinus roxburghii* in these forests can rarely be seen and the transition can be marked by the presence of shrubs like *Woodfordia fruticosa*, *Rhus parviflora* and *Rhus continus*.

The influence of man on account of dense settlements and is strong in these forests (Champion, 1923). Cutting, grazing and lopping have a marked effect. Fires lead to a secondary savanna type vegetation and sometimes to grasslands (Puri *et.al.*, 1989). In the valley there is a tendency to destroy forests for agriculture and on the terraces remains of these forests are represented by species like *Rhus continus*, *Rhus parviflora*, *Carissa carandas*, *Euphorbia royleana* and the species of *Rubus, Indigofera* and *Rosa* are largely resistant to cattle grazing and capable of coppicing.

3.3 FOREST COVER MAPPING

The Indian Institute of Remote Sensing in Dehradun has had an

interest in the investigation of vegetation types from aerial photography and satellite imagery (Van Es 1972, Tiwari 1986), Saxena (1986) mapped gross changes in forest cover in Rajaji National Park. The Forest Survey of India (1989) has published detailed statistics on the extent of landuse and forest cover types for parts of Rajaji and surrounds. Van ES 1974 identified and mapped the following landuse/Forest vegetation categories from the aerial photographs and Satellite imageries pertaining to the study area:

1) Northern dry mixed deciduous forest on the flat areas
2) Northern dry mixed deciduous forest on flat areas (degraded)
3) Tropical hill valley swamp forest
4) Tropical hill valley swamp forest (degraded)
5) Northern dry mixed deciduous forest on Shivalik hills
6) Northern dry mixed deciduous forest on Shivalik hills (degraded)
7) Himalayan Subtropical scrub forest
8) Himalayan subtropical scrub forest (open)
9) Sal (*Shorea robusta*) forest.
10) Plantation
11) Khair-sissoo (*Acacia catechu-Dalbergia sissoo*)
12) Khair-sissoo forest (*Acacia catechu-Dalbergia sissoo*) (open)

13) Himalayan chir pine (*Pinus roxburghii*) forest

14) Banj oak (*Quercus leucotrichophora*) forest

15) Moist Deodar (*Cedrus deodara*) forest

16) Grassy area

17) Cultivation

18) Irrigated cultivation

19) Terraced cultivation

20) Habitation

21) Tea gardens and orchards

The important categories within the study area are shown in Fig.3.3.

3.4 ECOLOGY AND DISTRIBUTION OF SAL

The genus *Shorea* is represented by four specie in India viz. S. *robusta* Gaertn.f. 2. S. *assamica* Dyer, 3. S. *talura* Roxb. 4. S. *tumbuggaia* Roxb. Of these Sal, (*Shorea robusta*) is the most important form forestry point of view.

3.4.1 Habit and Habitat of Sal

Sal is highly gregarious tree, very often forming predominantly pure crops over extensive areas. In suitable localities, trees have nearly straight, clear, cylindrical boles. Trees above middle age have rounded crowns and a strong branch system, whereas poles have roughly conical or elongated crows. The bark is dark brown with longitudinal fissures, which are deep in pole stage and become shallow when the tree advances in age. Other morphological characters are: Leaves 10-20 cm by 6-12 cm, the mature ones somewhat coriaceous, ovate-oblong; Petiol 1.9-2.5 cm, stipulate 0.8 cm, falcate, pubescent. Panicles 12.5-22.5 cm long clothed with pale velvety pubescence. Three conspicuous colours of inflorescence distinguishable, viz. pink, cream and light pink or pinky cream, the colour differentiation depending with age of inflorescence is seen in moist sal forest. Inflorescence unilateral.

Flowers sub-sessile, petals about 1.3 cm long, pale yellow, tapering upwards, 12-13 nerved, anthers with a bearded appendages, ovary pubescent, Stigma 3-denticulate, Fruit formed of calyx with segments sometimes subequal, base 0.8 cm, ovate, pubescent; wings 6.3 cm, linear, 10 nerved.

3.4.2 Distribution

According to 1971-72 estimates, Sal forests occupied abo- 116,000 sq.km. or broadly 14.2% of total forest area in India. This figure has gone down considerably since then though exact figures are not available. In India the Sal occupies two main regions separated by Gangetic plains namely northern and central Indian regions. In the former, the extreme north-west limit is Palampur (H.P). The main and almost continuous stretches of Sal forest in Haryana, sub Himalayan tract as far east as Darrang district of Assam. Sporadic occurrence of sal has been reported from Subansiri District of Arunachal Pradesh. It is common in Himalayan valleys and ascends in the outer hills to 1,220 m and occasionally to 1525 m. South of Brahamaputra river in Assam, Meghalaya and further upto Tripura (Fig.3.4.2).

In Central Indian region Sal commences near the Ganga in Santhal parganas to Palamau, Hazaribagh, Chhota Nagpur (Bihar), Purulea, Bankura, Bardhwan and Birbhum District of West Bengal, Jaypore, Palkonda (Orissa) to Srikakulam District of Andhra Pradesh and Eastern part of Madhya Pradesh in Districts of Shahdol, Sorguja, Jabalpur, Mandla, Balaghat, Bilaspur, Raigarh and Bastar. Overall the state-wise distribution of Sal in India is as follows: Himachal Pradesh, Haryana, Uttar Pradesh, Bihar, West Bengal, Assam, Meghalaya,

Arunachal Pradesh, Tripura in first northern range. While South Bihar, West Bengal, Madhya Pradesh, Orissa and Andhra Pradesh in second range in Central India. The distribution of Sal within the general climatic type is governed by the conditions of topography, geology and soil (Mooney 1947).

3.4.3. Ecology

A great deal has been written on the Sal ecology in India. Important authors being Troup (1921), Champion (1933), Mooney (1947), Waheed Khan (1953), and Puri (1951). Joshi (1978) has compiled the silvicultural aspects of sal for forestry purposes. It is still not clear whether a sal forest is a climax over most of the area it occupies or whether it has attained its present state by the aid of the human factor. The status of the sal varies in different parts of the country.

In the Bhabar area, the sal forests are almost pure and a girdle along the outer Himalaya adjacent to Dehradun. The common associates of Sal are *Buchanania lanzan*, *Aegle marmelos*, *Terminalia tomentosa*, *Lagerstroemia parviflora*, *Syzygium cumini* and *Adina cordifolia*.

Ecologically sal forests are present on the conglomerates and sandstones of the Shivalik. Many workers in the past correlated local geology with distribution of sal. The best sal however, occurs on deep loamy soils covering or derived from crystalline rock. Puri (1951), in the Shivaliks, correlated the occurrence of Sal with geology, alternating strata of Shivalik clay and conglomerate Shivalik clay which are ferruginous indicating low pH value are found to be best suited to Sal. On conglomerates, sal occurs in low percentage in tree canopy, occurrence of various plant communities with structural geology and pH values of soil has been also correlated. Hole (1919) is of opinion that the excess of the organic material is detrimental to Sal regeneration. Bhatnagar (1960a) also reported that the soil having low organic matter and pH had good growth of Sal. Puri (1951) is of the opinion that low subsoil acidity high subsurface and subsoil calcium and high organic matter are indicative of poor growth and regeneration of some sal forests in Madhya Pradesh. Similar results have been presented by Bhatnagar (1960, 1961) and Seth and Bhatnagar (1959). Rodgers *et.al.* (1986) described the effects of wild fire on plant structure and species composition in uniform sal forests near Dehradun. The study indicated that opportunistic weeds and herbs dominated the frequently burnt areas but species like *Callicarpa* and

Costus were more common in unburnt areas. Rajvanshi *et.al.* (1983) compared the undergrowth of sal forest and *Eucalyptus* plantation at Golatappar, Dehradun and found that though the *Eucalyptus* plantation had considerably more (65) species compared to sal forest (37) but most of them were weedy. In Kumaun Himalayan foothills, Rao and Singh (1985) studied the population dynamics of Sal and reported the die-back habit of Sal seedling which suggested the ability of the species to withstand unfavourable period. But no comprehensive studies have been undertaken on the overall status of sal and its associated species in outer Himalaya and Shivaliks.

3.4.4. Regeneration

A great deal of work has been done on this problem. The Data prior to 1933 has been summarised by Champion (1933), Puri *et.al.* (1989). The important report include Anonymous 1927, 1940, Raynon, E.W. (1940), Bailey (1919, 1936), Chatterjee and Thapa (1970), De (1942), Divakar (1941), Osmaston, F.C. (1928), Puri (1951, 1953, 1955, 1957) and Pande (1961). The later work was summarised by Puri (1950-51) who categorised the sal forests of India based on the regeneration into the following:

i) The type of regeneration is found in I-II quality of sal. This occurs on light soil derived in situ from Schists, geneisses, sandstones and Quartzites and also on red group or red soils which are transported and occur at the bottom of hills.

ii) Low quality sal forests with mixed canopy, which may be climax with other species. The establishment period of sal regeneration in these forests is variable, generally long but sure. These occur on somewhat heavier soils formed *in.situ* from the ferruginous strata of the Shivaliks, Pisolitic laterites in Madhya Pradesh and Bihar. Here the soil is well drained, aerated, loose and rich in Fe oxides, Mn and Al mixed with Quartzites.

iii) This category is Mature Sal forests with no regeneration and regular and unbroken canopy. They occur on soils derived from trap and basalt or bauxite and heavy laterite *in situ* or on transported soil in valley bottoms. These soils are poorly drained, deep black or chocolate in colour are very clayey and compacted.

iv) Mature or immature sal forest with regular canopy, with heavy or

moderate evergreen undergrowth but unestablished regeneration the exact ecological status is difficult to assess. These occur mostly in transported soils on flat areas in U.P. Soils are deep and show zonation with clayey black layer at the top and sandy layer at the bottom. The humus is somewhat basic, with high organic matter, badly drained and suffer draught in summer. When the canopy is open grasses come in profusion.

v) Yadav (1966) reported that both fine and coarse textured soils which are acidic and non-calcarious support good sal regeneration provided the conditions of moisture supply, aeration and drainage in good conditions. Natural regeneration is hampered both by coarse textured and excessively bouldery soils having deficient moisture retention with high accumulation of organic matter as well as by clayey soils with poor permeability.

Studies on 'Sub-tropical vegetation' in general are also limited (Puri *et.al.* 1989). No study exists on the distribution and regeneration of *Anogeissus latifolia*, a common associate of sal in higher slopes of Shivaliks (*cf.* Joshi 1958).

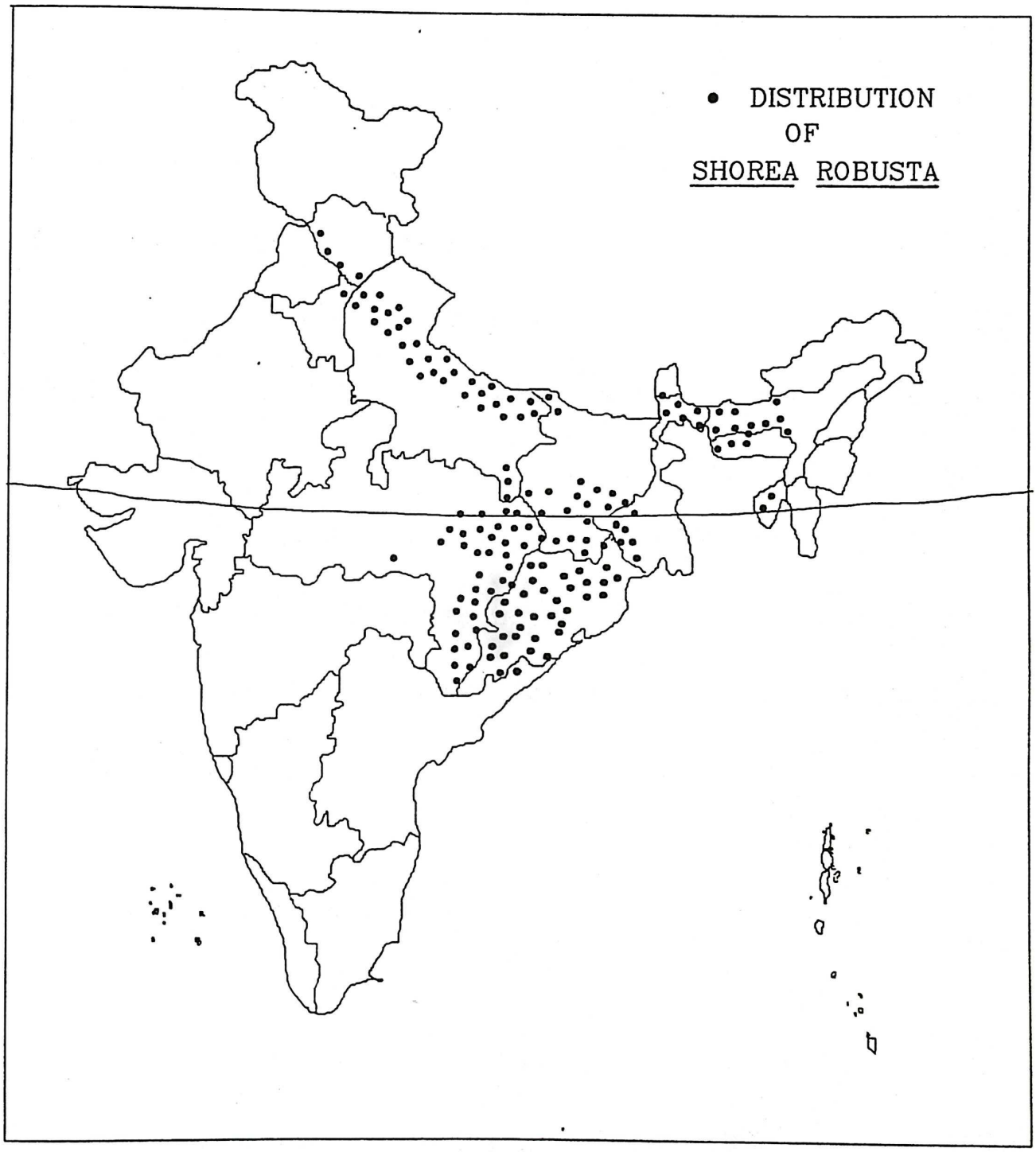


Fig: 3.4.2 : Map showing distribution of Sal (Shorea robusta) in india.

4.0 METHODOLOGY

The phytosociological analysis of woody vegetation was an important part of present study. Because the entire study was focused on the status of forests along the gradients of altitude and human use, utmost care was taken in adopting methods accordingly. The Intensive study area was approximately 50 km in length and 10 km in width i.e. 500 km^2. The study area has three different ecological zones viz. Shivaliks, Doon Valley and Outer Himalaya (Chapter 3.0). The area was primarily stratified into these three zones. Each zone was further stratified according to altitude and level of disturbance viz. disturbed, less disturbed and protected areas (Table-4.0).

4.1 FIELD METHODS

In order to achieve the objectives (Chapter 1), the vegetation was sampled in all the strata during September-May, 1992, 1993 and 1994. The sampling unit was a rectangular plot of 20 m x 5 m covering an area of 100 m^2. The shape and size of quadrat was determined following the species area curve method and from the empirical view

points (Mueller-Dombois and Ellenberg 1974). Although, many studies in the outer Himalayan region have used square plots of 100 m^2 (10 m x 10 m) area e.g. Adhikari 1988, Bargali *et.al.* 1987, 1989. Singh, *et.al.* 1994), I preferred a rectangular plot because of the following reasons:

a) In an undulating terrain, laying exact square plots of 10 m x 10 m becomes cumbersome. Once, random point and direction are determined in the field, it is easy to stretch the 20 m tape or string in any type of terrain for sampling.

b) Rectangular plots are more efficient than square or circular plots because of the general tendency of clumping in the vegetation. This was also suggested by Greig-Smith (1952, 1964).

c) The sampling intensity per sample unit is more in rectangular plot and variance is reduced between plots, despite the apparent variation within the sample unit.

d) Other sampling methods e.g. line transects (McIntyre 1953), or distant methods (Curtis and McIntosh 1950) need a large sample size in order to attain a higher level of precision.

The data were collected for the structural aspect of the vegetation along with human-animal disturbance such as lopping, cutting, browsing, path, disturbed, undisturbed etc. Field collection of data was done in such a way that each zone was covered in different seasons of the year to quantify the change in trees and shrub layer along with Sal (*Shorea robusta*) regeneration. The data sheet used for field work is given in appendix-3.

The tree and shrub layer was quantified using stratified random samples following the standard techniques (Cain and Castro 1959, Phillips 1959, Mishra 1968, Shimwell 1971, Mueller-Dombois and Ellenberg 1974, Moore & Chapman 1986, Bonham 1989). In whole of the study area about 254 plots were laid i.e. minimum of about 75 plots in each stratified zone in order to run the statistical tests.

Abiotic variables such as topography altitude, aspect, soil moisture, texture and biotic factors such as human and animal (domestic as well as wild) were systematically recorded for each sampling station. Relative use of livestock and wild animals by direct use was beyond the scope of this work, hence indirect evidences were recorded by counting pellets/dung groups along a belt transect of 20 x 2 m at each sampling station. Regeneration, number of three tree species i.e. Sal (*Shorea robusta*), Dhai (*Anogeissus latifolia*), and Chir

(*Pinus roxburghii*), were recorded in each sampling plot. Canopy cover was estimated for each group i.e. tree species and shrub layer individually in each plot throughout the field work. The topographic features (% Frequency) of the sample plots in the study area are given in Table 4.1.

4.2 ANALYTICAL METHODS

The girth of trees at breast height (GBH) was noted for basal area calculation. The density (D), percentage frequency (%F), abundance (Ab), relative frequency (RF), Relative density (RD), Basal area (BA), relative dominance (RDom), Importance Value Index (IVI)etc. of each tree species were calculated from the quadrat data as per the following formulae (Mishra, 1968).

i) Density (D) $= \frac{\text{Total no. of individuals}}{\text{Total no.of quadrates studied}}$

ii) Abundance (Ab) $= \frac{\text{Total no. of individuals}}{\text{No. of quadrates of occurrence.}}$

iii) % Frequency (%F) $= \frac{\text{No. of quadrates of occurrence}}{\text{Total no. of quadrates studied.}} \times 100$

iv) Relative density (RD) $= \frac{\text{No. of individuals of species} \times 100}{\text{No. of individuals of all species.}}$

v) Relative frequency (RF) = $\frac{\text{No. of occ. of the spp. in the Quadrate}}{\text{No. of occ. of all spp.}} \times 100$

vi) Relative Dominance (RDom) = $\frac{\text{Basal area of a species}}{\text{The basal area of all species}} \times 100$

vii) Basal area = $C^2/4\pi$[c=Girth of the species]

viii) Importance Value Index (IVI) = RD+RF+RDom

The maturity of forests in order to compare the successional stage in each area was calculated using maturity Index value(MI) following (Pechi-Sermolli 1948). This is based on the principle that when the succession has entered into advance stage the total no. of species will reduce. Therefore, the higher the frequency % of the species and smaller the number of sporadic species, the more mature is the community.

ix) Maturity index (MI) = $\frac{\text{Total \% Frequency of a locality}}{\text{Total no. of species present}}$

To assess the overall similarity of different localities with respect to species diversity 'The index of similarity' (IS) were worked out for Shivaliks, Doon valley and outer Himalaya. The study is based on the 'community coefficient concept' of Jaccard (1912) and centred on the presence, absence relationship between the number of species. Thus

it expresses the ratio of the common species found in the vegetation (Mueller-Dombois and Ellenberg 1974). Here I have used the modified version of Jaccard's formula, by Sorenson (1948) as:

$$\text{x) Index of Similarity} = \frac{2C \times 100}{(A+B)}$$

where C= No. of common species in two areas
A = Total no. of species in area A and
B = Total no. of species in area B.

Thus the values were tabulated in terms of the species presence, their relationship and composition. The data collected in the field were entered and stored in PC-XT Computer using Foxbase. Summarization of data was done initially and later subjected to intensive analysis using packages such as TWINSPAN for vegetation classification (Bray and Curtis (1957), Hill (1979) and SPSSPC for statistical analysis (SPSS, Inc-1987).

Table. 4.0 : **Stratification of the study area (Vegetation types: DDS = Dry Deciduous Sal, MDS = Moist Deciduous Sal, S-A = Shorea Anogeissus, SM = Sal Mixed; S-A-P = Shorea - Anogeissus - Pinus, SV = Scrub Vegetation; Terrain Type: 0 = Flat, 1 = Gentle Slope, 2 & 3 = Steep Slopes, 4 = Ridge and ; Distribance Category: H = Heavy, M = Medium and L = Low).**

Primary Strata	Secondary Strata			
	Locality	Vegetation Type	Terrain Type	Distribution Category
Shivaliks (300 - 850 m)	Mohand - Lower	DDS, SV	0,1,2	H
	Rajaji NP	DDS, S-A	2,3,4	L
	Shivaliks Slopes	S-A	2,3	L
	Shivaliks Ridge	S-A	2	M
	Kaurapani Top	S-A-P	2,3	L
		SM		
Doon Valley (600 - 700 m)	Asarori	MDS	1,2,3	L
	Karuapani Lower	MS	0	L
	Chandrabani	MDS	0	M
	FRI Vicinity	MDS, SV	0	M
Outer Himalaya (1200 - 1800 m)	Rajpur (Upper)	DDS, SV	1,2	M
	Malsi - Upper	SV, DDS	2,3	M
	Transitional Zone	SV, DDS	2,3	H

Table. 4.1 : **Topographic features (% Frequency) of the sample plots in the study area (plots were not taken on the slopes with > 70°).**

Topographic feature	Shivaliks	Doon Valley	Outer Himalaya
0, Flat	19	31.70	4.05
1, Gentle Slope	53	64.63	81.08
2, Steep slope	5	1.2	10.80
3, Ridge top	21	2.4	4.05
4, Rau bank	2	-	-
N	100	82	74

5.0 RESULTS

This chapter summarises the broad findings of the study. In total 256 plots i.e. 100 from Shivaliks 82 from Doon Valley and 74 from outer Himalaya were analyzed using PC - XT Computers and various softwares. The following sections deal with the results on community composition, diversity, species richness, regeneration of important trees, species distribution, Importance Value Index (IVI), girth class distribution, and abiotic and biotic factors influencing the vegetation.

5.1. COMMUNITY COMPOSITION

The 'TWINSPAN' analysis of the vegetation data showed a total of 17 types of tree species associations. In all, 50 tree species which occurred in the sample plots were subjected to this analysis. Fig. 5.1 shows the dendrogram of tree communities in the study area. The groups were segregated at 5 levels and Eigen values indicating the significance level ranged from 0.216 to 0.729 except two cases where the values were below 0.20 The associations are shown in table 5.1. Of the 50, four species happen to be planted in certain localities viz.

Melia azadirach, Cinnamomum camphora, Salix acmophylla and *Eucalyptus* species. These and other rarer species viz. *Boswellia serrata, Bridelia retusa, Dalbergia sissoo, Buchananiana lanzan, Terminalia chebula* etc. didn't figure out in the communities or were represented within only a few plots. The characteristic features of these communities are as follows:

A: *Bridelia retusa* - *Casearia tomentosa* - *Cordia myxa*: This community was found only in a few mesic sites of Shivalik region, mainly near the junctions of Sal forests and *Acacia* - *Zizyphus* woodland with stable alluvial soil and relatively flat terrain.

B: *Cassia fistula* - *Mallotus philippinensis* - *Terminalia alata* - *Garuga pinnata*: This appears to be a loose association of widely occurring species. Depending upon the site history e.g removal of sal through selection felling etc, the abundance of these species varies.

C: *Anogeissus latifolia* - *Mitragyna parviflora* - *Semecarpus anacardium*: Gentle hill slopes in the southern parts of

Shivalik had this community with average canopy cover < 50 % Undergrowth of this community in less disturbed areas comprised of grasses such as *Chrysopogon fulvus, Heteropogon contortus* and shrub *Woodfordia fruticosa, Gardenia turgida, Carissa carandas* etc.

D: *Emblica officinalis* - *Kydia calycina* : These three species of this community occur widely but sparsely through out the study area. The former being one of the favoured Minor Forest Produce (MFP) and the latter is an excellent fodder species. In nature, such a community is rather difficult to identify.

E: *Shorea robusta* - *Terminalia alata* - *Mallotus philippinensis*: Most of the gentle shivalik slopes basically in shady, less exposed areas represent this community, especially in less disturbed areas. This is considered as a true climax community in the region. Besides, occasionally *Ficus benghalensis, Ficus rumphii, Helecteris isora, Aegle marmelos* etc. are found in this association.

F: *Terminalia bellirica* - *Garuga pinnata* - *Flacourtia indica* : This is yet another loose association of trees where all the species are also found in association with Sal. Such an association is however, more prominent on the higher slopes of shivaliks.

G: *Shorea robusta* *Anogeissus latifolia* *Terminalia alata* - *Mallotus philippinensis* : This, perhaps represents the dry deciduous sal category of Champion & Seth's (1968) classification. Allthe higher slopes of shivaliks on steeper slopes fall under this type of community.

H: *Shorea robusta* *Terminalia alata* - *Adina cordifolia* : This type of association has been recognized throughout the distribution range of sal in Bhabar belt. In the study area, however, *Adina cordifolia* was rather sparse as compared to eastern part of Rajaji and Corbett NPs.

I: *Syzygium cumini* - *Shorea robusta*: Deep ravines, stable river beds and stream banks are characterized by this community. Areas under this community indicate the presence of perennial water.

J: *Pinus roxburghii* - *Terminalia chebula* - *Shorea robusta* : This community forms a narrow belt along higher slopes of shivaliks and outer Himalaya. Chir pine in this area is often referred as shivalik pine or sub-tropical pine and differs from the extensive pine forests of temperate pine region in its sparse cover. Other associates of this community are *Terminalia chebula, Anogeissus latifolia* etc.

K to N: *Shorea robusta* - *Pinus roxburghii* - *Terminalia alata; Shorea robusta* - *Pinus roxburghii* and other pine association: These categories have figured out in the analysis owing to local abundance of certain species or clumping of *Pinus roxburghii* in some patches. In nature, perhaps, these will be difficult to segregate from each other.

O: *Shorea robusta* - *Mallotus philippinensis* : This forms almost monoculture in the parts of Doon Valley especially adjoining Rajaji NP. *Clerodendrum infortunatum, Callicarpa macrophylla* are the common understorey species. It is often referred as moist deciduous sal.

P: *Shorea roubsta* - *Syzygium cumini* : Moist deciduous sal in doon valley merges with certain edaphic categories such as swamp forests and riverine patches. The community mentioned here is the typical of the riverine or low lying mesic site.

Q: *Pinus roxburghii* - *Kydia calycina* : This was figured out in only one plot and doesn't appear to form a distinct community range enough to be distinguishable in nature.

An important community which can be easily distinguishable in the field i.e. *Dalbergia sissoo - Acacia catechu* did not segregate in TWINSPAN analysis. The likely reason for this could be inadequate sampling in and around Rau beds.

5.2 DIVERSITY AND SPECIES RICHNESS

In all, 104 species of trees and shrubs were recorded within the sample plots. Shannon-Weiner Index for tree species were 2.15, 1.39 and 0.43 for Shivaliks, Doon Valley and outer Himalaya respectively. A comparison of woody species based on 74 plots from each zone showed that species richness was highest in Shivaliks

followed by Doon Valley and outer Himalaya, though the differences were minor (Appendix - I). *Anogeissus latifolia,* a species frequent in Shivaliks was absent in Doon Valley and outer Himalaya. It thus makes a significant difference in vegetation of these zones. Sorenson's similarity index for Shivaliks - Doon Valley, Doon Valley - outer Himalaya and Outer Himalaya - Shivaliks were 45.85 %, 55.04 % and 53.70 % respectively (Table 5.20). This indicates that the Shivaliks and Doon Valley were most dissimilar in terms of species composition. Though Shivaliks and outer Himalaya are separated by Doon Valley. They showed higher similarity. In general however, all the three regions show marked differences from each other. The alfa and beta diversity of one or two zones may be lower but the overall diversity of the study area is likely to be high compared to many areas of similar climatic zone. Appendix - II gives a list of species encountered in the study area including common grasses and climbers.

5.3. REGENERATION AND SUCCESSIONAL TRENDS

Sal (*Shorea robusta*) figured out as most dominant species in all the three zones with varying regeneration status. Table 5.31 shows the overall density of Sal and *Anogeissus* saplings along with the total

shrub densities in Shivaliks, Doon Valley and outer Himalaya. Interestingly, outer Himalayan belt had highest density of saplings (46 ± 12.08) followed by Doon Valley (21 ± 4.22) and Shivaliks (14 ± 3.64). *Anogeissus* regeneration was observed only in some parts of Shivaliks. No saplings or seedlings of *Pinus roxburghii* were found within the sample plots. *Mallotus philippinensis, Ougenia dalbergioides* and *Pyrus pashia* had fairly good regeneration as indicated by high density of their saplings and individuals at higher age class. Other species e.g., *Dalbergia sissoo, Terminalia bellirica, T. chebula, Bridelia retusa, Toona ciliata, Semecarpus anacardium* figured out very low in terms of sapling production. The average ratios of saplings and pole size (< 30 cm) crop of sal in the Shivaliks, Doon Valley and outer Himalaya were 21:1, 84:1 and 63:1. Of the total Sal population, the pole size crop comprised 20%, 6% and 13% in Shivaliks, Doon Valley and outer Himalaya respectively. In all the three cases there was no correlation between tree canopy cover and number of sal saplings: Correlation Coefficient (r) for Shivaliks r= 0.10 P= 0.30, for Doon Valley r= 0.27 P= 0.01, and outer Himalaya r=.16 P= 0.16. But there was a slight correlation between shrub cover and number of Sal saplings (r = 0.29 P= 0.007). On the other hand, there was slight negative correlation between total tree canopy cover and *Anogeissus*

saplings (r = - .12 P= < 0.05) and negative correlation between total shrub cover and number of *Anogeissus* saplings (r = - .18 P= < 0.005) in Shivaliks. Maturity Index (Table 5.32) of Shivaliks, Doon Valley and Outer Himalaya were 8.61, 7.55 and 20.16 which indicates that forests of Doon Valley were much more mature than the adjacent zones. This trend is shown, perhaps due to a large number of mining activities in the outer Himalaya and heterogeneous and fragile nature of Shivaliks.

5.4. IMPORTANCE VALUE INDEX (IVI)

Importance value Index of sal were 262.92, 234.86 and 83.86 in outer Himalaya, Doon Valley and Shivaliks respectively. (Table 5.41, 5.42 and 5.43). Outer Himalayan zone had only six species. IVI values of Sal, *Anogeissus* and Pinus in various localities are given in Table 5.44. Highest IVI of Sal was observed in Chandrabani, Doon Valley (288.62) and lowest of Indian Military Academy and adjacent areas (124.83). This is likely due to influence of man in the form of selective logging. Figures 5.41 - 5.4.15 show the IVI values of major tree species in various localities.

5.5 GIRTH CLASS DISTRIBUTION

Frequency (%) of girth class distribution of sal in the entire study area is shown in Table 5.51. Of 1001 Sal trees measured, pole size i.e. 10 - 20 cm GBH were only 4 % (of 30 cm limit taken in section 5.3). The individual sites and zones, however varied considerably in the girth class distribution. In outer Himalaya % occurrence of Sal trees at pole size was 7.92 % (Table 5.52). On the other hand older or mature trees (> 140 cm GBH) were distributed unequally within the three zones. Highest frequency of this class was in Shivaliks (22.35%) followed by Doon Valley (17.18 %) and outer Himalaya (0.76%). In Outer Himalaya there was no tree above than 140 cm in GBH. Highest GBH recorded in the study area was 350 cm at Mohand. Besides Sal, *Mitragyna parviflora, Ficus benghalensis, Ficus religiosa, Bombax ceiba, Terminalia bellirica* and *Terminalia tomentosa* attained GBH around 300 cm Figs 5.51 - 5.53 show the distribution GBH class of Sal in various localities. Average girth of sal was highest ($\bar{X}$ = 126.26 $\pm$12.34) and lowest in the transition zone of outer Himalaya ($\bar{X}$= 56.02 $\pm$ 6.44).

5.6. INFLUENCE OF ABIOTIC FACTORS

Topography, aspect, soil, terrain types were the primary abiotic variables recorded while sampling the vegetation. Other factors such as rainfall, moisture content, relative humidity and mean monthly temperature were taken from local meterological sources. Of the big trees (GBH > 200 cm and height Class = > 20 m) 38 % were found on flat area, 56 % on gentle slopes and only 5.26 % on steeper slopes. Of these trees 60 % were Sal, 17 % *Terminalia tomentosa*, rest of them belonged to miscellaneous species viz. *Ficus, Albizia, Pinus roxburghii, Mitragyna parviflora* etc. Maximum girth of *Anogeissus* was found to be 200 cm on gentle slopes.

5.7 BIOTIC FACTORS

Table 5.7 shows the average density of pellet groups / droppings belonging to wild and domestic animals in the study area. This shows that the forests in Doon valley were least used by wild ungulates while Shivaliks were utilized maximum by them. This is primarily due to heavy human disturbance in the valley. Grazing pressure by domestic livestock was highest in Doon Valley followed by outer Himalaya and

Shivaliks. The domestic and wild herbivores are known to influence the vegetation types of an area but due to lack of detailed experimental studies, exact role of each species could not be figured out.

Influence of man due to grass cutting, burning, lopping, timber and MFP collection is most pronounced in these regions. Wide spread *Lantana* cover is indicative of this. Doon valley had the highest average density of *Lantana* thickets (17.38 per 100 m^2) followed by Shivaliks (9.22 per 100 m^2) and outer Himalaya (7.88 per 100 m^2). *Anogeissus latifolia* was highly preferred species for lopping. In Shivaliks, for example, nearly 98 % of this tree were lopped. Overall percentage of trees lopped in Shivaliks, Doon Valley, and outer Himalaya were 76.89, 69.24, and 53.04 respectively.

Table. 5.0 : List of tree species and their codes used in analysis and figures 5.4 to 5.5.15.

Code No.	Tree species
1.	Acacia catechu Willd
2.	Adina cordifolia Hk Ver. Haldu
3.	Albizia procera (Roxb) Benth
4.	Anogeissus latifolia Wall
5.	Bauhinia racemosa Lamk
6.	Bauhinia malabarica Roxb
7.	Bombax ceiba L
8.	Randia dumetorum Lamk
9.	Bridelia retusa Spreng
10.	Casearia tomentosa Roxb
11.	Cassia fistula L
12.	Cinnamomum camphora F. Nees
13.	Cordia myxa L
36.	Dalbergia sissoo Roxb
14.	Boswellia serrata Roxb
16.	Emblica officinalis Gaertn
17.	Ficus bengalensis L
18.	Ficus religiosa L
19.	Buchanania lanzan
20.	Flacourtia indica (Burm.f.) Merr
21.	Garuga pinnata Roxb
22.	Kydia calycina Roxb
23.	Litsea monopetala (Roxb) Pers
24.	Litsea glutinosa (Lour) Robins
25.	Mallotus philippinensis (Poir) Baill

26. Melia azedarach L
27. Mitragyna parviflora Korth
28. Ougeinia dalbergioides Benth
29. Pinus roxburghii Sargent
30. Premna barbata Wall
31. Semecarpus anacardium L
32. Shorea robusta Gaertn.
33. Sterculia villosa Roxb
34. Syzygium cumini (L) Skeels
37. Terminalia chebula Retz
35. Terminalia bellirica Roxb
38. Terminalia tomentosa W. & A.
39. Toona ciliata Roem
40. Grewia elastica L
41. Pyrus pashia L
42. Wrightia tomentosa Roem and Schult.
43. Ficus hispida L.f.
44. Grewia laevigata Vahl
45. Salix acmophylla L
46. Grewia hainesiana L
47. Nyctanthes arbor-tristis L
48. Eucalyptus species
49. Butea monosperma Roxb. Ham

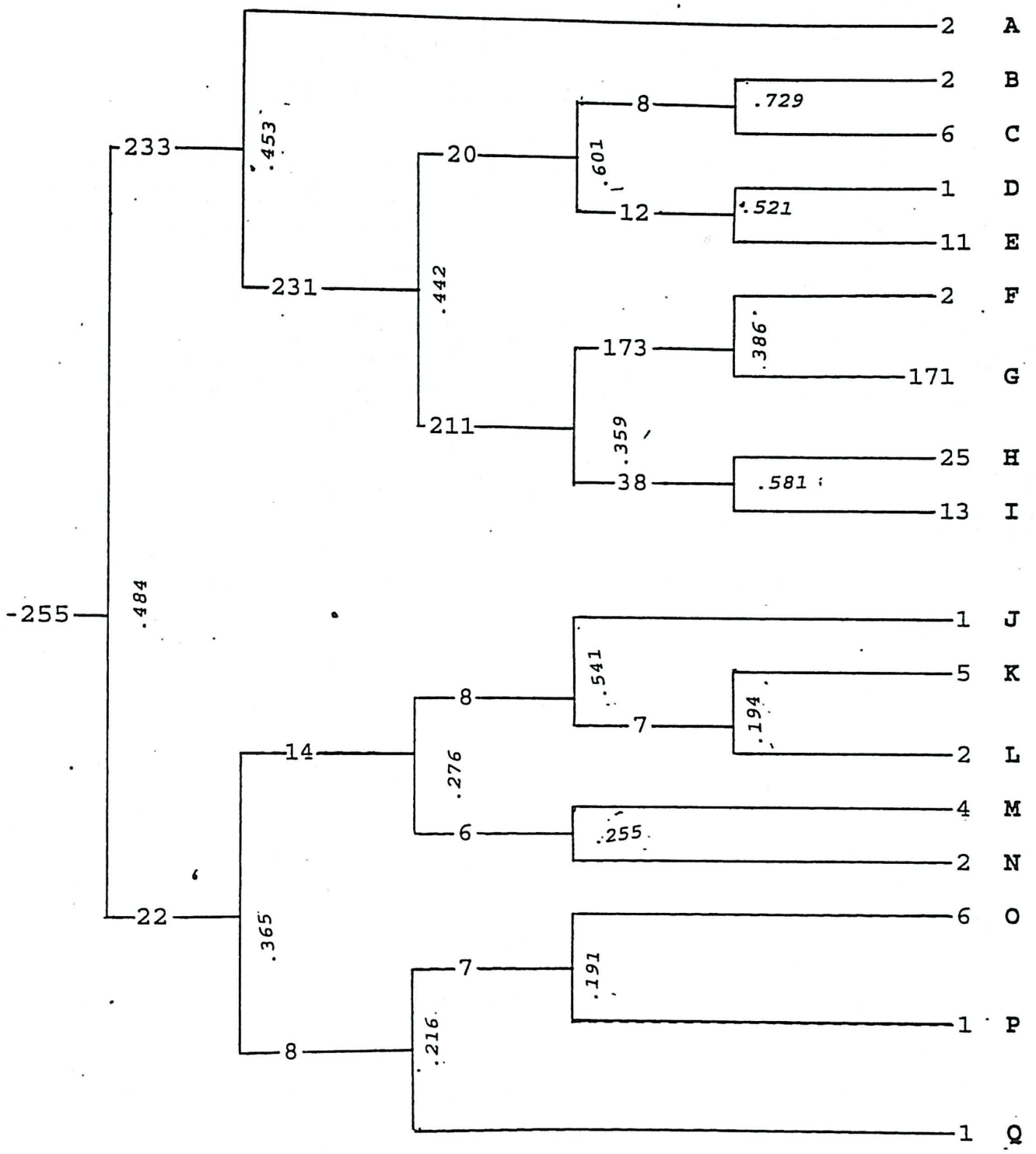


Fig. 5.1 : Dendrogram showing the association of tree species in the study area based on TWINSPAN analysis. The numeric figures indicate the number of plots and Eigen Values are shown in italics (Plant associations as indicated by the letters A - Q are given in Table 5.1 following this figure).

Table. 5.1 : Tree species associations identified along the gradient of Shivalik - Outer Himalaya as shown in the dendrogram (Fig.5.1).

Category	Species association	No. of sample plots
A:	*Bridelia retusa* *Casearis tomentosa* *Cordia myxa*	*2*
B:	*Cassia fistula* *Mallotus philippinensis* *Terminalia tomentosa* *Garuga pinnata*	*2*
C:	*Anogeissus latifolia* *Mitragyna parviflora* *Semecarpus anacardium*	*6*
D:	*Emblica officinalis* *Kydia calycina*	*1*
E:	*Shorea robusta* *Terminalia tomentosa* *Mallotus philippinensis*	*11*
F:	*Terminalia bellirica* *Garuga pinnata* *Flacourtia indica*	*2*
G:	*Shorea robusta* *Anogeissus latifolia* *Terminalia tomentosa* *Mallotus philippinensis*	*171*

H:	*Shorea robusta* *Terminalia tomentosa* *Adina cordifolia*	*25*
I:	*Syzygium cumini* *Garuga pinnata* *Shorea robusta*	*13*
J:	*Pinus roxburghii* *Terminalia chebula* *Shorea robusta*	*1*
K:	*Shorea robusta* *Pinus roxburghii*	*5*
L:	*Shorea robusta* *Pinus roxburghii* *Terminalia tomentosa*	*2*
M:	*Pinus roxburghii* *Shorea robusta* *Terminalia tomentosa*	*4*
N:	*Pinus roxburghii* *Permna barbata*	*2*
O:	*Shorea robusta*	*6*
P:	*Shorea robusta* *Syzygium cumini*	*1*
Q:	*Pinus roxburghii* *Kydia calycina*	*1*

Table. 5.7 : Mean pellet groups (#/ 100 m^2) of livestock and wild animals encountered in the study area.

Zone	No.	Domestic Animals	Langur	Wild Ungulates
Shivaliks	100	7.42	2.15	3.10
Doon Valley	82	12.37	2.98	0.91
Outer Himalaya	72	8.68	2.22	1.92

Table . 5.20 : Sorenson's Similarity Index (SI) of three zones based on tree and shrub species (n = 74 each). [SH = Shivaliks, DV = Doon Valley, OH = Outer Himalaya]

Areas of Comparision	SH - DV	DV - OH	SH - OH
Similarity Index	45.04	55.04	53.70

Table. 5.31 : Density (# per 100 m^2) of Sal and Anogeissus saplings and total shrubs in the study area with ± SE 95% confidence level.

Zone	Sal Sapling Density	Anogeissus Sapling Density	Total Shrub Density	Average # Shrub per 100 m^2	Shrub Canopy Cover %
Shivaliks	14±1.82	1±0.2	44±2.1	5±0.1	41±1.4
Doon Valley	21±2.11	0.00	55±2.32	7±77	42±1.21
Outer Himalaya	46±6.04	0.00	63±2.67	6±0.11	38±1.39

Table. 5.32 : Maturity Index of Sal Forests in the Shivaliks, Doon Valley and Outer Himalaya.

Zone	Shivaliks	Doon Valley	Outer Himalaya
Maturity Index	8.61	7.55	20.16

Table. 5.41 : Relative Frequency (RF), Relative Density (RD), Relative Dominance (RDom) and IVI of important species in Outer Himalaya

S.No.	Species	R.F.	R.D.	R.Dom	IVI
1.	*Shorea robusta*	91.89	89.47	81.56	262.92
2.	*Pinus roxburghii*	20.27	8.01	12.94	41.22
3.	*Syzygium cumini*	4.05	1.14	2.31	7.50
4.	*Toona ciliata*	2.70	0.69	1.79	5.18
5.	*Grewia elastica*	1.35	0.46	1.07	2.87
6.	*Terminalia chebula*	1.35	0.23	0.34	1.92

Table. 5.42 : Relative Frequency (RF), Relative Density (RD), Relative Dominance (RDom) and IVI of important species in Shivaliks.

S. No	Species	R.F.	R.D.	R.Dom	IVI
1.	*Shorea robusta*	83.00	46.03	54.84	183.86
2.	*Terminalia tomentosa*	42.00	10.29	14.04	66.34
3.	*Mallotus philippinensis*	32.00	9.57	3.33	44.89
4.	*Anogeissus latifolia*	22.00	6.50	3.06	31.56
5.	*Pinus roxburghii*	15.00	5.23	7.93	28.16
6.	*Premna barbata*,	13.00	2.71	1.78	17.48
7.	*Syzygium cumini*	12.00	2.53	1.81	16.33
8.	*Kydia calycina*	8.00	1.62	0.50	10.12
9.	*Nyctanthes arbor-tristis*	6.00	2.71	0.30	9.01
10.	*Mitragyna parviflora*	4.00	0.72	3.09	7.82

Table. 5.43 : Relative Frequency (RF), Relative Density (RD), Relative Dominance (RDom) and IVI of important species in Doon Valley.

S. No	Species	R.F.	R.D.	R.Dom	IVI
1.	*Shorea robusta*	88.89	70.86	75.11	234.86
2.	*Terminalia bellirica*	17.28	5.19	5.32	27.79
3.	*Syzygium cumini*	13.58	4.39	2.70	20.67
4.	*Terminalia tomentosa*	8.64	2.59	5.97	17.21
5.	*Mallotus philippinensis*	11.11	2.20	0.61	13.92
6.	*Melia azadirachta*	8.64	1.80	1.46	11.89
7.	*Eucalyptus species*	6.17	3.19	1.98	11.35
8.	*Bombax ceiba*	7.41	1.60	1.02	10.03
9.	*Premna barbata*	6.17	1.40	0.89	8.46
10.	*Albizia procera*	6.17	1.00	1.03	8.20

Table. 5.44: IVI Values of Sal, Anogeissus and Pinus in various localities

STRATA	LOCALITY	IVI		
		SAL	ANOGEISSUS	PINUS
SHIVALIKS	Mohand and Rajaji NP.	159.38	38.45	7.42
	Shivalik Ridge	199.01	28.48	51.84
	Karuapani Range	258.14	-	-
	Shivalik Range top	133.99	56.13	60.54
DOON VALLEY	Asarori Range	266.74	9.31	-
	Chandrabani	288.62	-	-
	F.R.I. Vicinity	138.55	-	8.72
	I.M.A. Vicinity	124.83	-	-
	Karuapani Swamp	242.17	10.52	-
OUTER HIMALAYA	Rajpur area	254.40	-	54.72
	Above Malsi	275.33	-	27.61
	Trans. Zone	261.55	-	30.55

Table. 5.51 : Girth class distribution of Sal in the entire study area.

Girth Class (Cm)	Frequency	%
< 20	40	4.0
21 - 40	80	8.0
41 - 60	167	16.7
61 - 80	197	19.7
81 - 100	267	26.7
101 - 120	85	8.5
121 - 140	44	4.4
> 141	121	12.1
Total	1001	100.0

Table. 5.52 : Girth class distribution of Sal (Shorea robusta) in three zones.

Girth class (Cm)	Shivaliks		Doon Valley		Outer Himalaya	
	No.	%	No.	%	No.	%
< 20	4	1.56	5	1.40	31	7.92
21 - 40	19	7.45	10	2.81	51	13.04
41 - 60	30	11.76	42	11.83	95	24.29
61 - 80	43	16.86	47	13.23	107	27.36
81 - 100	75	29.41	108	30.42	84	21.48
101 - 120	21	8.23	50	14.08	14	3.58
121 - 140	6	2.35	32	9.01	6	1.53
> 140	57	22.35	61	17.18	3	.76
N	255	25.5	355	35.5	391	39.1

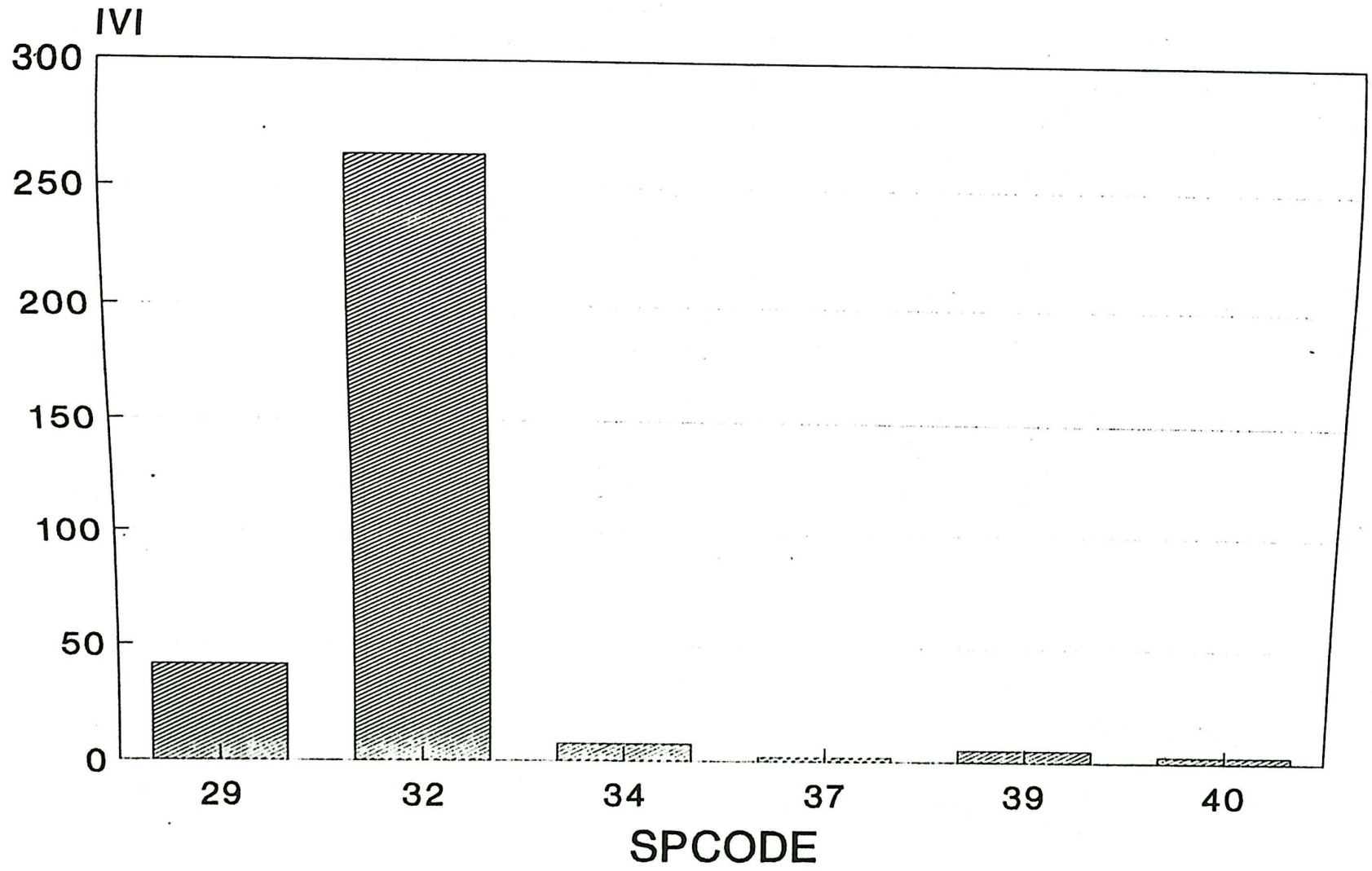


Fig 5.4.1: IVI of major trees in outer Himalaya

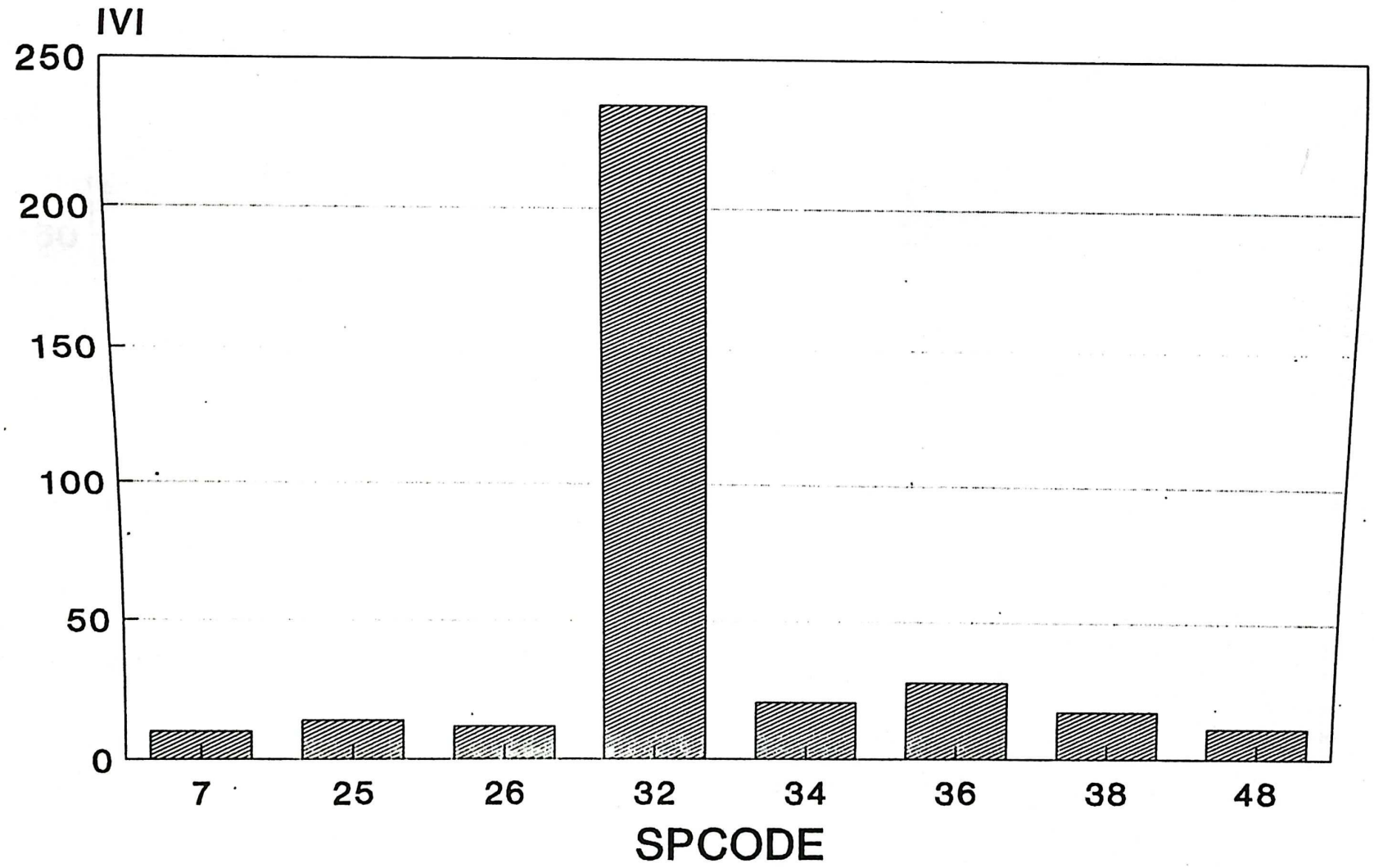


Fig 5.4.2: IVI of dominant species in Doon Valley

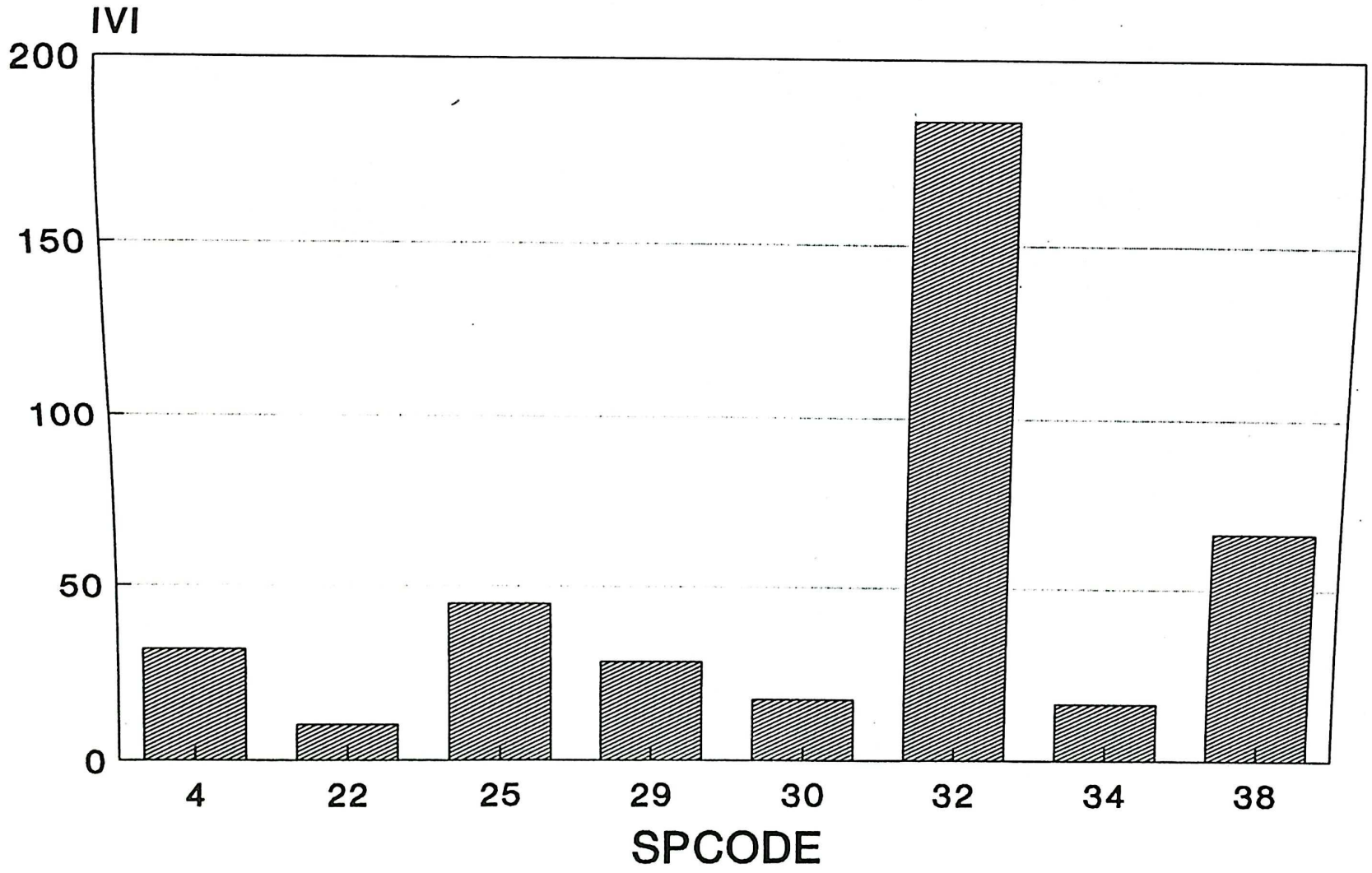


Fig 5.4.3: Overall IVI of major species in Shivaliks

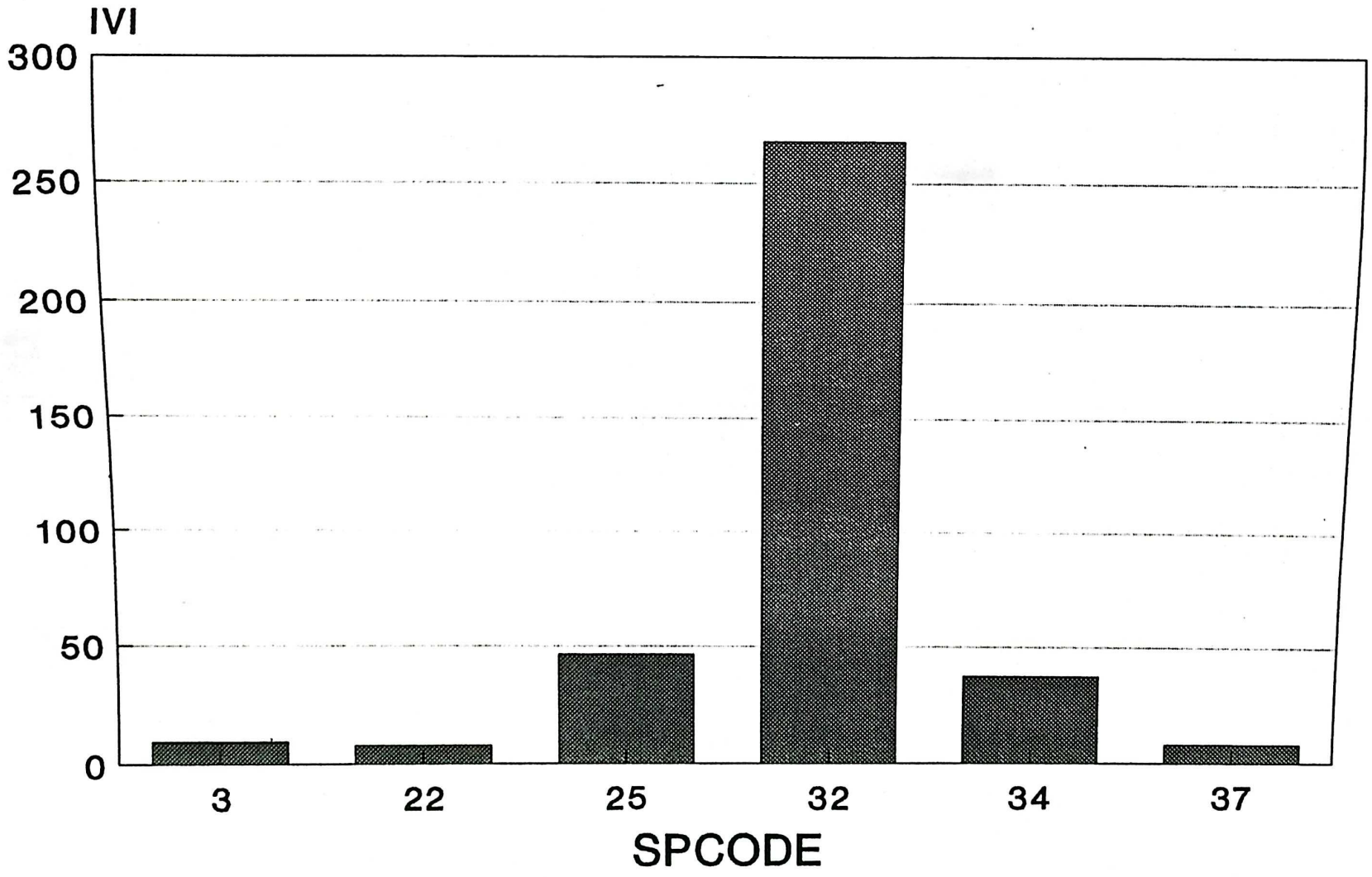


Fig 5.4.4: IVI of major tree species in Asarori

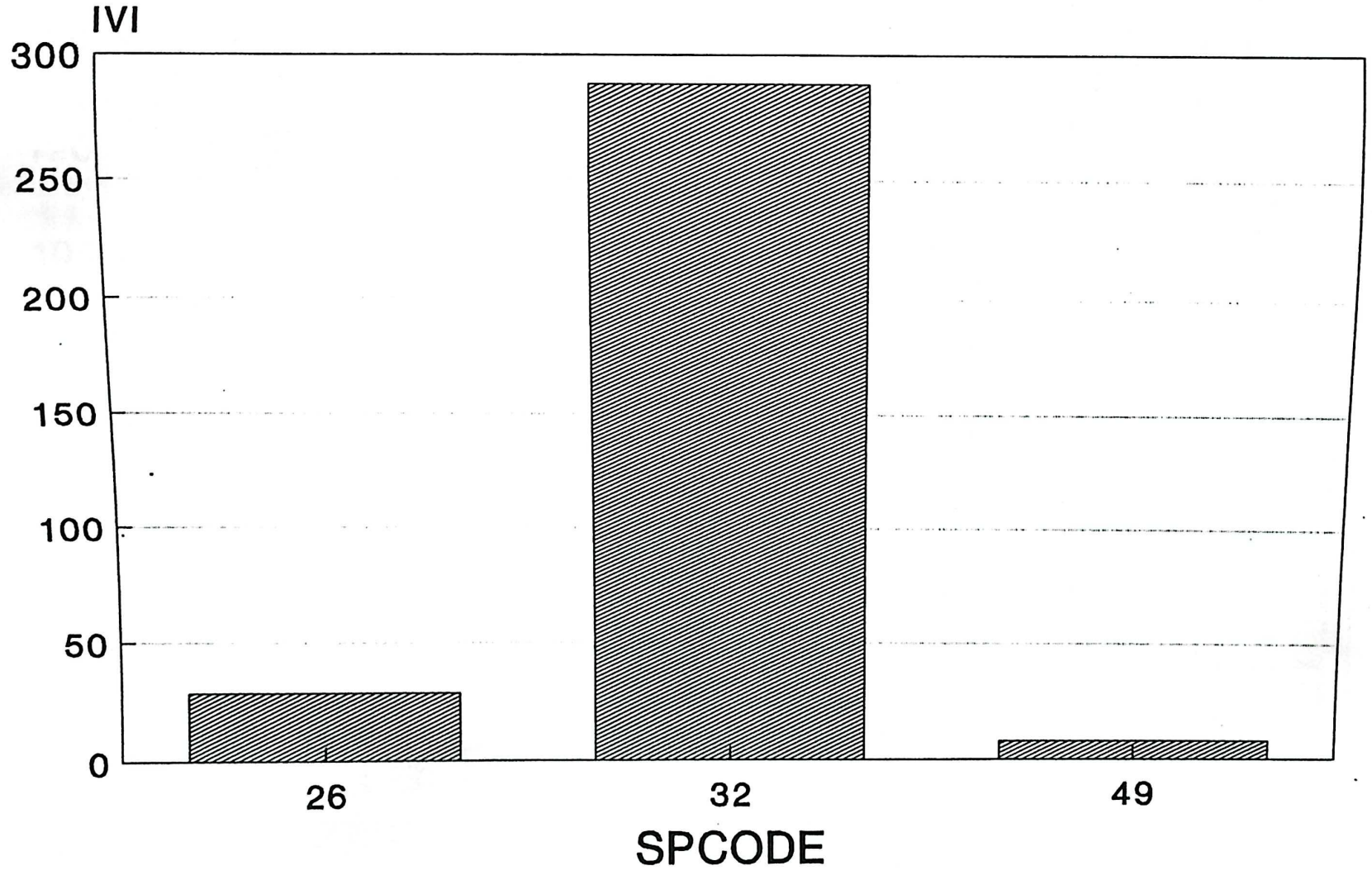


Fig 5.4.5: IVI of major tree species in Chandrabani forest

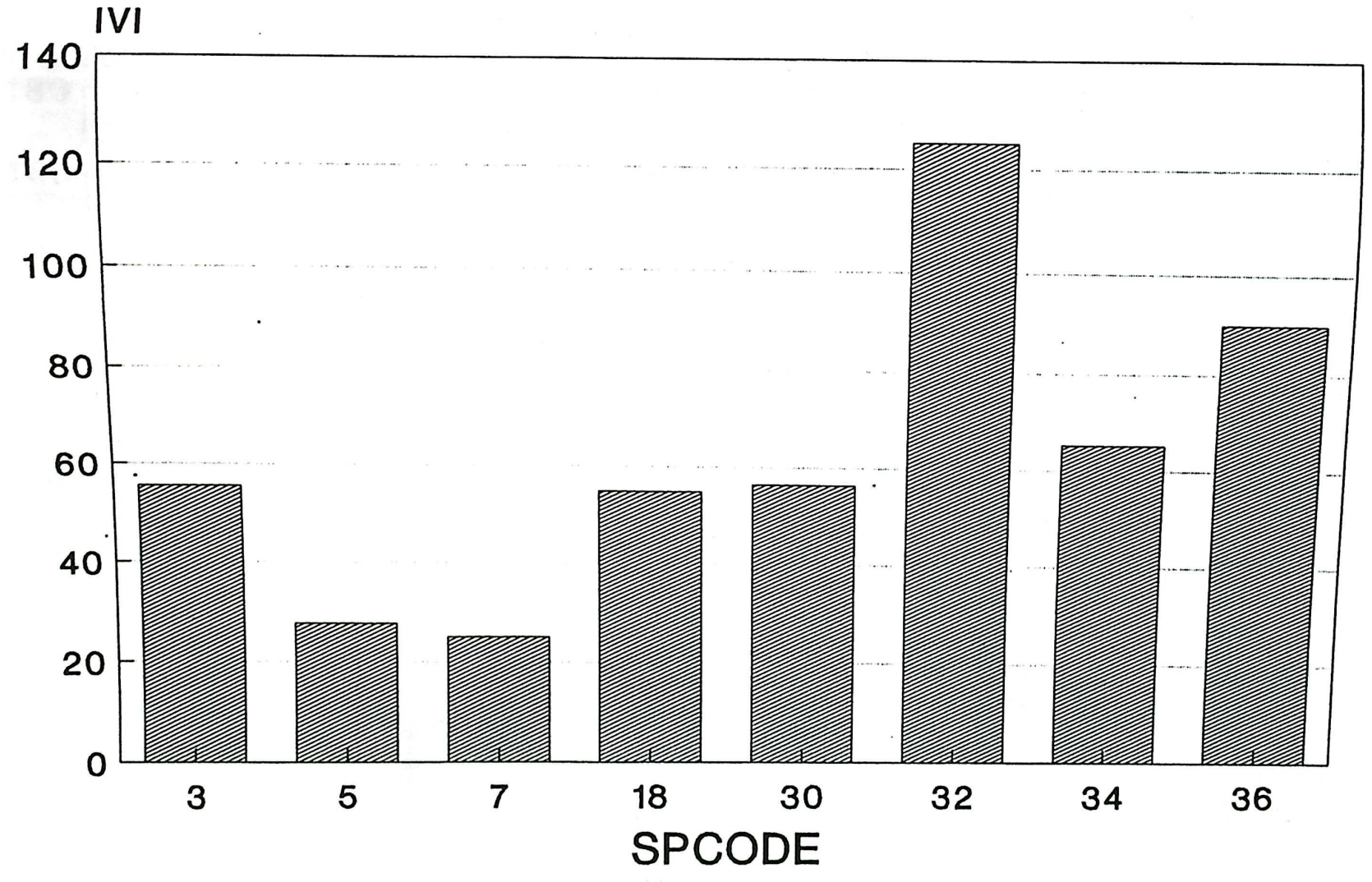


Fig 5.4.6: IVI of major trees in IMA vicinity

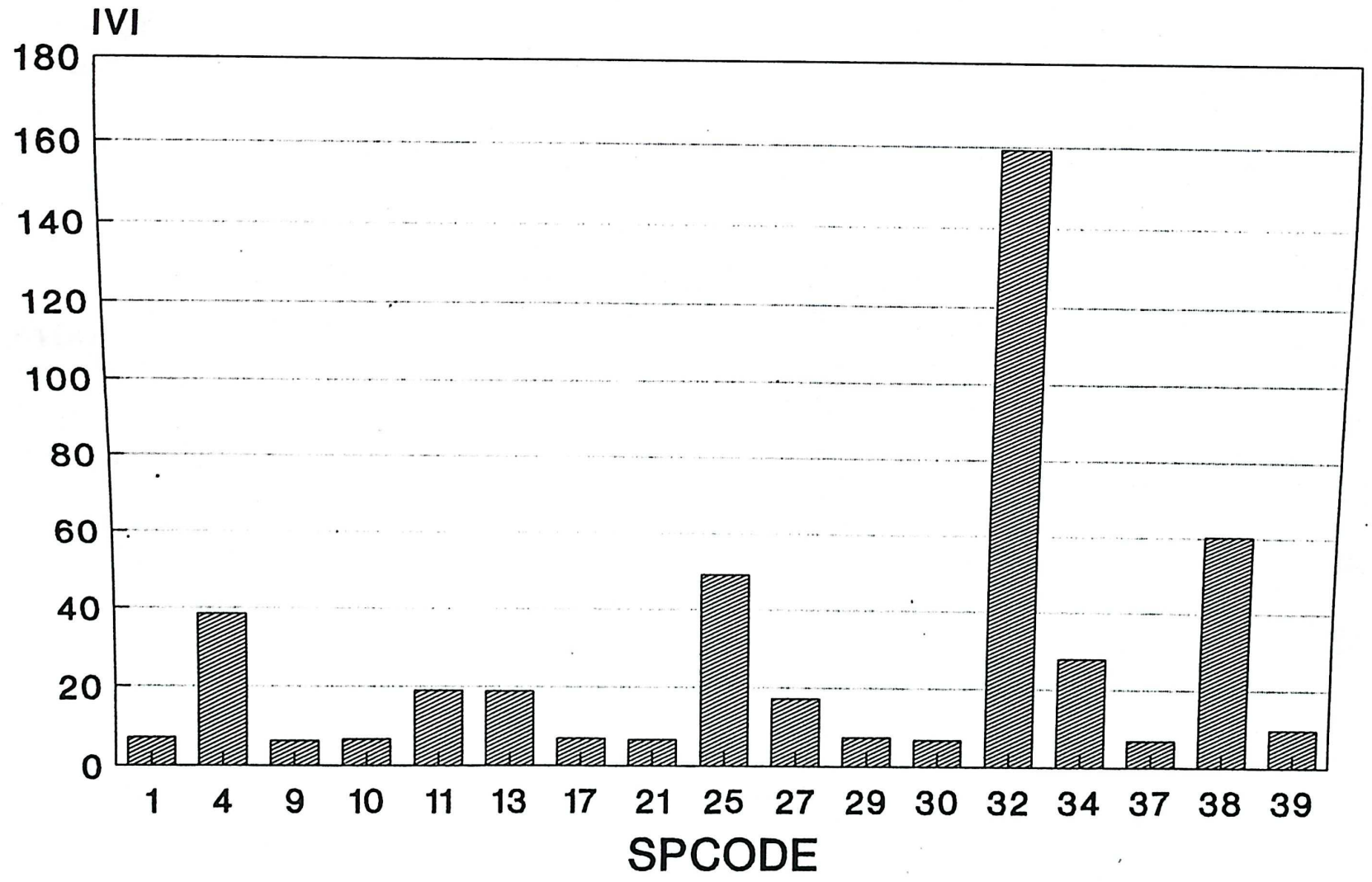


Fig 5.4.7: IVI of major species in Mohand area

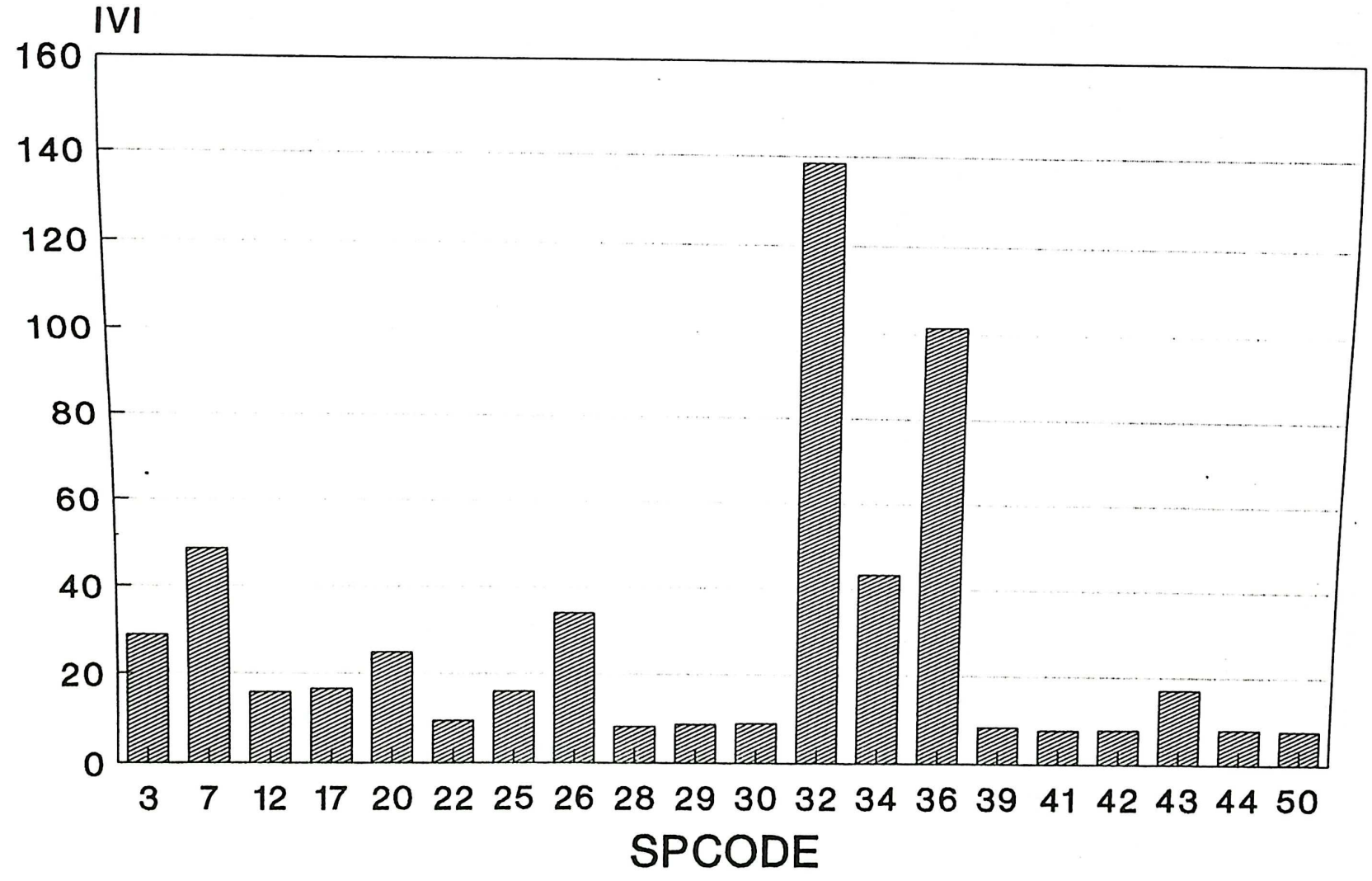


Fig 5.4.8: IVI of major tree species in FRI vicinity

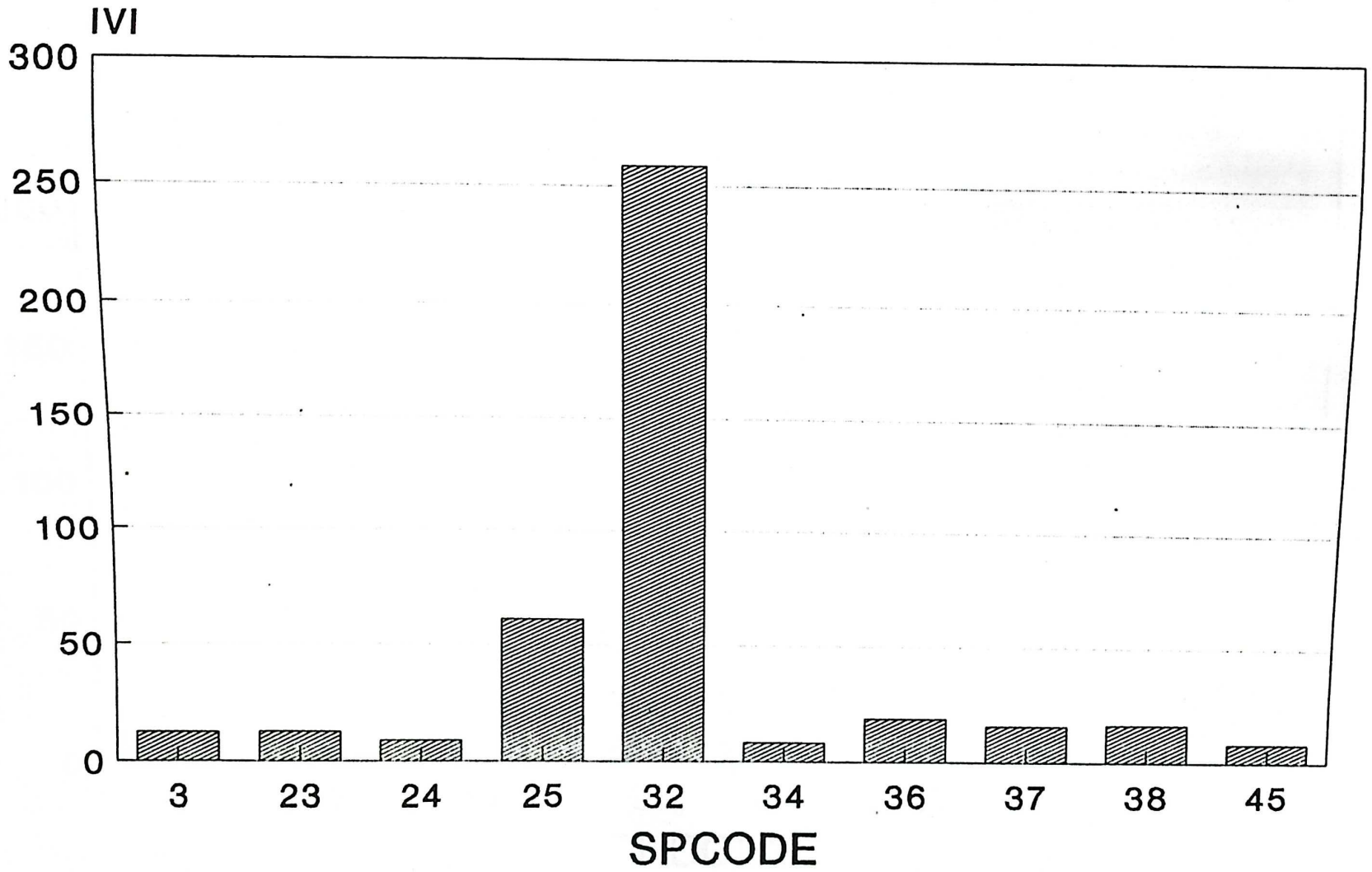


Fig 5.4.9 : IVI of major tree species in Karuapani ridge

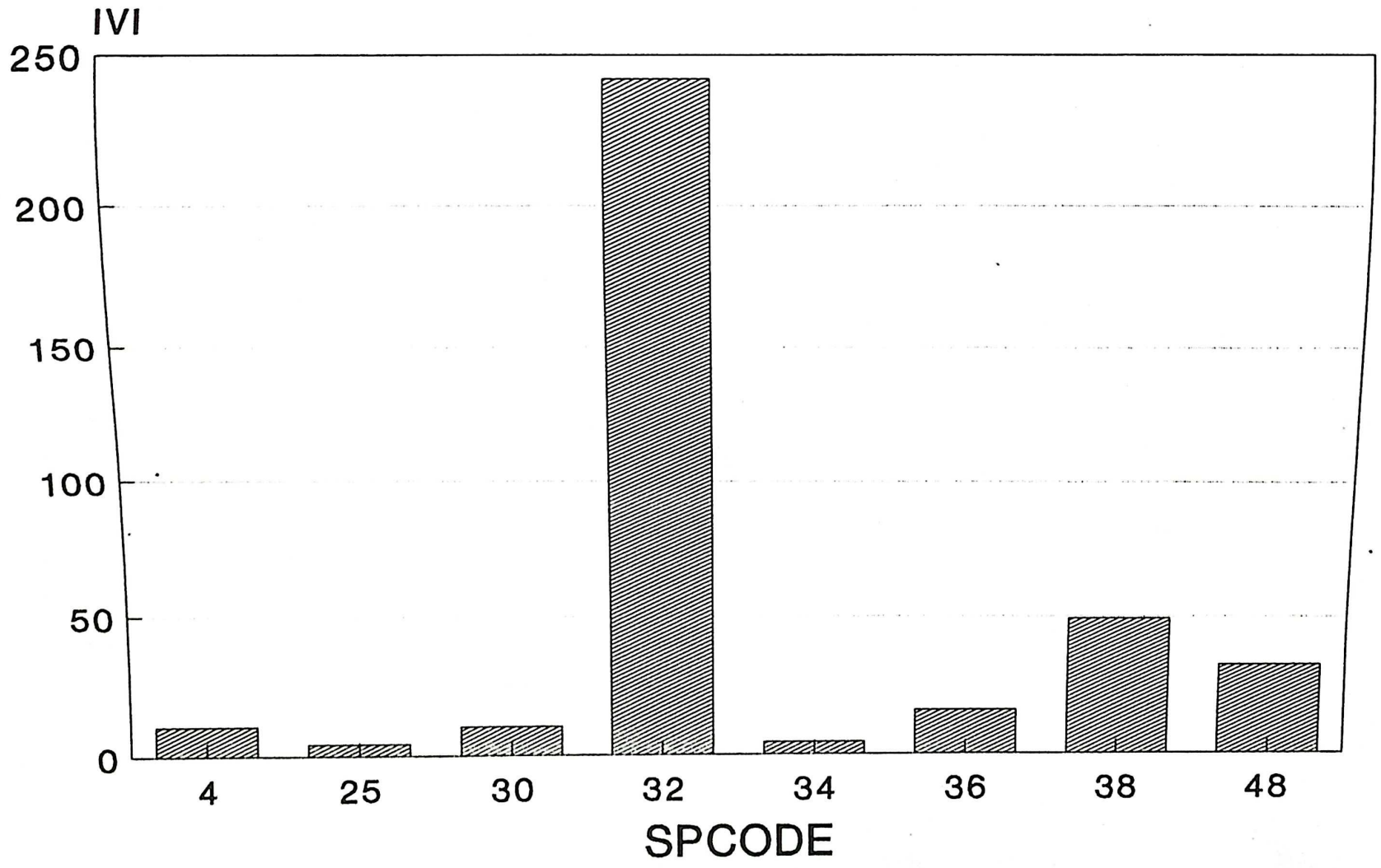


Fig 5.4.10: IVI of major tree species in Karuapani swamp

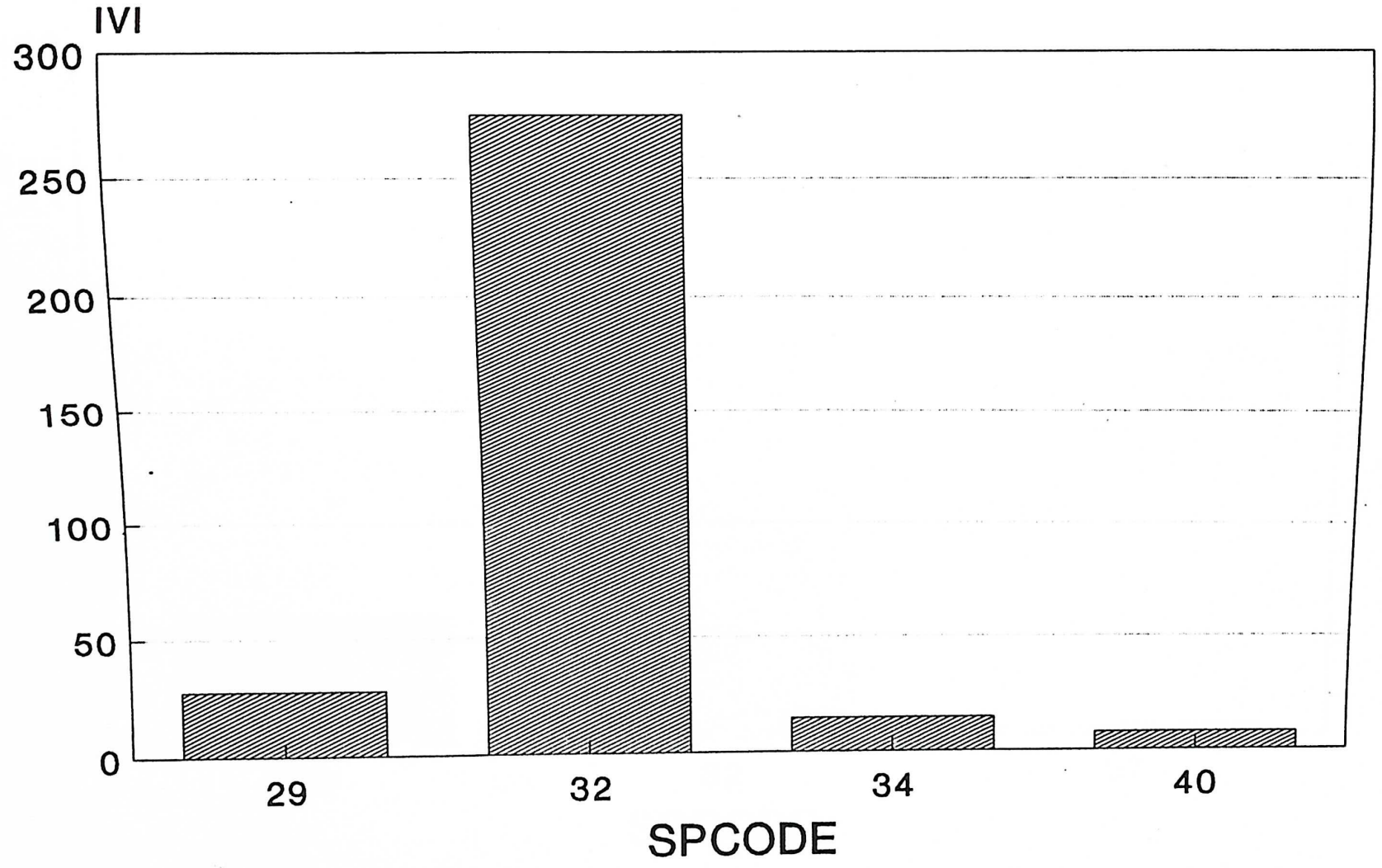


Fig 5.4.11: IVI of major tree species in Malsi area

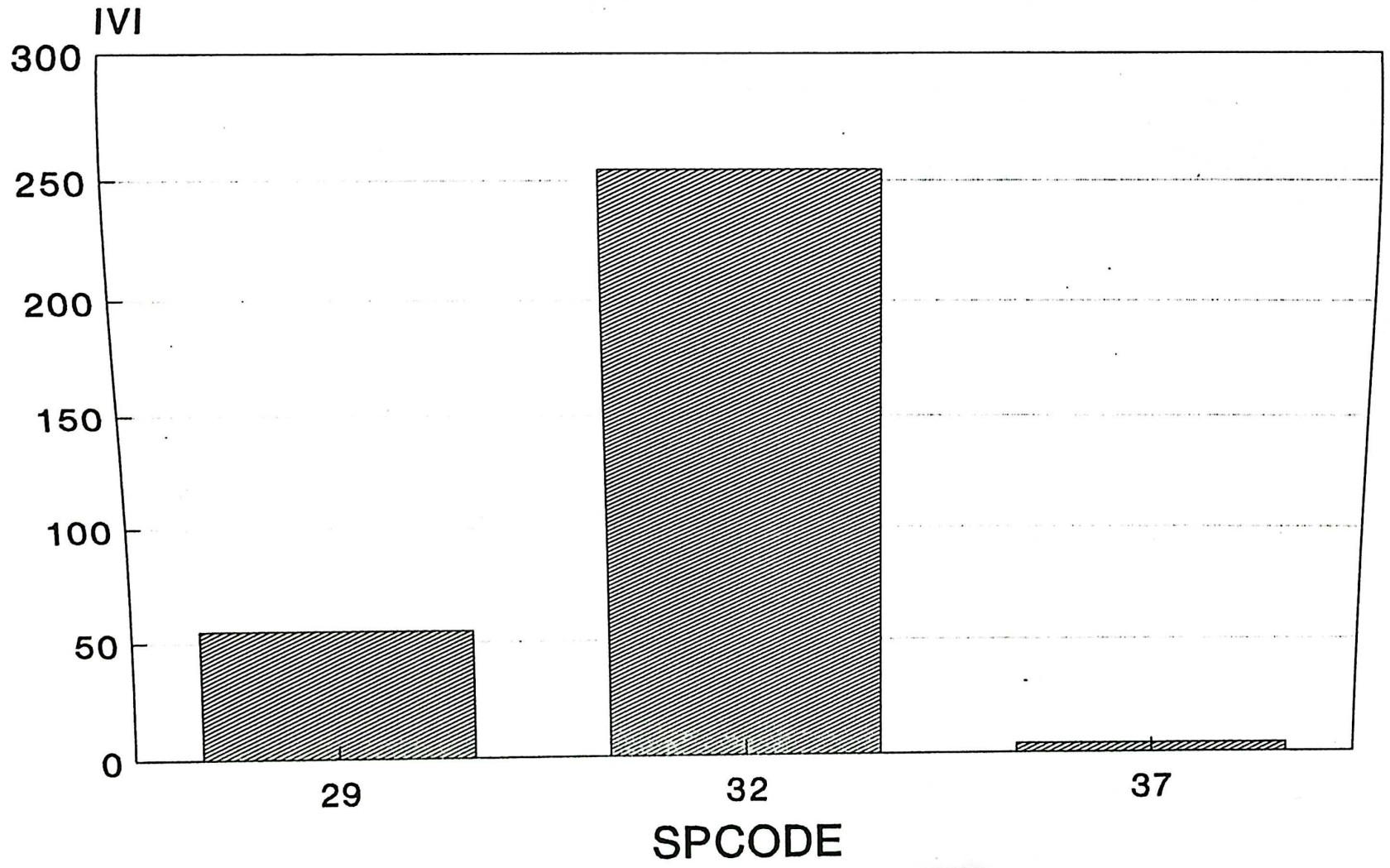


Fig 5.4.12: IVI of major tree species in Rajpur vicinity

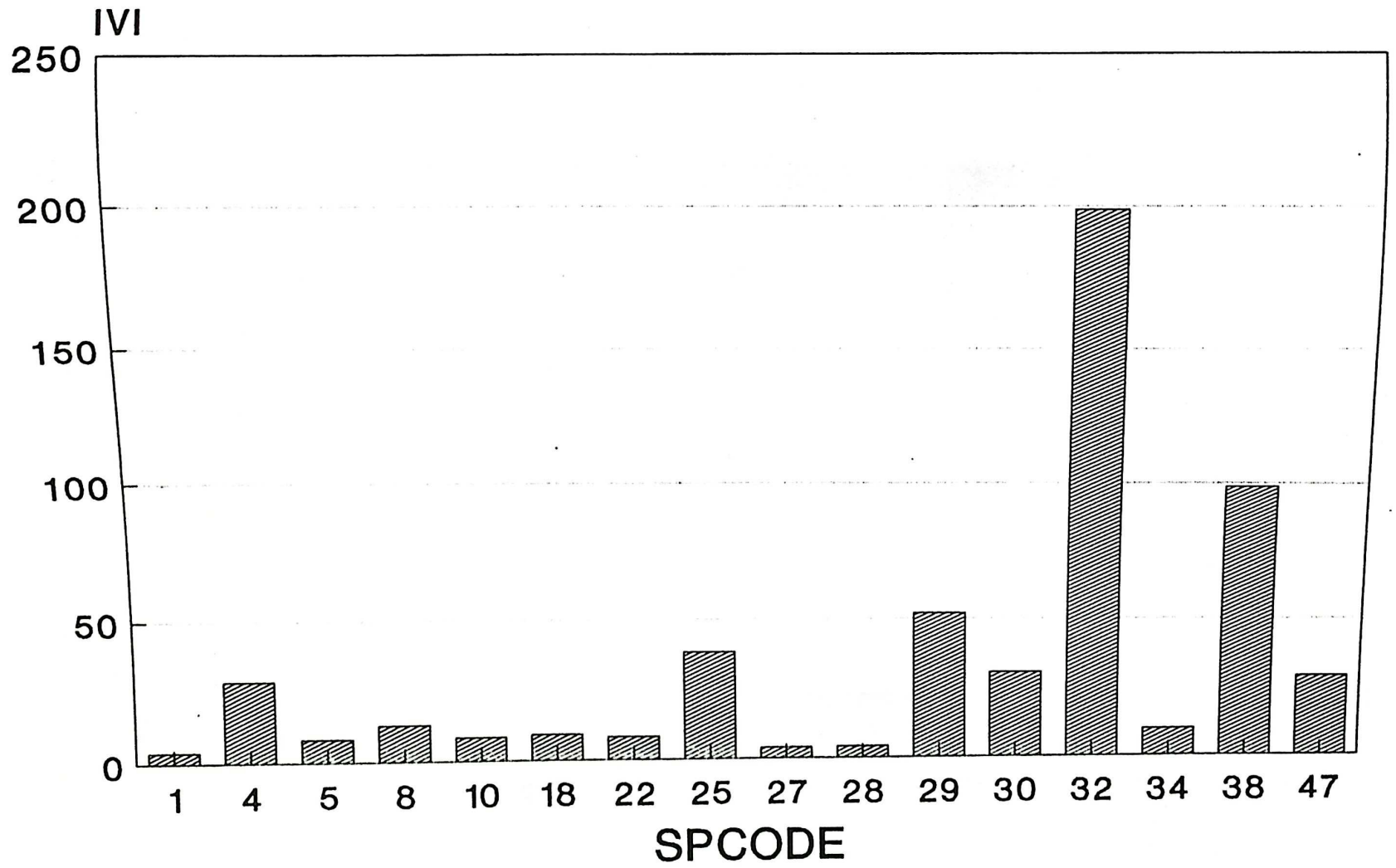


Fig 5.4.13: IVI of major trees on higher Shivalik slopes

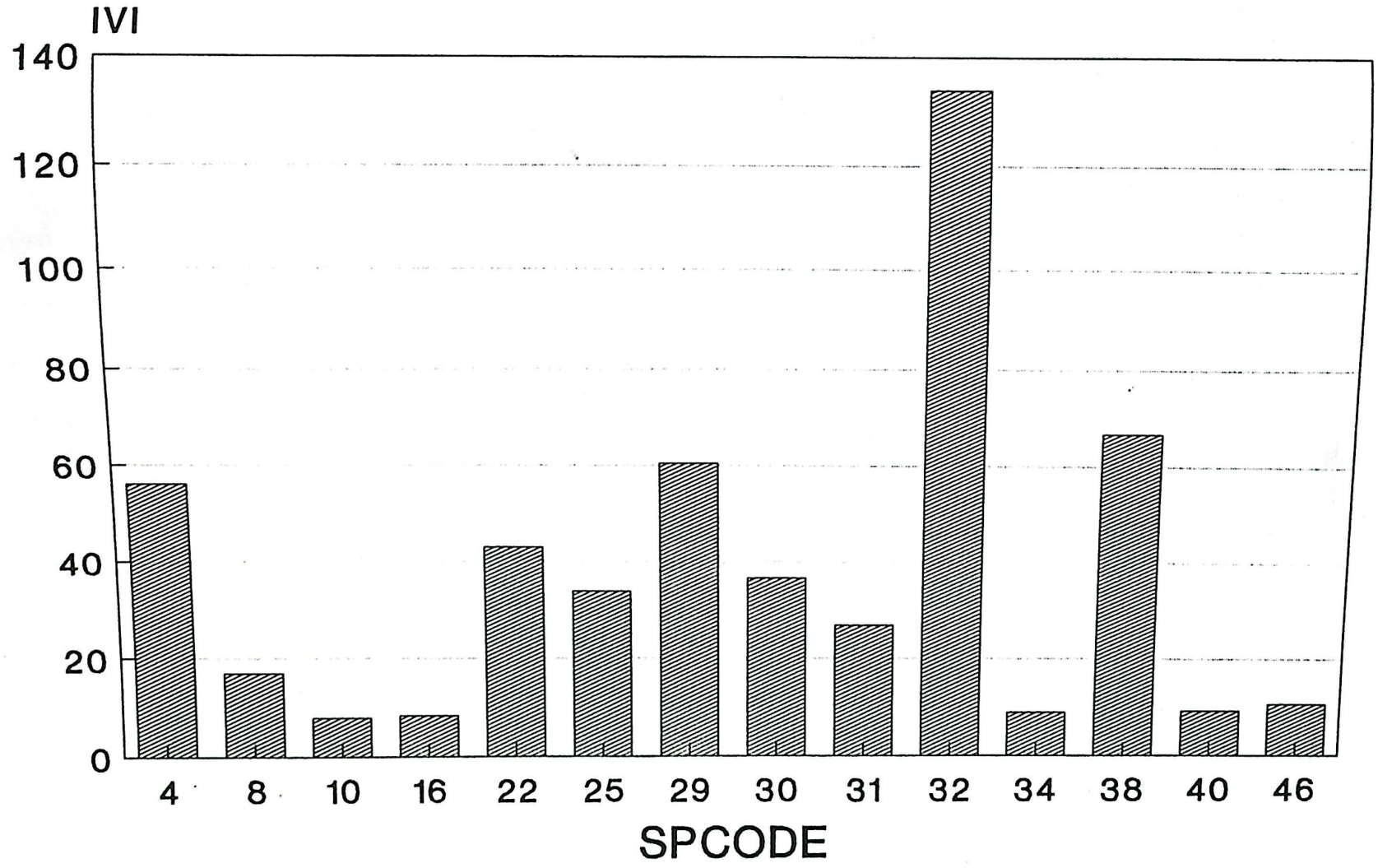


Fig 5.4.14: IVI of major tree species along Shivalik ridge

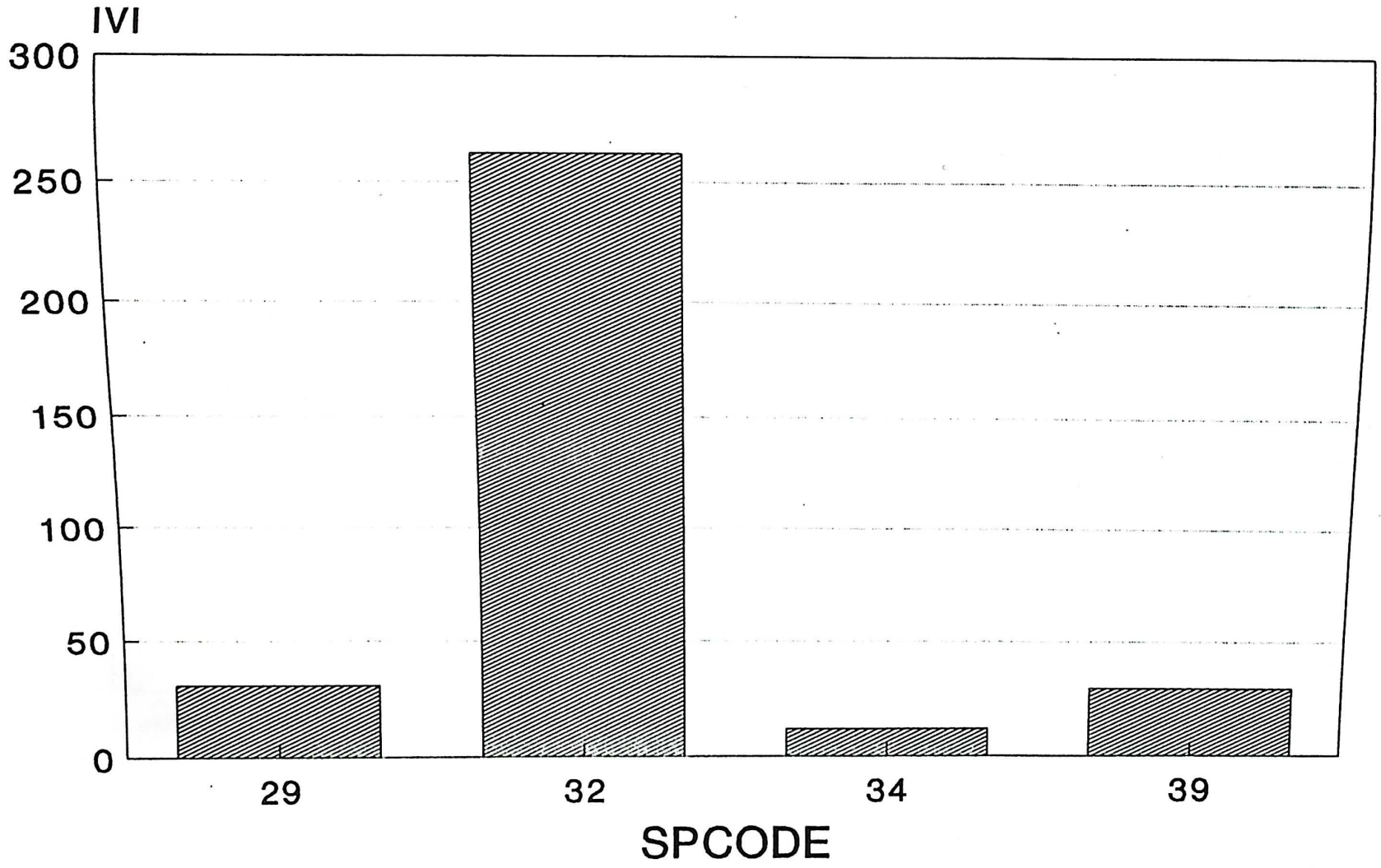


Fig 5.4.15: IVI of major trees along Himalayan ecotone

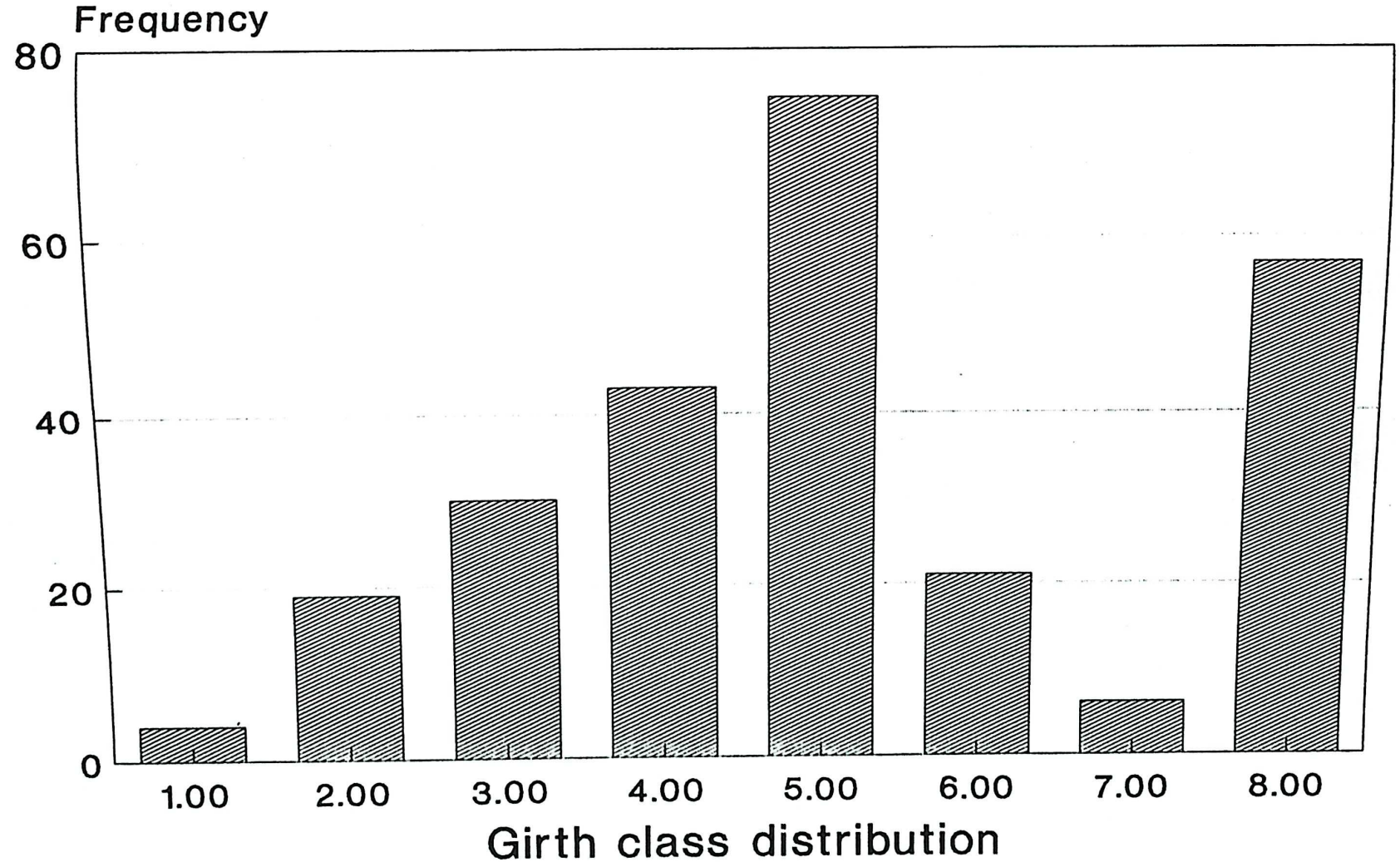


Fig 5.5.1: Girthclass distribution of Sal in Shivaliks

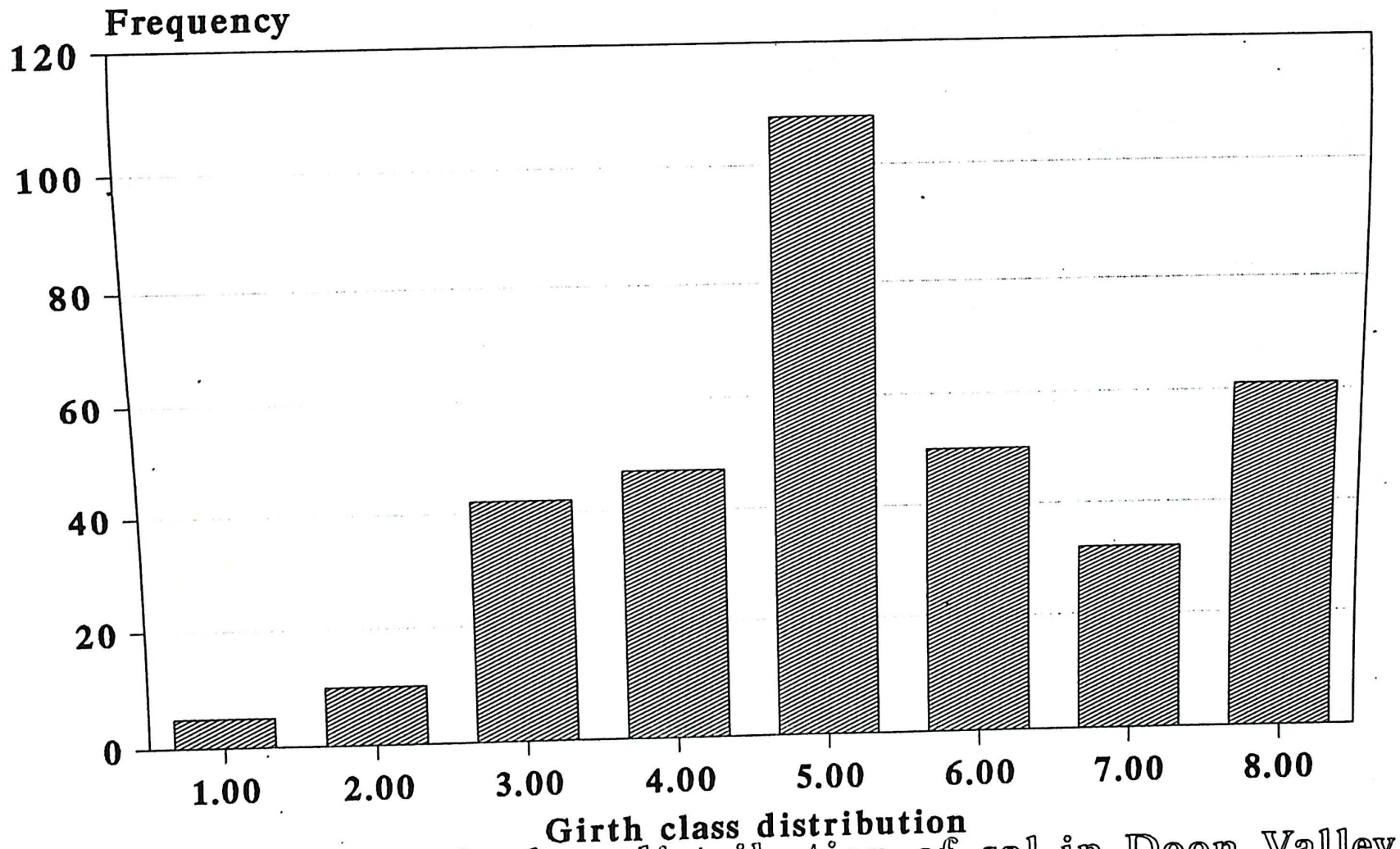


Fig. 5.5.2: Girth class distribution of sal in Doon Valley

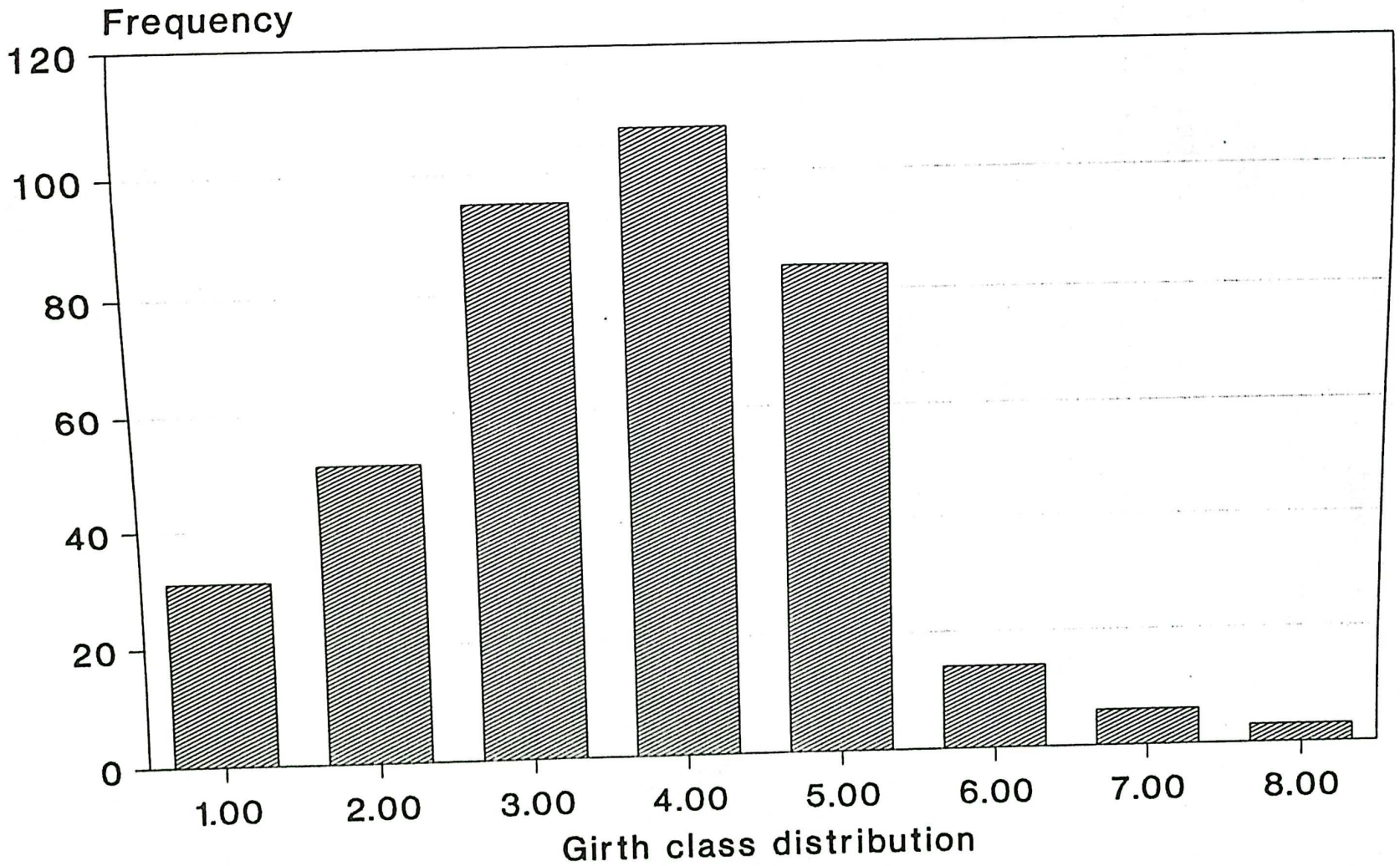


Fig.5.5.3: Girth class distribution of sal in outer Himalaya

6.0 GENERAL DISCUSSION

This study reveals the structure, composition and current regeneration status of natural vegetation along a topographic and human use gradient in the subtropical zone of northern India. The study area had two important ecotones viz. man made edge of sal (*Shorea robusta*) forest towards Upper Gangetic Plains and natural ecotone towards outer Himalaya. Since Natural Ecotones are good indicators of environmental changes, studies on the vegetation of such zones serve as baseline data for future monitoring. This study also shows that the climax species of this area i.e. Sal seems to have adequate regeneration and ability to withstand the current level of disturbance. However, this is not so for several other species associated with sal. This means that forests around Dehra Dun and adjacent tracts of Shivaliks and outer Himalaya despite predominance of sal, are loosing diversity and 'normal' course of succession is likely to be diverted in coming decades. The opening of forest canopy and increasing cover of *Lantana* has replaced natural understorey of Sal in most of the areas. This study showed that though *Lantana* cover protects Sal seedlings from frost and desiccation but species diversity is greatly reduced where there is greater invasion of this exotic weed.

A number of factors affect the spatial distribution of a species within the community (Greig - Smith 1983; Kershaw, 1973), either by modifying the environment in a favourable way or by influencing the regeneration of a species. One species may have a beneficial effect over other, or else the species having a differential tolerance capacity to varying environmental conditions show positive associations (Grime

1974, Pielou 1977 Harper 1977). Thus the mosaic or patchy spatial distribution of species must be due to many factors such as reproduction, soil, moisture, altitude and geographical boundaries. In two ecological boundaries of the study area i.e. Shivaliks and outer Himalaya Sal appears to interact with other species and its habitat factors in a different ways. Doon Valley being located in between these two zones provides moderate climate and other ecological conditions. Whereas the Sal (*Shorea robusta*) is found in all three ecological zones with high degree of dominance.

6.1 DIVERSITY, REGENERATION AND STATUS OF FORESTS

The forests in the study area varied much in cover and species composition. Seventeen types of associations identified through TWINSPAN indicate the range of variation and patchiness of vegetation. The diversity of tree species in Shivaliks (H=2.15) is quite comparable with some other parts of outer Himalaya (e.g. Tewari & Singh 1985) but much lower than eastern Himalaya and N.E. India in the subtropical belt (Mishra and Ramakrishnan 1983). Doon Valley and Outer Himalaya showed relatively low tree species diversity. This could be due to past forestry operations to promote Sal regeneration. On the other hand, if species diversity is seen at shrub and herbaceous layer, the picture is likely to be different. Number of shrub species per unit area were higher in Doon Valley than in Shivaliks (Table 5.31). Similarly, floristic surveys (Babu 1977, Dakshini 1960, Gupta 1928) have indicated that Doon Valley is very rich in herbaceous flora. Rodgers *et. al.* (1990) reported 623 species of plants from about 400 km^2 area of Western Rajaji NP (Shivaliks) including 24

species of Himalayan affinity, 32 species of opportunistic weeds, four of them being exotic. Rodgers *et al* (1990) have also stressed that overgrazing and other disturbances in Shivaliks have altered the habitat conditions and species diversity. Some of the rare endemic plants from the study area include *Catamixis bracharoides* (Asteraceae), *Rauwolfia serpentina* (Apocyanaceae), *Eremostachys superba* (Lamiaceae), *Tropidia curculioides* (Orchidaceae). Of these, *Eremostachys superba* (Plate XIVb), restricted to a small patch in Shivaliks, is highly threatened due to overgrazing by buffaloes.

As indicated in section 5.3, some of the communities which form early seral stage e.g. *Acacia catechu - Dalbergia sissoo* and some species of intermediate seral stages such as *Bridelia retusa, Toona ciliata, Terminalia bellirica*, etc had very little regeneration in the study area largely due to *Lantana* thickets lopping and overgrazing. In all the areas which are free from *Lantana* thickets, understorey species such as *Mallotus philippinensis* had fairly good regeneration. The tree species which are heavily lopped by Gujjars as well as local people in the study area were : *Terminalia tomentosa* (Syn *T.alata), T. bellirica, Bridelia retusa, Anogeissus latifolia, Ficus spp. Litsea monopetala, Grewia elastica, G. hainesiana* etc. Thorough sal is not a preferred fodder tree, it is lopped occasionally during early summer (March - April) in some areas when it has fresh flush and acute shortage of forage. This coupled with intensive grazing does influence the regeneration of all species negatively.

Once, during the study period (February - March 1993) Sal had abundant seed production compared to normal years, a phenomenon typical of many Dipterocarps. Some of the areas with abundant Sal seedlings were marked in and around the Wildlife Institute of India

Campus Chandrabani under controlled conditions to monitor during the subsequent years. The areas fully exposed (without any shrub or tree cover) had > 95% seedling mortality. On the other hand areas with > 20 % and < 60 % tree and shrub cover had least mortality of seedlings (50 - 60%) during the subsequent year. The secondary scrub vegetation free from livestock grazing and canopy opening in this area has allowed establishment of abundant Sal saplings (Plate VIII b). Chengapa 1944, Pandit 1992 have also reported that Deptrocarps regenerate well when canopy is partially opened. Fire, frost and overgrazing have ben reported to influence the Sal regeneration (Singh & Singh 1988).

Abiotic factors viz., topography and site location in terms of south facing Shivaliks versus northern shady slopes influenced the structure of the vegetation. The effect of aspect has been well documented for Himalayan region (Schweinfurth 1957, Osmaston 1927, etc.). Similarly effects of altitude on Himalayan forests haven been studied (e.g. Saxena & Singh 1987, Bhatt 1988; Rawal 1991) as in other parts of world (Rochow 1972, Ogden & Powell 1974, Druit *et.al.* 1990, etc.). However, in the study area, especially between 250 1300 m elevation the effect of altitude was less pronounced and other factors dominated. No systematic observations could be made on the effect of fire on the Sal vegetation. This aspect has been studied in this region (Rodgers 1986, Rodgers *et.al.* 1986).

6.2. OTHER CONSERVATION ISSUES

Dehra Dun, a fast growing urban centre in the Himalayan foot hills, needs proper environmental and township planning. A master

plan for its overall development exists (Anonymous 1984) which proposes some parts of forest land into agriculture. The plan also indicates that the administration has failed to check the conversion of agricultural land into urban use. Thus all the land taken from forests is likely to be urbanised in near future. The land proposed for afforestation in the south - eastern side is unlikely to be converted into forests as this predominantly valuable land is producing famous Basmati rice. The adverse impact of deforestation on environment particularly in the valley are well known. It is found that the agricultural land has been reduced from 7280.24 hac. (26.78 %) to 6277.67 hac (26.227 %) between 1971 to 1981. At the some time a number of orchards have converted to agricultural land.

The, Master plan proposal indicates an increase in urban land from 3802.75 hac. to 7590.13 hac (i.e. 98.37 %) to accommodate proposed 6,00,0000 population in 2001 A.D.as against about 5,00,000 in 1991.

In developmental planning of Dehra Dun, the environmental issues should be related to social and economic planning in such a way that environment is recognised as an integral part of society and its economy should be treated separately. Consequently, development of a master plan for Mussoorie and Dehra Dun and its compatibility with its environment must be assessed in terms of impacts, effects and risks associated with the process of any type of industrial development in these two towns. It is because the impacts on Doon Valley environment are mainly created by the interaction of i. population growth ii. technological and structural growth, iii. accelerated economic development and iv. political and social settlements i.e. refugees after 1947 partition. The environmental assessment should

be made in the valley which should provide the basis for developmental decisions and aim to mitigate so that the area can be safe of the expected harmful effects.

The status of the forest is of great concern in this context where its demands are much more than the forest productivity just because of daily requirements i.e. fire wood, housing, fodder etc. Planners and management authorities should allocate funds in town planning and forestry growth in a balanced manner to have an environment friendly package in and around Dehra Dun. This has been stressed by other authors in recent past e.g. (Gupta, 1981)

In Doon Valley reduction of land under forest and agriculture has been taking place in part. This has already affected the environment of the area beyond desirable limits. The need is imminent to plan and improve forest cover and landuse under agriculture and pastures. Overgrazing needs to be curbed. The requirement of pasture land should be worked out on the basis of cattle population and measures should be worked out to check indiscriminate grazing. This is applicable especially in case of Gujjars who are settled in fragile slopes of Shivaliks and of Rajaji National Park.

In areas where there is terraced farming the top soil is washed away in every rainy season. Specific type of plantation is to be

promoted so that the these farms can be protected from soil erosion at the same time the farmers may get the required fodder and timber from their own land. Forest Department may develop separate strategy to conserve such farming areas. This should consider the selection of better fodder or timber species.

Besides, heavy grazing and lopping in Shivaliks, reckless mining in outer Himalaya (Mussoorie hills) have been the major cause of eco-destruction in the study area. There are over 52 quarries of limestone and many more slopes prone to natural land slips in the area. Recently several sites have been rehabilitated through afforestation by Eco Task Force of Infantry Battalion, Indian Army under the technical guidance of Central Soil and Water Conservation Research Institute (ICAR), Dehra Dun.

The key issues regarding overall conservation in Doon Valley and adjacent areas of Shivaliks and outer Himalaya can be summarised as below.

i) Microclimatic conditions in the Doon valley are very special i.e. cooler than U.P. plains and warmer than the Himalaya and therefore of prime importance in ensuring the environment congenial for the inhabitants.

ii) Environmental quality depends on maintaining ecological balance which demands fresh air and clean water. Continuation of Limestone kilns is one example which affects the environmental quality of the Dehra Dun valley.

iii) Forest in the area and green coverage within the valley has a special significance in the making of the good environment. It must be preserved.

iv) Industrialisation, an essential economic activity for upliftment of any area, especially hilly area like Dehra Dun needs a careful look in any scheme of developmental planning.

v) The fragile ecosystems of Shivaliks and their natural flora and fauna need greater care and intensive management. Rehabilitation of Gujjars, controlling soil erosion and widening of raus in Rajaji as well as Shivalik Forest Division should be dealt on priority basis.

6.3 CONCLUSIONS

6.3.1. The structure and composition of vegetation in Shivaliks and Outer Himalaya are strongly influenced by the topography, and past and present management practices. Altitude had less significant role within 400 - 1400 m range.

6.3.2. Seventeen types of tree species associations were identified based on TWINSPAN analysis along the gradients of topography and human use. Of these, 8 associations were rather loose (based on only few plots) and unidentifiable in the field. These represent the man influenced communities.

6.3.3. Of the three strata i.e. Shivaliks, Doon Valley, and Outer Himalaya, Shivaliks had highest diversity of tree species (H = 2.15) followed by Doon Valley (H = 1.39) and Outer Himalaya (H = 0.43). Sorensosn's similarity Index showed that all the three areas were quite dissimilar in terms of species composition.

6.3.4. The Forests of Shivaliks and outer Himalaya appeared less mature and in a State of flux due to diverse topography and heavy

undisturbed parts) were much mature successionally (maturity index = 7.55). The outer and inner 'tension' zones appeared to be in a state of change and pre-climax state. Degraded sites e.g. field borders and pure scrubland were not sampled.

6.3.5. Sal, as expected, figured out as most dominant species in all the three zones with IVIValues 262.92, 234.86 and 183.86 in outer Himalaya, Doon Valley and Shivaliks. Locality wise, highest IVIof Sal was observed near Chandrabani in Doon Valley (288.62) and lowest on Shivalik ridge (133.99).

6.3.6. Mean density of Sal saplings (and coppices) was highest in outer Himalaya (46 $\pm$ 12.08/ 100 m^2) and lowest in Shivaliks (14 $\pm$ 3.64/ 100 m^2) at 95 % Confidence Interval. But the sapling/coppices to pole size crop ratio showed that Shivaliks, as a whole, had better recruitment. But, Malsi area at the junction of Doon Valley and outer Himalaya showed best regeneration, if considered alone.

6.3.7. There was low no correlation between the density of Sal seedlings and tree canopy cover ($r = 0.10$ $p = 0.30$; $r = 0.27$ $p = 0.01$; $r = 0.16$ $p = 0.16$ for Shivaliks, Doon Valley and Outer Himalaya respectively.

Shivaliks, Doon Valley and Outer Himalaya). But cover and density of Sal had significant, low correlation (r = 0.29 p = 0.007). Most of the *Lantana* thickets provided shelter to Sal seedlings. But overall diversity of within *Lantana* thickets was very low compared to other forested areas.

6.3.8. Absence of *Anogeissus latifolia* from the sample plots marked the vegetation of Shivaliks from Doon Valley and outer Himalaya. *Anogeissus* saplings had negative but low correlation with tree canopy cover as well as shrub cover in Shivaliks r = - 0.12 p = < 0.05 and r = - .18 p = < 0.005 respectively. This warrants further experimental studies on effect of microclimatic conditions on the regeneration of Sal and *Anogeissus*.

6.3.9. Rehabilitation of pastoral communities from Rajaji and adjacent Shivaliks, control of soil erosion in fragile tract of Bhabar through afforestation, terraced cultivation with tree based farming in outer Himalaya, maintaining the forest cover through rehabilitation of eroded and mined sites are recommended for the conservation of forests and environmental stability in the study area.

6.3.10. A detailed long term environmental monitoring project is required along the outer and inner 'tension belts' of Sal in order to predict the future climatic and successional changes in the area.

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APPENDIX - I

A Comparative List of Tree and Shrub Species in Shivaliks (SH), Doon Vallley (DV) and Outer Himalaya (OH) based on 74 plots in each zone (+ = presence and - = absence of species)

Species	SH	DV	OH
Acacia catechu Willd	+	-	-
Adina cordifolia Hk Ver.	+	-	-
Albizia procera (Roxb) Benth	+	+	-
Anogeissus latifolia Wall.	+	+	-
Ardisia solanacea Roxb.	-	+	+
Asparagus racemosus Wild.	+	+	+
Bauhinia recemosa Lamk.	+	-	-
Bauhinia malabarica Roxb.	+	-	+
Bauhinia vahlii W. & A.	+	-	+
Bombax ceiba L.	-	+	-
Boswellia serrata Roxb.	+	-	-
Bridelia retusa Spreng.	+	-	-
Callicarpa macrophylla Vahl.	-	+	+
Carissa carandas L.	+	+	+
Casearia tomentosa Roxb.	+	-	+
Cassia fistula L.	+	-	-
Catunaregam spinosa (Thunb) Tiruv.	+	+	+
Celastrus paniculata Willd.	+	+	-
Celmatis gouriana Roxb ex DC.	-	-	+
Cinnamomum camphora Nees	-	+	-
Clerodendrum infortunatum Gaer.	+	+	+
Colebrookia oppositifolia Smith.	+	-	+
Cordia myxa L.	+	-	-
Cudrania javanensis Treul.	-	+	+
Dalbergia sissoo Roxb.	-	+	-
Debergeasia hypoleuca Wedd.	-	-	+
Dendrocalamus strictus (Roxb) Nees.	+	-	-
Desmodium gangeticum (L) DC.	+	-	-
Deutzia staminea Br.	-	-	+
Dioscorea belophylla Voigt. ex Haine	-	-	+
Ehretia laevis Roxb.	+	-	-
Emblica officinalis Gaertn.	+	-	+
Eupatorium adenophorum Spreng.	+	+	+
Ficus benghalensis L.	+	+	-
Ficus religiosa L.	-	+	-
Ficus hispida L.	-	+	+
Ficus palmata Forsk.	+	-	+
Flacourtia indica (Burm.f.) Merr.	+	-	+
Garuga pinnata Roxb.	+	-	-
Glochidion velutinum Wight.	-	+	-
Grewia elastica Royle	+	-	-
Helicteres isora L.	+	+	-
Holarrhena antidysenterica Wall.	+	-	+
Ichnocarpus frutescens Br.	-	-	+
Inula cappa (Buch-Ham ex D.Don) DC.	-	+	+
Jasminum pubescens Willd.	+	+	+
Justicia adhatoda L.	+	-	+
Kydia calycina Roxb.	+	+	-

Lantana camara L.	+	+	+
Lawsonia alba Lamk.	-	-	+
Limonia acidissima L.	+	-	-
Litsea glutinosa (Lour) Robins	-	+	-
Litsea monopetala (Roxb) Pers.	-	+	-
Mallotus philippinensis (Poir) Baill	+	+	+
Melia azedarach L.	-	+	+
Milletia auriculata Baker	+	+	+
Mimosa himalayana Gahble	-	+	+
Mitragyna parviflora Korth	+	+	-
Nyctanthes arbor-tristis L.	+	+	+
Ougeina dalbergioides Benth.	+	-	-
Phoenix acaulis Buch-Ham.	+	-	+
Pinus roxburghii Sargent.	+	-	+
Pogostemon benghalense (Burm.f.) Ktze	-	-	+
Premna barbata Wall.	+	+	+
Pyrus pashia Buch-Ham ex D.Don.	-	+	+
Ricinus communis L.	+	-	+
Salix wallichiana Anders.	-	-	+
Sapium sebiferum Roxb.	-	+	-
Semecarpus anacardium L.	+	-	+
Shorea robusta Gaertn.	+	+	+
Smilax ovalifolia Roxb.	+	+	+
Sterculia villosa Roxb.	+	-	-
Stereospermum suaveolens DC.	-	+	+
Syzygium cumini (L) Skeels.	-	+	+
Terminalia alata Heyne ex Roth.	+	+	-
Terminalia chebula Retz.	+	+	+
Toona ciliata Roem.	+	+	+
Ventilago calyculata Tulasne.	-	+	-
Vitex negundo L.	-	+	+
Woodfordia fruticosa Kurz.	+	-	+
Wrightia tomentosa Roem & Sch.	-	+	-
Xylosma longifolium Clos.	-	+	+
Ziziphus mauritiana Lamk.	+	+	+
Zizyphus xylopyra Willd.	+	+	-
Grewia laevigata L. Vahl.	-	+	-
Grewia hainesiana L.	+	-	-
Eucalyptus spp.	-	+	-
Tectona grandes	+	+	-
Bambusa arundinaceas Willd.	+	+	-
Murraya koenigii Spreng.	-	+	+
Murraya paniculata L.	-	+	-
Dryopteris spp.	-	-	+
Solanum indicum L.	-	+	-
Butea monosperma Roxb. Ham.	-	+	-
Ipomea fistulosa	-	+	-
Urtica dioica L. Roxb.	-	-	+
Mimosa hamata L.Gamble.	-	-	+
	67	56	54

APPENDIX - II

Scientific and Vernacular names of important Trees, Shrubs and Grasses in the study area.

Scientific name	Vernacular name	Family
Acacia catechu Willd	Khair	Mimosaceae
Adina cordifolia Hk	Haldu	Rubiaceae
Albizia procera (Roxb) Benth	White shiris	Mimosaceae
Anogeissus latifolia Wall	Bakli	Combretaceae
Apluda mutica L	Charola	Poaceae
Ardisia solanacea Roxb	-	Myrsinaceae
Arundinella nepalensis Trin	Bichhla	Poaceae
Arundo donax L	Nal,Nakdura	Poaceae
Asparagus racemosus Willd	Satrawal	Liliaceae
Bauhinia vahlii W & A	Maljhan	Caesalpiniaceae
Bauhinia recemosa Lamk	Jhinglora	Caesalpiniaceae
Bauhinia malabarica Roxb	Papri	Caesalpiniaceae
Bombax ceiba L	Semal	Bombaceae
Boswellia serrata Roxb	Salai, Salar	Burseraceae
Bridelia retusa Spreng	Dhai, Kaja	Euphorbiaceae
Butea monosperma (Kamk) Tamb	Dhak	Fabaceae
Callicarpa macrophylla Vahl	Daia	Verbenaceae
Carissa carandas L	Karonda	Apocynaceae
Casearia tomentosa Roxb	Chilla	Samydaceae
Cassia fistula L	Amaltas	Caesalpiniaceae
Catunaregam spinosa (Thunb) Tiruv.	Pindalu	Rubiaceae
Celastrus paniculata Willd	Malkangini	Celastraceae

Celmati[illegible] Roxb ex DC	Bel	Ranuncula[illegible]
Cinnamomum camphora L	Kapoor	Lauraceae
Clerodendrum infortunatum Gaer.	Kara	Verbenaceae
Colebrookia oppositifolia Smith	Binda, Bindu	Lamiaceae
Cordia myxa Linn	[illegible]sora	Boraginaceae
Cudrania javanensis Treul.	M[illegible]	Moraceae
Cymbopogon martinii (Roxb) Wats	Ro[illegible]ha, Mircha	Poaceae
Cynodon dactylo[illegible] Pers	Dub	Poaceae
Dalbergia sissoo Roxb	Sheesam	Fabaceae
Debergeasia hypoleuca Wedd	Tusnara, Siaru	Urticaceae
Dendrocalamus strictus (Roxb) Nees	Bans, Bamboo	Bambusaceae
Desmodium gangeticum (L) DC	Shalpanni	Fabaceae
Desmostachya bipinnata Stapf	Dab, Kunja	Poaceae
Deut[illegible]aminea Br	Ghuçtai	Saxifraga[illegible]
Dican[illegible]um annulatum (Forsk) Stapf	Nali, Janeer	Poaceae
Dioscorea belophylla Voigt. ex [illegible].	Turan	Dio[illegible]
Ehretia laevis Roxb	Chamroor	Boragine[illegible]
Emblica officinalis Gaertn	Aonwala	Euphorb[illegible]
Eucalyptus sp.	Safeda	Myrt[illegible]
Eupatorium adenophorum Spreng	Kalahansa	Aster[illegible]
Ficus benghalansis L	Bargad	[illegible]eae
Ficus religiosa L	[illegible]epal	[illegible]ceae
Ficus palmata Forsk	Bedu, Anoli	[illegible]
Ficus h[illegible]da L	Kaksha	[illegible]
Flacourtia indica (Burm.f.) Merr	Kandia	[illegible]
Garuga pinn[illegible]a Roxb	Khanpat	[illegible]
Glochidion velutinum Wight	Anwin, Chamari	[illegible]
Grewia elastica Royle	Dhaman	Tili[illegible]
Grewia hainesia[illegible] Hole	[illegible]a	Tili[illegible]

Grewia laevigata Vahl	Kath Bhemal	Tiliaceae
Helicteres isora L	Marorphal	Sterculiaceae
Heteropogon contortus L	Kumeria	Poaceae
Holarrhena antidysenterica Wall	Kuda,Duddi	Apocynaceae
Ichnocarpus frutescens Br.	Belkamu	Apocynaceae
Imperata cylindrica (L.) Beauv	Pula,Siru	Poaceae
Inula cappa (Buch-Ham ex D.Don) DC	-	Asteraceae
Jasminum pubescens Willd	Chameli	Oleaceae
Justicia adhatoda L	Bansa	Acanthaceae
Kydia calycina Roxb	Pulla	Malvaceae
Lantana camara L	Kuri	Verbenaceae
Lawsonia alba Lamk	Mehndi	Lythraceae
Limonia acidissima L	Kathbel	Rutaceae
Litsea monopetala (Roxb) Pers	Karkawa	Lauraceae
Litsea glutinosa (Lour) Robins	Chandna	Lauraceae
Mallotus philippinensis Baill	Rohini	Euphorbiaceae
Mellia azeadarach L	Neem	Meliaceae
Milletia auriculata Baker	Gauj	Fabaceae
Mimosa himalayana Gahble	Alay,Khinkari	Mimosaceae
Mitragyna parviflora Korth	Faldhu	Rubiaceae
Murraya koenigii (L.) Spreng	Gandhela	Rutaceae
Murraya paniculata (L.) Jack	Marchula	Rutaceae
Nyctanthes arbor-tristis L	Kurri	Nyctanthaceae
Oplismens compositus Beauv	Dumdobra	Poaceae
Ougeina dalbergioides Benth	Sandhan	Fabaceae
Phargmites karka Trin	Narkul	Poaceae
Phoenix acaulis Buch-Ham	Khajoor	Palmaceae
Pinus roxburghii Sargent	Cheer	Pinaceae
Pogostemon benghalense Kuntze	Raundera	Lamiaceae

A

Premna barbata Wall	Bakar	Verbenaceae
Pyrus pashia Buch-Ham ex D.Don	Mehal	Rosaceae
Ricinus communis Linn	Arandi	Euphorbiaceae
Saccharum spontaneum L	Kans	Poaceae
Salix wallichiana Anders	Bhainshra	Salicaeae
Sapium sebiferum Roxb	Tareharis	Euphorbiaceae
Semecarpus anacardium L	Bhilawa	Anacardiaceae
Setaria glauca Beauv	Ballu	Poaceae
Shorea robusta Gaertn. Dipterocarpaceae	Sal	
Smilax ovalifolia Roxb	Kakadara	Smilacaceae
Solanum indicum L	Bhut,Kataya	Solanaceae
Sorghum halepense (L.) Pers.	Baru	Poaceae
Sterculia villosa Roxb	Undala,Gudgula	Sterculiaceae
Stereospermum suaveolens DC	Padal	Bignoniaceae
Syzygium cumini (L) Skeels	Jamun	Myrtaceae
Tectona grandis L	Sagon	Verbenaceae
Terminalia alata Heyne ex Roth	Aain	Combretaceae
Terminalia chebula Retz	Arad	Combretaceae
Terminalia belerica Roxb	Baheda	Combretaceae
Themeda arundinacea (Roxb) Ridley	Tappara	Poaceae
Toona ciliata Roem	Tun	Meliaceae
Ventilago calyculata Tulasne	Kalibel	Rhmnaceae
Vetiveria zizanioïdes (L.) Nash	Khas,Ganara	Poaceae
Vitex negundo L	Shimalu,Sumalu	Verbenaceae
Woodfordia fruticosa Kurz	Dhaula	Lythraceae
Wrightia tomentosa Roem & Sch.	Dudhi	Apocynaceae
Xylosma longifolium Clos	Kandhara	Bixaceae
Zizyphus mauritiana Lamk	Ber	Rhamnaceae
Zizyphus xylopyra Willd	Ber	Rhamnaceae

APPENDIX - III

DATA SHEET

VEGETATION STUDY IN SHIVALIKS AND OUTER HIMALAYA

Plot No:

Date:

Locality & Altitude:

Soil:

Topography: Flat / Gentle sl. / Steep / Ridge / Rau bank

Disturbance: Path / Grazing / Lopping / Cutting / Undisturbed
Aspect : N ; S ; E ; W ; 0

Tree species (>5 m ht +20 cm gbh)	GBH (cm)	Height class*	L/C/B **	TCC (%) ***
1.				
2.				
.				

Pole & Seedling Regeneration:

Shorea

Anogeissus

Pinus

Quercus

Shrubs & Lianas: #

1.

2.

.

.

Grasses

Herbs

Cattle/WL dung in 20 x 2 m belt:

Remarks:

* I=< 1 m; II= 1 - 2 m; III= 3-5 m; IV= 5 - 10 m; V= 10 -20 m; VI= >20 m.

** L = Lopping; C= Cutting; B= Browsing

*** Over all cover of Trees/ Shrubs/ Grasses/ herbs (%).