REGENERATION STATUS OF PROTECTED AND DISTURBED FORESTS PATCH OF RANIKHET, UTTARAKHAND

Thesis

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By

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(Prateek Verma)
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June, 2019
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CERTIFICATE

This is to certify that the thesis entitled **“REGENERATION STATUS OF PROTECTED AND DISTRIBUTED FORESTS PATCH OF RANIKHET, UTTARAKHAND”** submitted in partial fulfillment of the requirements for the degree of **Master of Science** with major in **Environmental Science** of the college of Post Graduate Studies, G.B. Pant University of Agriculture and Technology Pantnagar, is a record of bonafide research carried out by **Mr. Prateek Verma,** Id. No. **52541,** under my supervision, and no part of the thesis has been submitted for other degree or diploma.

The assistance and help received during the course of this investigation have been duly acknowledged.

Pantnagar
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We, the undersigned, members of the Advisory Committee of **Mr. Prateek Verma,** Id. No. **52541** a candidate for the degree of **Master of Science** with major in **Environmental Science** and minor in **Veterinary Gynaecology and Obstetrics** agree that the thesis entitled **"REGENERATION STATUS OF PROTECTED AND DISTRIBUTED FORESTS PATCH OF RANIKHET, UTTARAKHAND"** may be submitted in partial fulfillment of the requirements for the degree**.**

(Uma Melkania)
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Member

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Introduction

Chapter 1 INTRODUCTION

"The forest is not merely an expression or representation of sacredness,
Nor a place to invoke the sacred;
The forest is sacredness itself.
Nature is not merely created by God, nature is God.
Whoever moves within the forest can partake directly of sacredness,
Experience sacredness with his entire body,
Breathe sacredness and contain it within himself,
Drink the sacred water as a living communion;
Bury his feet in sacredness,
Open his eyes and witness the burning beauty of sacredness."

- Richard Nelson

Forests have always been a mainstay of liveliness and sacredness from the time immemorial. Forests have an inescapable mystery and sense of wonder about them. In the above lines, *Richard Nelson* himself has beautifully described the forest as a mesmerizing and wonderful creation of God and dwelling in the lap of forest fulfill one's sense and soul with purity and serenity.

Forests are one of the most important natural resource. They play a very important and critical role in developing the country socially, culturally, historically, economically and industrially. They also play an essential part in maintaining the ecological balance. Forests are important not only for the sustenance of livelihood but also act as a store box for biodiversity to sustain and grow. Forests are even responsible to provide clean air by releasing oxygen in a greater proportion and also maintain and improve moisture content in the soil and also in the ecosystem. Because of this the streams are regularly maintained with water flow and become perennial. The leaf that falls of from the trees into the ground helps in making the soil humus rich. The geographical conditions created within the boundaries of forest ecosystem naturally helps in facilitating diverse flora and fauna. But the increasing catastrophes like mass wasting, cloud bursts, avalanches contribute in degradation of soil a lot, causing threat to the extinction of many wild species of the plants.

For the environment conservation, sustainability of forest ecosystem is of utmost importance. The degradation of forests certainly causes a vulnerable effect on various systems, such as environment, climate, water resources, agriculture bio-diversity and human health of course. These land degradation problem not only cause detrimental effect on the flora and fauna but also cause a negative effect on the lives of tribal communities residing in the forest. Therefore, the action in order to conserve the soil, water, forests and biodiversity are essential for the welfare of not only present but for the welfare of future generations as well.

Forest Regeneration

Natural regeneration is an inherent ability of floral species to reproduce and proliferate and is a clear indicator of health of forest ecosystem. The regeneration potential of forest is solely responsible for the communities to thrive within the ecosystem boundary. After biotic and abiotic disturbances, it is the regeneration that acts as a soul for the sustenance of forest. Hence, regeneration is the key process for increasing the longevity of the forest. The desired species composition strongly depends upon its seed production, as when the seed production is high, there will be greater chances of the sustenance of species as when these seeds come in contact with the soil, they germinate under favorable condition. If the proportion of the seeds is high, the chances of germination increases and so does the regeneration potential of species. The seedling and saplings ability to grow and develop, acts as critical factor for successful regeneration **(Good and Good, 1972)** The population structure of forest can be ascertained by the fact that if in a population there is large number of seedlings and saplings as compared to trees, then it can be claimed that the forest has good regeneration but when the condition is reversed and population constitute greater number of trees as compared to seedling and sapling, then the forest displays a relatively low regeneration potential **(Saxena and Singh, 1982)**. Therefore, for predicting future composition of any forest, main focus should be devoted on the growth condition of seedlings and saplings. The existence of seedlings, saplings and tress in various age groups i.e., from young to old also provides us an idea of regenerating forests **(Chauhan *et al.*, 2001)**. Regeneration does not only indicate the improvement in the status of the tree species quantitatively but it also concentrates on the qualitative aspects. The structure and composition of the forest also relies more on regeneration capability. The different phyto-sociological characters offer better quantitative knowledge about the distribution, characters, pattern and composition of the species **(Saxena and Singh, 1984; Ralhan *et al*., 1982)**. There are basically three major groups namely seedling, sapling and trees on the basis on which regeneration is judged. Therefore, regeneration determination requires intensive research as it involves data collection, data analysis and data interpretation. It acts as a baseline for taking necessary steps for the conservation and management of forest.

In a different aspect, regeneration potential can also be defined as the ability of a species to complete the life cycle. Under varied environmental condition, regeneration serves as cradle for species composition, evenness and richness **(Khumbongmayum *et al.*, 2006)**. Regeneration not only depicts the present condition of the forest but an important determinant to access the future condition of the forest as well **(Malik and Bhatt, 2016; Sharma *et al*., 2014)**. The regeneration potential varies from place to place because various factors like climate, temperature, humidity; weather etc. play an important role in affecting the growth pattern and regeneration ability of the species. These were the crucial abiotic factors that affect the community but several biotic factors also influence the condition of the species such as over grazing results in the decline of the number of seedlings, the over exploitation of forest resource for fuel wood and fodder. Due to various other anthropogenic disturbances in the forest, the survivability of the species gets hampered. Therefore, distribution of forest species is not only confined to one factor but influenced by several factors. The mountain forests face a major problem of poor regeneration **(Krauchii *et al*., 2000)** and same is the case with Himalayan forest which experiences loss of habitat over time due to both manmade and natural activities. In a descriptive way, it includes various forms of land degradation, deforestation, adverse human impacts on plant resources and lowering of the productive capacity of rangelands. In addition to it, various other anthropogenic activities such as hill roads construction, forest fires, overgrazing, lopping of trees for fodder and fuel-wood collection and removal of leaf and wood litter from the forest floor are also affecting plant diversity in the Garhwal Himalayan region of India **(Singh *et al*., 2016).** There is a need of reliable data that can be determined by various sampling techniques that would help in drawing the exact interpretation of regeneration trend in forests in order to successfully conserve and manage the natural forests **(Ellu and Obua, 2005).**

In the Kumaon division, there is continuous chain crest and trough. In simple terms, hill ridges and valleys are observed in a continuous view. The upper part is well clothed with diverse and closely placed forest but in the lower part of the hill, the forest is scarcely distributed. This is because the lower part is inhabited by the villagers which are dependent on forest for their survival. So, time to time, they procure various things from the forest whether it's food, fodder, firewood or any other natural produce. These all practices in one way or the other disturbs the forest. Therefore, in low or valley area of Kumaon region, forests are observed in the form of patches. The chir and pine forests dominate in these hills. The timber forest composition varies from place to place depends upon the altitude and locality. The conifer forest covers most part of the hill along with oak trees. The species richness is not only highly influenced by altitude gradient (as each type of species thrive at a particular altitudinal range) but by soil and weather conditions as well. One of the problems observed in Kumaon hills, in case of timber trees is that their stems are generally twisted and not consider good for any kind of furniture making. So even though, the place is rich in timber but due to lack in qualitative character of the timber, it is found unfit for construction purpose.

In India however, legal connotation of forest is employed to classify an area as forest. An area of land recorded as forest in revenue records or proclaimed to be forest under a forest law or Act is described as forest. Thus, forest area is an area recorded as forest in the government records. According to the **Indian Forest Act (1927)**, the recorded forest area is categorized into:

Reserved Forest: Reserved forest is an area notified under the provisions of Indian Forest Act or State Forest Acts as forest having full degree of protection. In reserved forests all activities are prohibited unless permitted.

Protected Forest: Protected forest is an area notified under the provisions of Indian Forest Act or State Forest Acts as forest having limited degree of protection. In protected forests all activities are permitted unless prohibited.

Unclassed/Village Forest: Unclassed forest (or a village forest) is an area recorded as forest but not included in reserved or protected forest category. Ownership status of such forests varies from state to state.

According to the **Forest Survey of India, the Ministry of Environment, Forest and Climate Change, Govt. of India (2015)** report, the total forest cover in

Uttarakhand is estimated to be 24,295 sq. km (Twenty-four thousand, two hundred and ninety-five square kilometer). The reserved forest covers an area of approximately 16973 sq. km (69.86%), the protected forest covers an area of about 6319 sq. km (26.01%) while the unclassed forest constitutes only about 1003 sq. km (4.13%). There was a great variation observed in district wise division of forest. According to the **India State of Forest Report (2017),** the Almora district acquired a total forest cover of 1,718 sq. km, out of which Very Dense Forest (VDF) covers 199 sq. km., Moderately Dense Forest (MDF) is 837 sq. km and Open Forest (OF) is 682 sq. km.

But today the regeneration status of forest is on verge of deterioration. This is mainly due to lack of understanding about forestry and ecology of forest among new generation, a stubbornness of approach from funding bodies and lack of incentives for rural communities to care for the forests. The process of industrialization and rapid increase in population due to the unplanned urbanization policies has increased the demand of forest land for agriculture which has resulted in illegal deduction of forest resources along with invasion of forestlands. The forests are facing a constant threat as the woods are being cut down and the land is utilized for either cultivation of crops or for the settlement of people. Therefore, it's a high time to realize this deteriorating condition of the forest resource, otherwise the coming future generation will struggle to survive.

Forest diversity

Among the natural resources of Ranikhet, forests are the most important, both economically and environmentally. The overall floral community of the district Almora may be classified into Tropical, Himalayan, Sub-tropical and Sub-alpine and Alpine vegetation. The alpine and sub alpine zones are regarded as storehouse of large number important trees and plant those posses' medicinal properties. Considering the various parameters, the vegetation of this region, can broadly be divided into four categories:

1. Sub-tropical Forest

These forest lies between the altitude range of 300 m and 1500 m and comprises of the following forest communities.

- **Sal Community**: - This is also known as ***Shorea robusta*** community.

  Altitudinal range: 300 m to 1000 m.

The major tree species found in this community are *Semecarpus anacardium, Madhuca longifolia, Adina cordifolia, Bauhinia vahlii, Cassia fistula etc*.

- **Chir / Pine Community**: - This is also known as ***Pinus roxburghii*** community.

  Altitudinal range: 1200 m to 1800 m.

  The major species that grow with the pine are *Pyrus pashia, Caseana elliptica, Syzygium cumini, Dalbergia sericea* etc.

- **Vijaysar Community**: - This is also known as ***Engelhardia spicata*** community.

  Altitudinal range: 800 m to 1500 m.

  The major tree species found in this community are *Sapium insigne, Syzygium cumini, Dalbergia sissoo* etc.

- **Ramal Community**: - This is also known as ***Macaranga pustulata*** community.

  Generally observed below eroded slope or riverine area.

  The major species found in this community are *Mallotus philippensis, Toona serrata* etc.

- **Faliyat Oak Community**: - This is also known as ***Quercus glauca*** community.

  Altitudinal range lies up to 1500 m.

  The associate tree and shrub species to this community are *Emblica officinalis, Pyrus pashia* and *Callicarpa arborea, Rubus ellipticus* respectively.

- **Chair Pine and Bany Oak Community**: **-** Altitudinal range lies between 1500 m to 1800 m.

  Major tree species found in this community are *Myrica esculenta, Rhododendron arboreum, Pyrus pashia* etc.

2. Sub-temperate forest

The forest communities of this zone are generally found 1800 m to 2800 m altitude. The plant communities which belong to this zone are: -

- **Deodar Community**: - This is also known as ***Cedrus deodara*** community.

  Altitudinal range: 1800 m to 2200 m.

The shrub species found in this community are *Rubus ellipticus* and *Berberis asiatica.*

- **Utis**: - This is also known as ***Alnus nepalensis*** community.

  Altitudinal range: 1800 m to 2200 m.

  The major species found in this community are *Rubus ellipticus* and *Betula alnoides*.

- **Horse chestnut Community**: - This is also known as ***Aesculus indica*** community.

  Altitudinal range: 2000 m to 2500 m.

  The major tree species found in this community *are Juglans regia, Litsea umbrosa, Betula alnoides* etc.

- **Kal Community**: - This is also known as ***Pinus wallichiana*** community.

  Altitudinal range: 2100 m to 2800 m.

- **Banj oak Community**: - This is also known as ***Quercus leucotrichophora*** community.

  Altitudinal range: 1800 m to 2200 m.

- **Rianj Oak Community**: - This is also known as ***Quercus lanuginosa*** community.

  Altitudinal range: 2000 m to 2500 m.

  The major tree species found in this community *are Betula alnoides, Myrica esculenta, Pyrus pashia* etc.

  Tilonj oak Community: - This is also known as ***Quercus floribunda*** community.

  Altitudinal range: 2200 m to 2700 m.

  The various co-dominant species found in this community *are Lyonia ovalifolia, Rhododendron arboreum, Litsea umbrosa* etc.

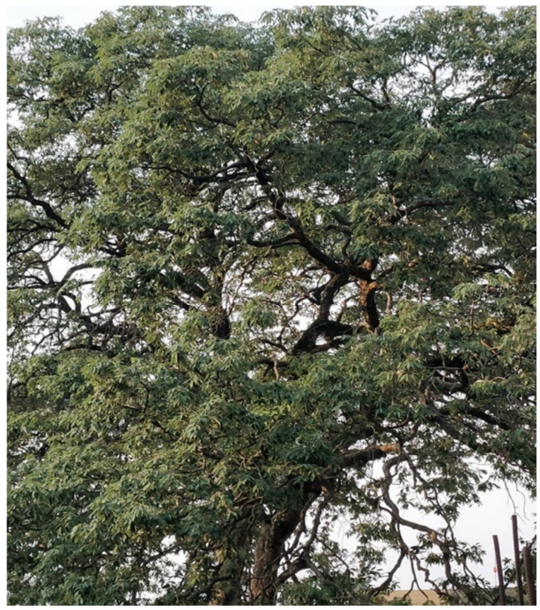
3. Sub Alpine Forest Community

This plant community is found in the altitudinal range of 2800 to 3800 m altitude. The major tree species found in this community *are* Bhojpatra (*Betula utilis),* Kharshu oak (*Quercus semecarpifolia)* and Silver fir *(Abies pindrow*).

4. Alpine Forest Community

This forest community is found between an altitude of 3800 m to 5000 m. Low shrubs and grassy meadows are more common categories of this community. The plant shape become smaller and cushion like with increase in altitude.

Table 1.1: The Main Tree Species Found in the Forest of Ranikhet.

Common Name	**Scientific Name & Description**	**Image**
Banj Oak	*Quercus leucotrichophora* (These forests are found in the whole area of Uttarakhand between 1,325 m and 1,925 m. It is used for firewood and charcoal manufacturing. It is a broad-leaved tree.)	
Deodar	*Cedrus deodara* (The Deodar is a tall coniferous tree used for house construction and paneling.)	

Pine	*Pinus roxburghii* (The forests exist mostly in the places of 1,000 to 1,650 m. This pine is used for making packing cases and paneling in interior decoration and also used as firewood.)	
Blue pine	*Pinus wallichiana* (The Blue Pine is also known as Kail. These are found mostly mixed with Deodar forests.)	
Sal	*Shorea robusta* (The Sal is found mostly in the foothills of the Himalaya in *Terai* and *Bhabar* areas (500 m~1,000 m). The forests are rich in species, such as Rohini, Amultas, Kanju and Amla.)	

Buransh	*Rhododendron arboreum* (It is an evergreen shrub or small tree with a flashy display of bright red flowers.)	
Kafal	*Myrica esculenta* (It is a large shrub. It also known with names box myrtle & bayberry.)	
Fir	*Abies pindrow* (It is a large evergreen tree that has a conical crown with level branches. The leaves are needle like, flattened in cross section and glossy dark green from above.)	

Reserved Forest of Ranikhet

According to the data provided by **Cantonment Board Ranikhet**, the forest area under reserved forest is reported to be 1,029 hectares. The Cantt Board Reserved Forest has 6 Beets, namely

1. East chaubattiya beet
2. Western chaubattiya beet chaubattiya zone
3. Western jhuladevi beet
4. East jhuladevi beets
5. East Sadar Beet sadar Zone
6. Western Sadar Bazar beet

Each beet of forests has a forest guard and a forest daroga is appointed for all beets of forest and its guards. Similarly, the tasks performed by all forest guards as well as forest darogas are inspected and verified by deputy forest ranger. Cantonment Council forest security appointed staff like Forest Ranger, Deputy Forest Ranger, Forest Daroga, Forest Guard, labors and gardeners.

Concern

The mechanism of regeneration may vary from place to place depending on the growth features of the species as well as the type of disturbance occurring in the forest. If the disturbances are in minute scale, then the regeneration does not get affected severely but the continuous and excessive interferences by human beings and the catastrophes that occur naturally like hill slides, forest fire etc. hampers the process of regeneration in the forest. Successful management and conservation of natural forests requires good awareness about the forest community and the factors affecting it, thus creating a better means for sustenance of livelihood on this planet. Therefore, the study of regeneration of forest trees has important implications for the management of natural forests **(Radha Ballabha *et al.*, 2014).**

OBJECTIVES OF THE STUDY

Keeping in view, the importance of various tree species the present study entitled **"Regeneration Status of Protected and Disturbed Forests Patch of Ranikhet"** has been formulated with the following objectives:

1. To study the flora species composition in protected and disturbed forest patch of Ranikhet.
2. To conduct phytosociological study of trees in selected areas.
3. To study the regeneration potential of tree species in protected and disturbed forest stand.
4. To understand and analyse the factors affecting the forest management in Ranikhet and suggest remedies.

Review of Literature

A literature review gives an overview of the field of inquiry that has already been done on the topic. The review helps to designing the objectives and methodologies which are appropriate and useful for study. In order to develop a sound framework, all such literature having direct and indirect bearing on the study was collected. The studies contained in this review include peer reviewed research and thesis work. Where it is logical, a summary of their findings is presented.

Bargali *et al.* (1987) conducted the research on the woody vegetation growing in the blue pine-mixed oak forest of the Kumaun Himalayas. The analysis was based on the variation caused in the structure and pattern of the species due to altitudinal gradient and biotic factors. It was observed that the most dominant species in all the stands was *Pinus wallichiana* with an IVI ranging from 87.6 at hill top of North East aspect to 486.1 at hill slope of North West aspect. In all the aspects, *Quercus leucotrichophora* was found to be the major associate of *Pinus wallichiana*, except on the hill top where *Cedrus deodara* and *Taxus baccata* were found to be the associates of blue pine, rather than the oak species. The East aspect (E) possessed the minimum tree density and total basal area of just 340 trees per hectare and 39.72 m^2 per hectare respectively while the maximum tree density of 1060 trees per hectare was found on the South West (SW) aspect and the maximum total basal area of 56.8 m^2 per hectare was recorded in North East (NE) aspect. The soil depth ranged from 13.7 cam to 28.1 cm while the moisture content in the soil ranged from 270to 45%. In general, the hill slope possessed the highest value for both soil depth and moisture.

Gosain *et al.* (2015) contended the phyto-sociological analysis of seedling, sapling and tree layers by laying down randomly 10 quadrates of 10×10m size in each of the sub-site. The size and the number of samples were determined by following the method of **Saxena and Singh (1984)**. For regeneration, each quadrate of 10×10m size were laid and the individuals having a stem girth of more than 31 cm which is referred to as Circumference at breast height (1.37 meters above ground level) were considered as adults, individual having CBH < 10 cm were consider as seedling and individual having CBH from 10-30 cm were considered as sapling **(Curtis and McIntosh, 1950)**.

The vegetation data were analyzed quantitively for abundance, density and frequency. The index of general diversity was calculated by using Shannon- Wiener index (H'). The concentration of dominance (Cd) was measured by Simpson's index **(Simpson, 1949)**. The norms for determining the regeneration potential were based on the density (number of individuals per unit area) of seedlings, sapling and adults of individual species. This phytosociological data helped to reveal the regeneration condition. If the number of saplings is greater than the number of adults but less than the number of seedlings, the particular species displays a good regeneration. Similarly, if the number of individuals of seedlings is greater than, lesser than or equal to that of saplings but the number of saplings is less than or equal to adults, the regeneration is considered as fair. If the species had no seedling and the number of individuals of saplings and adults obtained are either less or greater or equal to each other, the status of regeneration is referred to as poor. The absence of both seedlings and saplings of a tree species and the presence of only adults represents no regeneration while the absence of adults and the presence of either or both, the seedlings and saplings represent a new regeneration. Out of it, he derived that the regeneration potential of species has been highly influenced by various anthropogenic elements **(Barik *et al.*, 1996)**. The Himalaya's ecosystem is a very diverse sustaining a wide range of vegetation types. The biodiversity of this region is severely threatened by anthropogenic and natural disturbances.

Sharma *et al.* (2014) conducted his studies down the altitudinal gradient in the forests of Bhagirathi cantonment area that falls under Garhwal Himalayas. The sole principle of the analysis was to examine the growth pattern of the tree species at varied altitudes (elevation) in terms of various phytosociological factors such as dominance, species richness and the dynamics of regeneration, carbon storage and biomass in forests. Plot design of size 0.1 hectare was applied to determine the qualitative and quantitative vegetation of trees, saplings and seedlings. The highest mean tree density was found in *Q. semecarpifolia* and *A. spectabilis* forest association which lies at an altitudinal height of 2800 to 3100 meters (above sea level) while the minimum mean tree density was recorded in *Q. semecarpifolia and C. deodara* forest association which ranges from 3100 to 3400 meters height above sea level. From a height of 700 meters to the height of 3400 meters above sea level, the total basal area varied from 28.80 ± 5.27 m^2 per hectare to 99.69 ± 29.64 m^2 per hectare. The Shannon-Weiner index displayed highest value of 0.83 ± 0.14 for *A. latifolia–M. philippensis* forest association and the lowest value of 0.26 ± 0.09 for the forest association of *Quercus semecarpifolia–Cedrus deodara*. The association of *Q. floribunda–R. arboreum* displayed maximum similarity that is 85.23 ± 5.04% whereas, minimum percent 59.32 ± 5.18% was exhibited by the association of *A. latifolia–M. philippensis*. In the same way, the richness in species, seedling density, Shannon-Weiner index, Simpson index, total basal cover of forest and above the ground biomass density was showing progressive significance as altitude wise variation in different growth stages (seedling, saplings and adults). The overall biomass density values varied from 189.38 ± 14.35 megagram per hectare (between 1600 to 1900 meters asl) to 520.72 ± 114.57 megagram per hectare (between 3100 to 3400 meters asl). As a result, the overall carbon density on different heights, varies from 85.22 ± 6.46 megagram carton per hectare to 234.32 ± 51.56 megagram carton per hectare for the related elevations. The Canonical Correspondence Analysis (CCA) showed a multifaceted inter-relationship amongst mountain ranges, climatic or environmental variables and species clustering. The study showed that the pine species (*Pinus roxburghii*) was unvaryingly having an e□ect at lower altitudes on the territories of mixed and broad–leaved forests, whereas Cedrus deodara encroached the higher altitude habitats constantly. The research has also stipulated that the old growth coniferous broad-leaved forests at higher altitudes of Garhwal Himalaya like *Abies pindrow, Abies spectabilis, A. acuminatum, Betula utilis, Cedrus deodara, Quercus semecarpifolia and Rhododendron arboreum* have greater carbon storage ability and hence, suggested for carbon management by the process of a□orestation in higher altitudes of Himalayas.

Dutt *et al.* (2012) in his study made an attempt to recognize discrete zones of Phyto diversity in the island of North Andaman with the help of remote sensing technique, Global Information System and phyto-sociological field data. Zones were spotted via three factors namely- altitude, aspect and forest covers. Each categorized into separate zones and analyzed for eighteen species parameters in order to obtain phyto-diversity value. The result of the study in the North Andaman showed that ample of the area of the semi-evergreen forest was under high phyto-diversity category.

Sharma *et al.* (2009) in his monograph described that the state of Uttarakhand experiences extensive community forest management beyond the official framework that is legal upon all categories of forest lands. Traditional *Lath Panchayats*, unofficial Forest Committees/groups and even further recently, increased figures of *Mahila Mangal Dals* (aka village women's associations) are regenerating and managing utilization of Reserved, Civil or *Soyam* forest lands, often engrossing informal cooperation via Forest and Revenue Department team. These type of systems and associations still survived for more than two centuries, despite of state government's involvements and interferences and are the result of regional population's strong beliefs and traditions of the resource management at communal level. The majority of these unofficial community management systems contemplate the steady dependence of local livelihoods on mutual access and constitute a significant form of space for local forest management. Holta, is one of the case studies of a village where the village began the protection of its *soyam* land around the year 1986 solely on its own. Village water resources dried out and the firewood and fodder availability become inadequate as a consequence of unmanaged use of the forest by the villagers of the surrounding villages and infringement on communal land by the families of the locals. The youths of the village have successfully influenced the encroachers to evacuate the commons, and presented an example by leaving their own encroachments. Letters were forwarded to the heads of *Gram Panchayat* of associated nearby villages that anybody entering the forest area would be penalized. However, by improvement in the forest conditions & maintaining availability of water, resistance was declined. During the time of this case study, the village's biomass needs (except those of timber) were fulfilled from the revived forest. Vegetable cultivation was also achievable with regeneration of three natural water sources. Guidelines, rules and regulations were framed for the collection grass, useful herbs, trees, fodder for animals and firewood, and were strictly enforced by them.

Hussain *et al.* (2008) studied species configuration and community composition of twenty-three forest stands between the range of 1500 to 3000 meters altitudes in the region of Kumaon Himalaya. Over-all, nine hundred and two plots were sampled by following the plot sampling method. The density and biodiversity were computed for different vegetational layers of each stands. Twinspan recognized nineteen tree populations and seventeen ground vegetation populations. The maximum tree density was exhibited by *Q. floribunda-R. arboreum* assembly while the group of *A. pindrow* *and B. utilis* displayed the minimum diversity. *Myrsine africana* was found to be the most dominant shrub species in the area. Maximum tree species richness & diversity were recorded in Daphiadhura site. The Vinaiyak site exhibited a maximum diversity at the shrub level. *Betula utilis, Tsuga dumosa and Pinus wallichiana* were the rare tree varities in that site.

Kharkwal *et al.* (2010) conducted substantial sampling for vegetational examination in different forest locations ranging from 1600 to 2600 meters above sea level in Kumaun Himalayas. *Quercus semecarpifolia, Quercus leucotrichophora*, *Quercus floribunda*, and *Pinus roxburghii* were found to be the most dominant tree species in kharsu-oak, banj-oak tilonj-oak, and chir-pine forests, correspondingly. In the sampling study sites, the total density of trees, shrubs and herbs species varied from 10-28.6 individuals i.e., individuals per 100 m^2, 1.8-21.7 individuals per 25 m^2, and 28.1-103.6 individuals per m^2, respectively. In the same category, the total A/F (abundance-frequency) ratio of trees, shrubs & herbs, all over the sampling study sites varied from 0.23 to 1.25, 0.25-1.79 and 3.4 to 27.3, individually. The A/F (abundance-frequency) ratio in the recent study exhibited contagious pattern of distribution of herbs, shrubs and tree species.

Bargali *et al.* (2013) conducted a study to assess the consequences of various biotic disruptions on the growth, development and regeneration status of the tree as well as shrub species present in the oak forests of Nainital district of Uttarakhand. Two sites (inside and outside of the zoo) were selected with almost similar elevation of height 2100 meters above sea level, but with slight difference in the disturbances faced. The various phytosociological attributes were brought under study such as density, dominance, abundance and IVI of all the species of trees and shrubs. Regeneration potential of trees was examined by creating populations structures.

The richness of species in both trees, along with the shrubs layer was found to be maximum in the hill slope of disturbed site i.e., outside the zoo area. The species richness level was also maximum at hill slope for protected site (inside the zoo). *Quercus leucotrichophora* showed the highest dominance at the disturbed site with an IVI of 188.6 at hill base and 164.3 at hill slope, while *Cedrus deodara* possessed a highest IVI of 128.7 making it the dominant species in the hill top. Opposite to this, *Quercus floribunda* dominated not only the hill top (IVI = 211.08) but also the hill base and slope with a whooping IVI of 139.2 & 227.5 respectively. In protected forest patch, the density i.e., the number of individuals per unit area varied from 780 – 1000 individuals per hectare, while in disturbed it ranged from 260 – 780 individuals per hectare. The best regeneration was found in *Q. floribunda* and *Q. leucotrichophora* that exhibited higher number of seedlings and saplings as compared to adults. It was assessed that the oak tree species carry better regeneration ability in the areas of less anthropogenic disturbances.

Kumar *et al.* (2006) carried out a study in two different types of forests i.e., *Pinus roxburghii* (site-I) and *Anogeissus latifolia* (site-II) to analyze the distribution pattern of vegetation, regeneration status of the species and the effect of forest on the micro-climatic conditions. In site I i.e., the forest dominated by *Pinus roxburghii*, *Acacia catechu* was found to be a co-dominant species. On the other hand, in site II i.e., the forest dominated by *Anogeissus latifolia*, the allied species were namely *Emblica officinalis*, *Lannea coromandelica* and *Acacia catechu*. Therefore, higher density of trees in site resulted in reduced regenerating species density while the higher species diversity was also witnessed in the same site.

Among the forests, the regeneration level of species was highly favored by variable climatic conditions. The key problem associated through these forests was no existence of saplings, even though the seedlings were thoroughly present on both forest sites. The ruthless exploitation of growing seedlings even before they could enter the sapling stage is reason after the absence of sapling. The seedlings and saplings are cut down for firewood, leaf fodder for the animals. Thus, in a way to protect the resources provided by the forests for sustainable use, proper awareness is highly required against the anthropogenic instabilities such as falling down of trees and illegal cutting for fuelwood and minor timber, lopping for fodder and other desires and greed. This can help us achieve a better future for forest resources which can be saved in order to meet not only the needs of villagers but all the other people.

Gautam *et al.* (2016) studied the diversity pattern and regeneration status in unmanaged damp deciduous forests in reaction to the disturbances at Shiwalik Himalayas of India. The study revealed that all the factors of diversity patterns were increased to maximum under moderate disturbances. Any sort of alteration in the composition and also in structure brought by lot of disturbing agents certainly can cause hamper to forest functioning and sustainability. It also has repercussions on the fauna diversity that inhabit in the forests especially migratory animals, and on interaction reciprocity. Therefore, disturbances that exceed intermediate ranges even in the protected moist tropical forest may jeopardize its stability for which purpose it has been unmanaged or can say abandoned. Further research to understand and analyze the regeneration pattern and status of protected and disturbed forest patch of Ranikhet, it is essential to draw more practical, easy and appropriately applicable models to protect & conserve it.

Negi (2010) examined plant species richness at altitude range between 200 and 5800 m above sea level, considering altitudinal gradients i.e., 200 and 1000 m above sea level, altitudinal differences in the Indian Central Himalaya. The low elevation appears to be drier than higher, although precipitation varies in an inconsistent manner with elevation. Low temperature and also greater cloudiness at higher elevations might be the reason for increased precipitation. In this study a total of 2487 (two hundred and four eighty-seven) species were recorded, out of which 276 were trees, 355 shrubs, 112 climbers and 1744 herbs. The deciduous trees were maximum at an elevation of 600-800 m above sea level and evergreen trees were maximum at elevation of 1200-1400 m. Shrub species occurred at increased proportion in the altitude range of less than 200 to 4800 m above sea level. The total number of shrub species varied from 4600 m to 1400 m above sea level. The total number of species of climbers were maximum at an altitudinal range from 800-100 m above sea level for deciduous and evergreen species together. Along the altitude, it is observed that the geographic and climatic conditions change sharply.

The total number of species including all growth forms was found minimum near high altitude to mid altitude of tropical and subtropical belt due to over-lapping of climatic conditions. But with further increase in altitude it was decreased consistently, most likely due to decrease in atmospheric temperature with increase in altitude. The number of deciduous species was observed relatively more than evergreen species with no effect of the plant form, i.e. trees, shrubs, and climbers. It may be due to spatial fluctuation in climatic conditions. The study concludes that distribution and species richness pattern in this study region largely depends on the altitude and climatic variables like rainfall, temperature etc.

Tiwari *et al.* (2018) on his work on *Regeneration dynamics, population structure, and forest composition in some ridge forests of the Western Himalaya, India* analyzed the population structure, forest vegetation and also the regeneration status in various damp temperate mixed forests. The plot method was used to calculate the density, frequency and abundance of the species in each forest type. An overall of 60 sample plots (10 plots of 0.1 hectares in each site) were taken under study. The sample plots were laid out in such a pattern that the slope areas were minimized at the ridge sites. On the basis of data obtained by using the Shannon-Wiener diversity index **(Shannon and Weiner, 1963)**, Simpson dominance index **(Simpson, 1949)**, and evenness **(Pielou, 1966)**, the evenness and biodiversity pattern was determined for each forest types. The population composition along with the regeneration potential was determined by calculating the density of saplings, seedlings and adults. The criteria to distinguish between the three is the Diameter at Breast Height (DBH) which is considered at 1.37 meters above the ground. The individual having a DBH of greater than 30 cm were considered as adults while the individuals with a DBH between 10 and 30 cm or less than 10 cm are categorized as saplings and seedlings respectively. The different classes of regeneration were fair, good, poor, new and no that depicted the regeneration potential of various species. The above-mentioned classes were categorized as per **Dutta and Devi (2013)**, which were modified from the work of **Khan *et al.* (1987)**, **Shankar (2001)** and **Khumbongmayum *et al.* (2006).**

The different regeneration categories were depicted as: good, if the saplings possessed greater number of individuals as compared to adults but less individuals than seedlings; fair, if seedlings were more than or less than equal to the saplings, which were less than or equal to adults or if seedlings were equal to saplings and the both were more than adults, or if seedlings and saplings were equal with no adults; poor, if a species survives only in the sapling and adult stage but is deprived of seedlings; no, if both seedling and sapling stages are absent and only adults are found; new, if only saplings and seedlings are present.

Lal *et al.* (2018) on his study on *Natural Regeneration Status of Forest Community at Dandachali Forest, Tehri Forest Division in North West Himalaya Uttrakhand, India* evolved methods to harmonize the rates of exploitation and also regeneration. Data analysis has been done by following standard ecological methods

(Curtis and McIntosh, 1950; Grieg-Smith, 1957; Kersaw, 1973; Mueller-Dombois and Ellenberge, 1974; Dhar *et al*., 1997 and Samant and Joshi, 2005). On a whole, the study provides information about natural regeneration pattern at the community level. There is an immediate need to develop an adequate and appropriate strategy and action plan to have vision for the augmentation of natural regeneration and to secure artificial regeneration of the plant species so as to work for long term conservation management of species, habitats, and communities for safeguarding sustainable utilization of the resources. Outcomes of the present study can be used to build out conservation management and also the micro planning of this area for socio-economic development of inhabitants and biodiversity of the Himalaya.

Ballabha *et al*. (2014) in his research work studied the regeneration of two types forests in the Garhwal Himalayas of Uttarakhand. The Dhundsir Gad watershed is dominated by two types of forests namely *Anogeissus latifolius* forest and the second one which is dominated by *Pinus roxburghii* forest. The plot method was used to determine the composition of species in both the forests. Same criteria were applied to distinguish the seedlings, saplings and adults of each species i.e., by calculating their DBH values. The regeneration categories were same specified as per **Dutta and Devi (2013)**.

An overall fairly good regeneration was achieved in both types of forests, even though a better regeneration status was found in *Anogeissus latifolius* forest. The density of seedlings and saplings were found to be 1190 and 860 individuals per hectare respectively. While the number of seedlings and saplings in the *Pinus roxburghii* forests were comparatively low i.e., 1080 and 600 respectively. Most of the species displayed good regeneration in both the forests as the individuals were more in the lower diameter classes (seedlings and saplings) as compared to higher diameter classes. The tree species of *Acacia catechu, Anogeissus latifolius, Lannea coromandelica* and *Aegle marmelous* displayed good regeneration whereas, *Pinus roxburghii, Terminalia alata* and *Engelhardia spicata* showed fair regeneration.

Singh *et al*. (2014) studied two dominant forest types on an altitudinal gradient in the forest division of district Nainital. *Pinus roxburghii* and *Quercus leucotrichophora* were found as dominant tree species which were trailed by *Cedrus deodara, Acer oblongum, Ficus nerifolia, Prunus cerasoides, Cupressus torulosa, Quercus floribunda, Myrica esculenta and Rhododendron arboreum*. The density, richness and diversity of tree and sapling were observed highest in the forest type dominated by *Quercus leucotrichophora*. *Pinus roxburghii* dominated forest displayed the maximum dominance concentration, total basal area and seedling richness.

Sahu *et al*. (2007) conducted their study in a land mass of five hectare within the tropical deciduous forest of Boudh district, Orissa. A total number of one hundred and eighty-seven species were recorded out of which the number of trees were 91, shrubs were 10, and climbers were 12 and also the number of herbs species found in an area of 4 hectare sampled was 74. The pre-dominant tree species recorded were *Buchanania lanzan*, *Shorea robusta*, *Diospyros melanoxylon, Madhuca indica*, and *Cleistanthus collinus* species. Richness of the species have significantly reduced with an increase in girth category of tree species. The individuals having a having CBH less than 30 cm played a role of about 68.13% of species richness. The current study can aid as base forming report for monitoring and supporting the phyto-diversity of tropical deciduous forests of Orissa.

Singh *et al*. (2016) conducted their research during the years 2013-14 in the forests of Garhwal Himalayas. The ridges of Uttarkashi, Tehri and Pauri districts were taken under study for the richness, diversity and regeneration of species. *Q. floribunda* that was the most dominant tree species at the Dhanaulti region displayed poor regeneration due to absence of seedlings in all the three forests. The cause behind this might be some anthropogenic instabilities like overgrazing and wood collection for fuel and fire. The overgrazing condition by livestock usually cause destruction of the ground flora which hinders regeneration of tree species. It was further inferred that the evaluation of diversity and regeneration condition of different tree species is very much critical for sustainable management, utilization and conservation of the forests. The whole population composition of tree species disclosed the contribution of seedlings to the overall population was found highest, trailed by saplings and lastly the adult trees. It reveals that the total regeneration condition of tree species in the examined region is good and the communities in the future can sustain unless there is some sort of major environmental hindrance exerted by human activities. However, the survival, growth, development, and reproduction potential of the tree species exhibiting a condition of poor or no regeneration, may experience danger in future. Thus, an organized and appropriate management strategy is required for their sustainable utilization & conservation.

Sonam *et al.* (2017) carried out her research on *Vegetation analysis and regeneration status of Sauni-Binsar sacred natural forest, Ranikhet (Kumaun Himalaya)* during the year 2015-16 at three altitudinal zones of Sauni-Binsar sacred natural forest. Geographically, the study area lies between 29° 35' 60" N latitude and 79° 17' 28" E longitude under Almora district. A sum of thirty sampling quadrats of 10 m x 10 m i.e., 0.1 ha size were randomly placed so as to study the composition of saplings, seedlings and trees along the altitudinal gradient. In each sampling quadrat, individuals of tree species were counted and also their circumference at breast height denoted as CBH was measured. On the basis of CBH obtained, the individuals were classified into trees, if CBH > 31.5cm, saplings if CBH ranged between 10.5 to 31.5 cm and seedlings if CBH < 10.5 cm.

Various phyto-sociological traits such as density, frequency, abundance, Importance Value Index were calculated following **Curtis and McIntosh (1950)**. Basal area was calculated following **Mishra (1968)**. Regeneration potential of tree species was established on phyto-sociological data, **(Shankar, 2001)**. Individuals in seedling stage and sampling stage were not found at hill base. This is because of anthropogenic pressure in form of fodder collection, grazing, quarry of stone, looping, resin extraction, forest fire, etc. Three species had good regeneration at hill slope while three species having fair regeneration. Four species were recorded at hill top with fair regeneration followed by good regeneration associated with two species. Moreover, two species found as new in the hill top. The new regeneration towards upper altitude shows the adequate condition for growth and survival of the species towards increasing altitude. The hill base and top were less disturbed as there was no sign of lopping, grazing, human encroachment, etc.

Saha *et al.* (2016) stated through his research work that regeneration of a species is narrowed to a particular range of habitat and the degree of such condition is a major factor of its distribution in geographical terms **(Grubb, 1977)**.. The population composition is basically distinguished by the existence of reasonable population of adults, saplings and seedlings, indicating an effective regeneration of any species present in the forest. **(Saxena and Singh, 1984)**. The growing or existence of saplings underneath the adult trees with high and dense canopy also depicts the community composition the future **(Austin, 1977 and Pokhriyal *et al.*, 2010)**. In an analysis, **Pant**

and Samant (2012) said that the density i.e., the number of individuals of species at seedling and sapling phases differed from one community of forest to other community. The seedlings and saplings densities are mainly regarded as a regeneration capability of the forest. If the community displays a good regeneration status, it is considered as a sign of suitability of a specific species towards the environment. Climatic factors along with biotic factors affect the regeneration of varied species. Greater seedling density value convert to less sapling due to high biotic disturbance and struggle for space to grow and nutrients. The three major components were taken into account **(Good and Good, 1972)** which are responsible for the positive regeneration of the species of trees in a forest. These components possess the capability to introduce new seedlings, capability to improve survival rate of seedling and sampling and their ability to grow.

Thompson *et al.* (2003) in their study explained how species accumulation curves are influenced by richness of species which is referred in simple terms as total number of species, relative abundance and also diversity by using computer-generated simulations. Species richness gives the horizontal asymptote value boundary for any species accumulation curve. The curve's shape is affected by relative abundance and relative diversity, both. Replication at large proportion of unique species and a small number of abundant species show a species accumulation curve with a low-shoulder also known as the inflection point. The diversity is measured by Shannon-Weiner **(Shannon and Weiner, 1963)** and Simpson **(Simpson, 1949)** indices, for reproduction is positively correlated with the primary slope of the curve of species growth and accumulation. Species accumulation curve crosses when any single simulation has a large proportion of both abundant and rare species in comparison to other, that has an extra uniform distribution of abundance among species.

Sharma *et al.* (2002) in their study at three different altitudinal zones i.e., hill base, hill slope and hill top of both protected as well as disturbed hills of the Aravalli, Jaipur performed a survey. It was found that the vegetation comprising of herbs exhibited therophytic nature i.e., they can survive unfavorable or harsh weather conditions. It exhibited large no. of species during monsoons. The herbaceous vegetation displayed a higher biomass in the disturbed hill sites as compared to the protected hill sites. The net primary production (in one year) in protected hill was 430-587 gm^{-2} and in unprotected hill was 283-613 gm^{-2}. Seventy-eight plant species, seventeen of monocots and sixty-one of dicots were observed in study site. The presence of 50 herbaceous and 14 woody species (total = 64) at the protected hill site exhibited a higher species richness as compared to the 45 herbaceous and 5 woody species (total = 50) at the disturbed hill. This reveals that the diversity of woody species in protected hill was higher in comparison to those in unprotected hill.

Vidyasagaran *et al.* (2011) studied Mangroves vegetation of Kannur and found that there were seven different families containing nine genera which holds twelve species. The maximum genera were possessed by *Rhizophoraceae* with 4 species. The phytosociological examination showed that the highest density and relative density was observed of *Acanthus illicifolius* and *Avicennia officinalis* respectively. The highest relative frequency, IVI as well as RIVI value was also exhibited by *Avicennia officinalis* which evidently demonstrates the domination of the species among twelve mangroves species spread all over.

Whitman *et al.* (2007) observed and developed statistically practically based late-successional indices that can be utilized in the field to rapidly recognize greater conservation value of old forest. They have taken two different forests site for their study. On the basis of stepwise discriminant function analysis, the most appropriate single variable for both types of forest was living and dead tree densities. For upland spruce-fir forest, a suitable linear discriminant function was framed by adding one variable - large log count. The level of thresholds between late-succession and economically mature stands were nine large living and dead trees per 0.02 hectare of plot for northern hardwoods, eight large living and dead trees per 0.02 hectare of plot for upland spruce-fir forest. Indices were created with the help of old growth data in a way to offer reference levels with scores ranging from 0 - 10. The indices increased along the range of seral classes with the largest increases occurring in late seral stages. The indices were correlated with another late-successional attributes comprising large snag, large logs, abundance of seven LS epiphyte taxa, tree size distribution and dead wood variables. They used these indices to conserve old forest firstly by certified landowners, train foresters about ecological forestry, verify the implementation of late-successional management goals as well as assess trends of late-successional in the region of forest. Their approaches could be utilized in a process to develop LS indices for the regions which may prove helpful to conserve old forest. The area of old forest along with accompanying structures and processes are rapidly in a declining rate across temperate and boreal regions **(Freedman *et al*., 1996; Recher, 1996)**. A number of scoring systems have been formulated to overcome the challenge in identifying LS stands for the purpose of conservation **(McElhinny *et al*., 2005)**. In well managed landscapes, economic pressures work as a substantial barrier in allowing heavily harvested stands to be restored in accordance with old forest conditions.

Materials and Methods

3.1 Study area

The present study was carried out on a disturbed and mostly protected (managed by Cantonment Board) forest patch of Ranikhet, which is a beautiful hill station located in the Almora district of Uttarakhand state. The state of Uttarakhand, also known as the Dev Bhumi, is located in the northern zone of India and shares its local boundary with Himanchal Pradesh in the north west, Uttar Pradesh in the south and an international boundary with China in the north east and Nepal in the east. The land of Uttarakhand has an area of about 53,483 km^2 and lies between latitudes 28°43′ and 31°28′N and longitudes 77°34′ and 81°03′E. The state experiences temperate climatic conditions, except the areas that lie in the plains where the climatic conditions are more or less tropical. According to the report of **Forest Survey of India (2005)**, it was identified that 19% of the total geographical area of Uttarakhand remained under permanent cover of snow that includes glaciers and steep slopes, where the growth and development of tree vegetation is not possible due to harsh climatic conditions as well as physical limitations. The state has recorded a forest cover of 24295 km^2, which is equivalent to 45.43% of its geographical area.

Ranikhet, which is a cantonment town developed by the Britishers, is now entirely managed by Indian National Army. It is situated at coordinates 29.65^o N 79.43^o E in the Kumaon Hills at an elevation of 1,869 m above mean sea level. The study area is a home to an array of diverse flora & fauna where, Pine, Oak and Deodar are the dominant tree species. Since it is richly bestowed with serene natural and manmade attractions, it was one of the major attractions for not only the tourists from different states of India, but all around the globe. The forests that surround this area contain several wildlife species such as pine marten, red fox, barking deer, jackal, mountain goat, Indian hare and the members of wild cats like leopards n tigers etc.

The cantonment of Ranikhet is spread across two ridges namely Ranikhet ridge and Chaubatia ridge. Ranikhet ridge lies at an elevation of 1,824 m whereas Chaubatia ridge is situated at an elevation of 2,116 m above sea level. The cantonment also comprises of three distinct areas as mentioned here (in terms of increasing altitude height) - Alma Barracks at 1818 m, Deolikhet at 1823 m, and Chaubatia at 2125 m elevation. Most of the area around and under Ranikhet comes under reserved forest and is regarded as more or less protected. The cantonment forest where mainly this intensive study was carried out, is enclosed well-nigh on all sides by the forest of the Ranikhet range of West Almora Forest Division.

The forest patch of the study is outspread over a zone of flat or curved ridges having subsidiary edges and slopes from gentle to moderate gradient. Mainly in the north facing slopes or the rifts with humidity, a good growth pattern of oak is visible while the ridges of the southerly aspects, is referred to as the Chir zone, which experiences high disturbances in the past like overgrazing and human interference, which has left the soil in poor, shallow and dry condition.

Fig. 3.1: Location of Study Site

The protected forest is managed by the Cantonment Board thus it has a very less disturbance caused by humans, domestic animals and their requirements of fodder, fire wood and other anthropogenic activities. Even the discarding of risky green standing trees is allowed only with the approval of Divisional Van Adhikari, Almora. Any individual found illegally cutting trees from forest cantonment, hunting, mining and performing other illegitimate actions is charged with penalties in reference to cantonment act/Indian Forest Act and dhara.

The disturbed forest taken under study is comparably distressed due to the allowance of human activities such as collection of wood for fire, fodder, resin, lisa (gum), animal grazing, people visiting for camping and trekking, uncontrolled forest fire and other various factors. This site of disturbed forest is brought under study as it is adjacent to the protected forest and also shows significantly less difference with the protected ones.

3.2 Methodology

According to **Henle *et al.* (2004)**, regeneration is believed to be the most important and influential process for the survival and existence of species in any community. Under the pre-dominant environmental conditions, the potential reputation of regeneration of tree species is crucial in a forest which generally and more often depicts the future composition of the forests within a stand, in specific area and time. Therefore, the study of regeneration potential was carried out by following the *Stratified Random Sampling Technique* or simply the plot design method where random quadrats are laid down in a manner that the autocorrelation is minimized and the presence and count of species is different in each quadrat laid. The data were collected from 18 different sites i.e. 9 sites from disturbed forest and similarly 9 other sites belonging to protected forest, at minor yet varied altitudinal gradient namely from hill base, hill slope and hill top (3 sites in each altitudinal gradient for both the type of forests.)

At each site, 10 m × 10 m quadrats were placed. The enumeration for seedlings, saplings and trees was estimated by plotting a quadrat of an area 100 m^2 i.e., 0.01 hectare in each site covering an overall area of 1800 m^2. In each 100 m^2 (10 m × 10 m) quadrats, the species and the individuals were identified and counted. The criteria defined for the identification of seedlings, saplings and adults suggests that the girth of an individual's stem is measured at a height of 1.37 meters above the ground which is referred to as Girth at Breast Height (GBH). Thus, the individuals having GBH of less than 10.4 cm, they were considered as seedlings, while the individuals with GBH more than 31.5 cm were considered as adults and the ones having GBH between 10.4 and 31.5 were considered as saplings. The data was measured and collected individually and species wise. The density i.e., the number of individuals per unit area of seedlings and saplings was considered as a marker of the regeneration potential that designed the regeneration pattern of the study area.

Regeneration status of individual tree species have been investigated on the basis of their quantitative potential at different life-forms and it was based on the phytosociological data with different categories that depicted the type of regeneration any tree species is going through. The different categories of types of regeneration are:

- The regeneration is considered good, if the number of individuals of saplings is greater than that of adults but at the same time are less in number as compared to seedlings i.e., seedlings > saplings > adults.
- The regeneration is considered fair, if the number of seedlings is greater than or less than equal to the number of individuals of sapling and the saplings too have less or equal number of individuals in comparison to adults i.e., seedlings > or ≤ saplings ≤ adults; also either if the number of individuals of seedlings and saplings are equal yet greater than the adults individuals i.e., seedlings = saplings > adults or the seedlings and saplings are equal and no adults are found, this also signifies the fair regeneration.
- The regeneration is considered poor, if the species survives only at sapling and adult stage, but with no single individuals of seedlings.
- The species is considered to experience no regeneration, if the particular species survives only bat adult stage with neither seedling nor saplings.
- The regeneration is termed as new, if the species only has seedlings and saplings and no adults at all.

Since, population structure is the most authentic representative of future prospects and healthiness of any forest area, thus three layers of vegetation such as adults, saplings and seedlings were analyzed for determining the species richness, its density, frequency, abundance, and diversity in the disturbed and protected forest patch of Ranikhet.

Fig. 3.2: Field Data Collection

3.3 Community Structure

The field data was collected and used to calculate frequency, density, abundance and Importance Value Index (IVI) of each tree species by following the method described by **Zobel *et al.* (1987)**. The formulae used for the calculations of these attributes are presented below:

- **Frequency:** Frequency refers to the number of counts a specific plant species occurs in a quadrat. It is represented in percentage. The frequency can be calculated as follows:

$$\text{Frequency \%} = \frac{Number\ of\ quadrats\ in\ which\ the\ species\ occurred}{Total\ number\ of\ quadrats\ studied} \times 100$$

- **Density:** Density is defined as the total number of individuals of a species present per unit area. It can be calculated as follows:

$$\text{Density} = \frac{Total\ no.of\ individual\ of\ the\ species}{Total\ no.of\ quadrats\ studied}$$

- **Abundance:** Abundance is similar to density but in abundance the total number of individuals of a species is counted only in the quadrats in which the species actually occurred. It can be calculated as follows:

$$\text{Abundance} = \frac{Total\ no.of\ individual\ of\ the\ species}{Total\ no.of\ quadrats\ in\ which\ species\ occurred}$$

- **Importance Value Index (IVI)** gives the overall importance and status of each species in the community. It is calculated as the sum of relative values of density, frequency and abundance for all the three life forms i.e., seedlings, saplings and adults.

Relative values are the mean values of the original values and is represented in percentage. The values were obtained by the following relations:

$$\text{Relative Density} = \frac{Density\ of\ the\ species}{Total\ density\ of\ all\ species} \times 100$$

Or

$$\text{Relative Density} = \frac{Total\ no.of\ individual\ of\ the\ species}{Some\ of\ all\ the\ individual\ of\ all\ species} \times 100$$

$$\text{Relative Frequency} = \frac{Frequency\ of\ the\ species}{Total\ frequency\ of\ all\ species} \times 100$$

Or

$$\text{Relative Frequency} = \frac{No.of\ quadrats\ in\ which\ the\ species\ occurred}{Total\ no.of\ quadrats\ occurred\ by\ all\ species} \times 100$$

$$\text{Relative Abundance} = \frac{Abundance\ of\ individual\ species}{Total\ abundance\ of\ all\ species} \times 100$$

On the line of above-mentioned procedure **(Lal *et al.,* 2018)**, IVI is estimated as:

$$\text{Importance Value Index (IVI)} = Relative\ frequency + Relative\ density + Relative\ abundance$$

3.4 Measurement of Species diversity

Biological populations are communities vary in the number of species they possess and the information of this number is very vital in understanding the composition of the community. The total number of species present in a community is known as ***species richness***.

If the study is done in two communities having more or less the same number of species, there's a slight chance that one of the communities may be dominated by one particular type of species whereas the other one possessed equal or similar number of all the species. This, the relative abundance of species is also significant. This relative abundance of common and rare species is termed as ***evenness***. The communities that are dominated by one (or a few species) have a low evenness while the communities that have an even and diverse species distribution are considered to have a high evenness.

Species diversity includes both species richness and evenness. The communities that possess even distribution of large number of species are considered most diverse while communities that only possess few species which are moreover dominated by a single species are termed as least diverse.

3.4.1 Shannon – Weiner Index

The Shannon-Weiner index **(Shannon and Weiner, 1963)** gives us the idea about how the proportion of any individual specie plays a major role in the diversity of that forest land. It is based on measuring uncertainty. The degree of uncertainty is more or less directly or indirectly related to the diversity of a community.

If a community is dominated by a single species that means it has a low diversity, thus the uncertainty is low while if the diversity of any community is high, the uncertainty recorded is also high. The index provides us the idea of the diversity of a community by taking under consideration, the richness of the species and its proportion in a community. The formula is as follows:

$$\mathbf{H = -\sum (Ni/N) \log 2 (Ni/N)}$$

Where, H = species diversity,

Ni = total number of individuals of one species and

N = total number of individuals of all the species in that community.

3.5 Determination of contextual issues concerning forest management in Ranikhet

The process of regeneration of any species is constricted to an idiosyncratic range of habitat conditions and the extent of such conditions is a major causation of its geographical distribution. Successful regeneration often fortifies the long-term sustainability and life of the forests. Therefore, a detailed and appropriate understanding of the factors and processes (either natural or manmade and either biotic or abiotic) that influence regeneration of forest species is very crucial for proper management of forests as a resource to humans and an asset to the nature.

For the determination of several causes that might have resulted in the disturbance of ecological relationships in major or minor form, alteration of plant life history (if any) and an upward shift in the species richness and distribution, a survey was done with the local communities residing near the forest of our study sites. This survey basically aimed at deriving information from local people related to the demographic composition, for evaluating the level to which they were dependent on forest and their awareness level in terms of forest management. It was done by filling a questionnaire through individual or group contact method.

The questionnaire with which the following information was gathered is given below:

Questionnaire

Section 1: Demographic Information

1. Name:
2. Gender: Male(M) Female(F)
3. Age:
4. Total members in the household:
5. Contact details:
6. Village:
7. Main Occupation: Farming Job Other works

Section 2: Assessing dependence on forest

S. no.	Items	Yes	No
1.	Are you aware of the difference between protected and disturbed forest?		
2.	Are you dependent on forest for sustenance of livelihood?		
3.	Do you procure forest produce like wood, timber, fruits or foliage from the forest?		
4.	Do you sell forest produce in nearby market?		
5.	Are you dependent on forest to feed the livestock animals?		
6.	Do you perform agroforestry (growing crops in between the trees)?		
7.	Are you or your family members involved in furniture, basket or rope making activities?		
8.	Is slash & burn agriculture a common practice of this place?		
9.	Is this forest rich in fauna?		
10.	Do forest department officials visit the forest for checking and maintenance of forest?		
11.	Do they ever talk to you about forest management operations or practices?		
12.	Do you think that condition of the forest is deteriorating over time here?		
13.	Has the tree population and species increased over time here?		
14.	Are you aware about the factors hampering the forest growth?		
15.	Is forest management operation carried out in this area till now?		
16.	Do forest communities take a step for forest management or protection?		

Section 3: Forest related awareness

1. What kind of tree species found here?
2. What kind of animal species found here?
3. Which tree species grow faster?
4. Which forest produce has high market value?
5. What kind of produce you gather from forest?
6. What forest produce you sell in the market to fetch a good price for livelihood sustenance?
7. How many families living in this forest?
8. How much area is estimated to be under forest here?
9. Is there a problem of landslide or low water table?
10. What are factors responsible for deterioration of forest?
11. What is the management operation performed here for its protection (if any)?
12. Has plantation or afforestation ever done here (if yes, when & who did)?

With the careful examination of the study site and by the application of following sampling technique and methodology followed, a data is being generated, described in the next section, in order to determine and evaluate distribution pattern of the different species and their structural characteristics as well as the capacity of the regeneration of the forest species in Ranikhet region of Kumaon Himalayas.

Results and Discussion

Regeneration status of different tree species along the altitude (or elevation) within the protected and disturbed forest has been presented and discussed in this chapter. The various phytosociological parameters in six diverse species of trees were studied at three different altitude ranges which were hill top, slope and base. The results achieved are illustrated and discussed under the following heads.

4.1 Species composition

The species of trees show variation along the altitude, temperature, humidity, pH, rainfall, climate and other natural factors. The forest tree species found in both the sites were same as both the sites had more or less the same climatic condition, same altitude range and were adjacent to each other. Majorly six species of trees were recorded that were *Cedrus deodara*, *Pinus roxburghii*, *Quercus leucotrichophora*, *Myrica esculenta*, *Rhododendron arboreum* and *Abies pindrow*.

The assorted tree species were studied in both the sites by counting the number of individuals (seedlings, saplings and adults) along the three different altitudinal sites (top, slope and base) and the values are presented in figures and tabular form.

4.1.1 Tree species composition in protected forest

Three sites were taken based on different elevations i.e., hill top, hill slope and hill base. All six species of trees were studied along the tree sites.

4.1.1.1 Site I - Hill Top

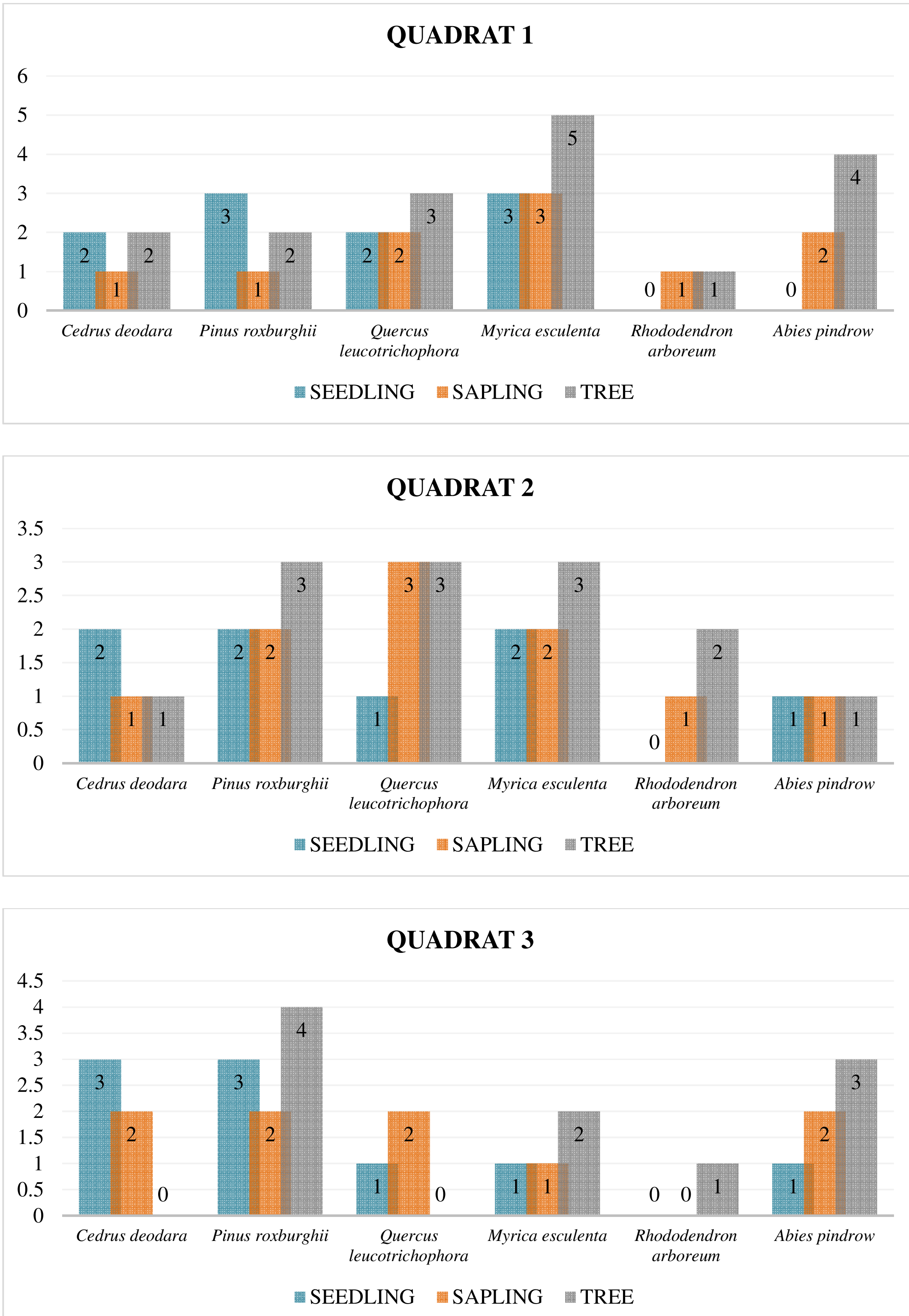


Figure 4.1: Tree species distribution (per 100 m²) in Site I (Hill Top)

Table 4.1: Frequency, density and abundance of tree species in Site I (Hill Top)

Species	Seedling			Sapling			Adults		
	Frequency (%)	Density (ind. per 100 m²)	Abundance	Frequency (%)	Density (ind. per 100 m²)	Abundance	Frequency (%)	Density (ind. per 100 m²)	Abundance
Cedrus deodara	100	2.33	2.33	100	1.33	1.33	66.7	1	1.5
Pinus roxburghii	100	2.67	2.67	100	1.67	1.67	100	3	3
Quercus leucotrichophora	100	1.33	1.33	100	2.33	2.33	66.7	2	3
Myrica esculenta	100	2	2	100	2	2	100	3.33	3.33
Rhododendron arboreum	0	0	0	66.7	0.67	1	100	1.33	1.33
Abies pindrow	66.7	0.67	1	100	1.67	1.67	100	2.67	2.67

In **Site I** (hill top) highest frequency of 100% was recorded for both seedlings and saplings in *Cedrus deodara*, *Pinus roxburghii*, *Quercus leucotrichophora* and *Myrica esculenta* **(Table 4.1)** while *Rhododendron arboreum* displayed a frequency of 0% which may be due to the environmental factors or nutrient and water availability. In adults, highest frequency of 100% was possessed by *Pinus roxburghii Myrica esculenta, Rhododendron arboreum* and *Abies pindrow.*

Density of the species gives an indication of the numeric strength of the species in a community. The highest density for seedlings was observed in *Pinus roxburghii* of 2.67 individuals per 100 m² followed by *Cedrus deodara* and *Myrica esculenta* with 2.33 and 2 individuals per 100 m² respectively. In the case of saplings, largest density was 2.33 individuals per 100 m² of *Quercus leucotrichophora* and the lowest was shown by *Rhododendron arboreum* i.e., 1 individual per 100 m². *Myrica esculenta* and *Cedrus deodara* displayed highest and lowest density of 3.33 and 1 individuals per 100 m² respectively in adults.

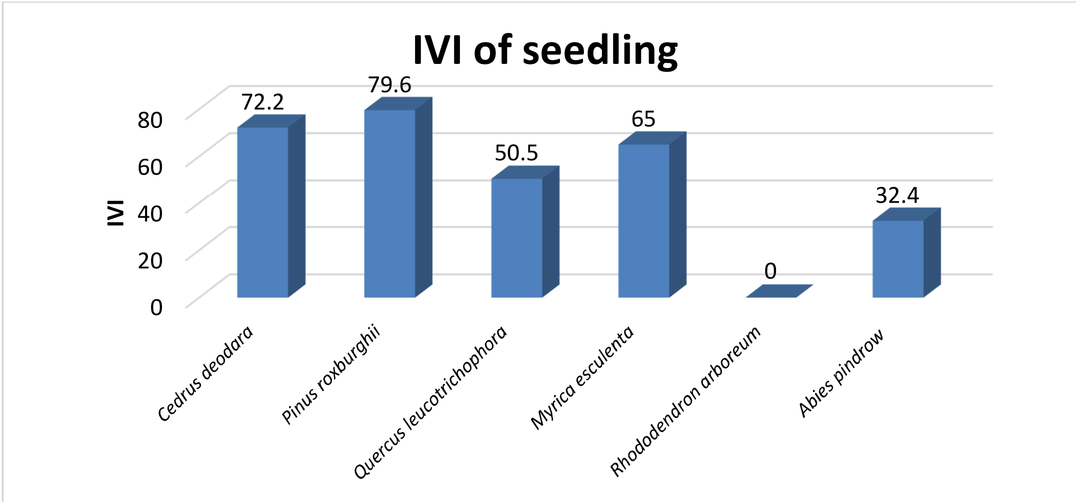
Abundance is calculated similar to density but only those quadrats are considered for calculation in which the species or individuals really occur. The maximum value of abundance was 2.67 individuals per 100 m² of *Pinus roxburghii* (in seedlings), 2.33 individuals per 100 m² of *Quercus leucotrichophora* (in saplings) and 3.33 individuals per 100 m² of *Myrica esculenta* (in adults) while the lowest abundance recorded in seedlings, saplings and adults were 0, 1 and 1.33 individuals per 100 m² respectively for *Rhododendron arboreum.*

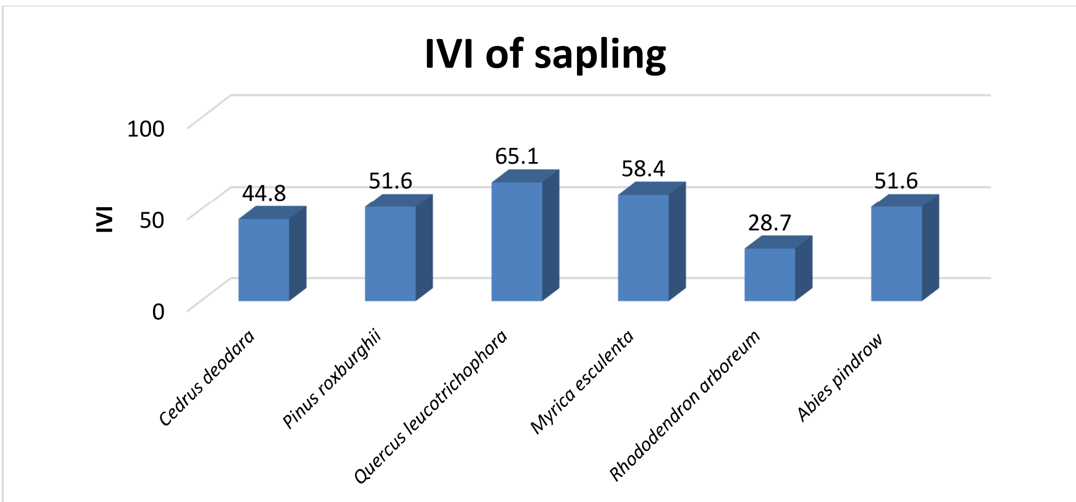
Table 4.2: Important Value Index of tree species in site I (Hill Top)

SPECIES	SEEDLING				SAPLING				ADULT			
	Relative Frequency	Relative Density	Relative Abundance	IVI	Relative Frequency	Relative Density	Relative Abundance	IVI	Relative Frequency	Relative Density	Relative Abundance	IVI
HILL TOP												
Cedrus deodara	21.4	25.9	24.9	72.2	17.7	13.8	13.3	44.8	12.5	7.5	10.1	30.1
Pinus roxburghii	21.4	29.6	28.6	**79.6**	17.7	17.2	16.7	51.6	18.8	22.5	20.2	61.5
Quercus leucotrichophora	21.4	14.8	14.3	50.5	17.7	24.1	23.3	**65.1**	12.5	15.0	20.2	47.7
Myrica esculenta	21.4	22.2	21.4	65.0	17.7	20.7	20.0	58.4	18.8	25.0	22.5	**66.3**
Rhododendron arboreum	0	0	0	0	11.8	6.9	10.0	28.7	18.8	10.0	8.9	37.7
Abies pindrow	14.3	7.4	10.7	32.4	17.7	17.2	16.7	51.6	18.8	20.0	18.0	56.8

Important Value Index (IVI) helps to determine the overall significance of each species in the community. In calculating this index, the percentage values of the relative frequency, relative density and relative abundance are summed up together and the value obtained is described as the Important Value Index or IVI of the species.

The highest IVI in seedlings was recorded for *Pinus roxburghii* of 79.6 while in the sapling layers, the highest IVI recorded was for *Quercus leucotrichophora* of 65.1. *Rhododendron arboreum* possessed lowest IVI in both seedling and sapling layers i.e., 0 and 28.7 respectively. *Myrica esculenta* was a dominant tree species in adults with an IVI of 66.3 and the lowest in the same category was recorded for *Cedrus deodara* that was 30.1.





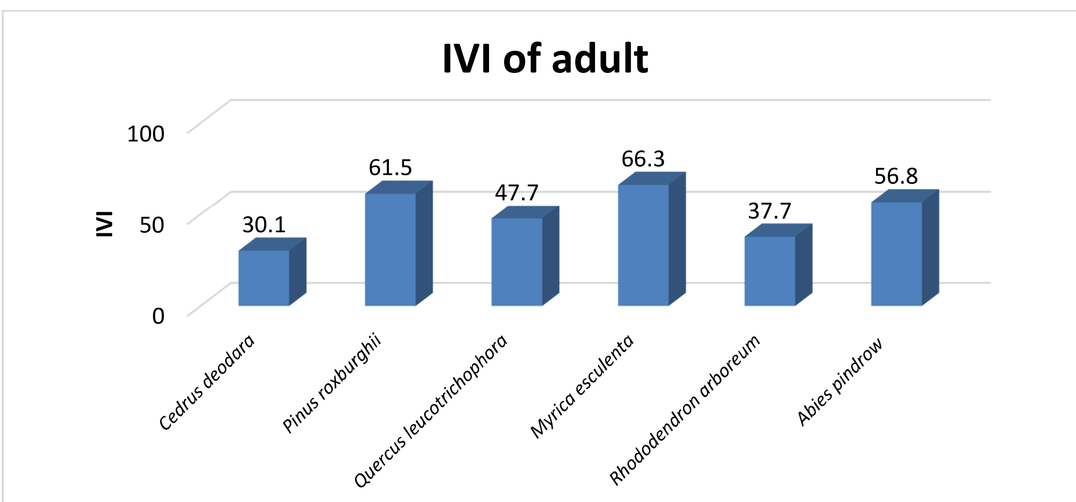


Figure 4.2: IVI of seedling, sapling and adults of tree species in Site I (Hill Top)

4.1.1.2 Site II – Hill Slope

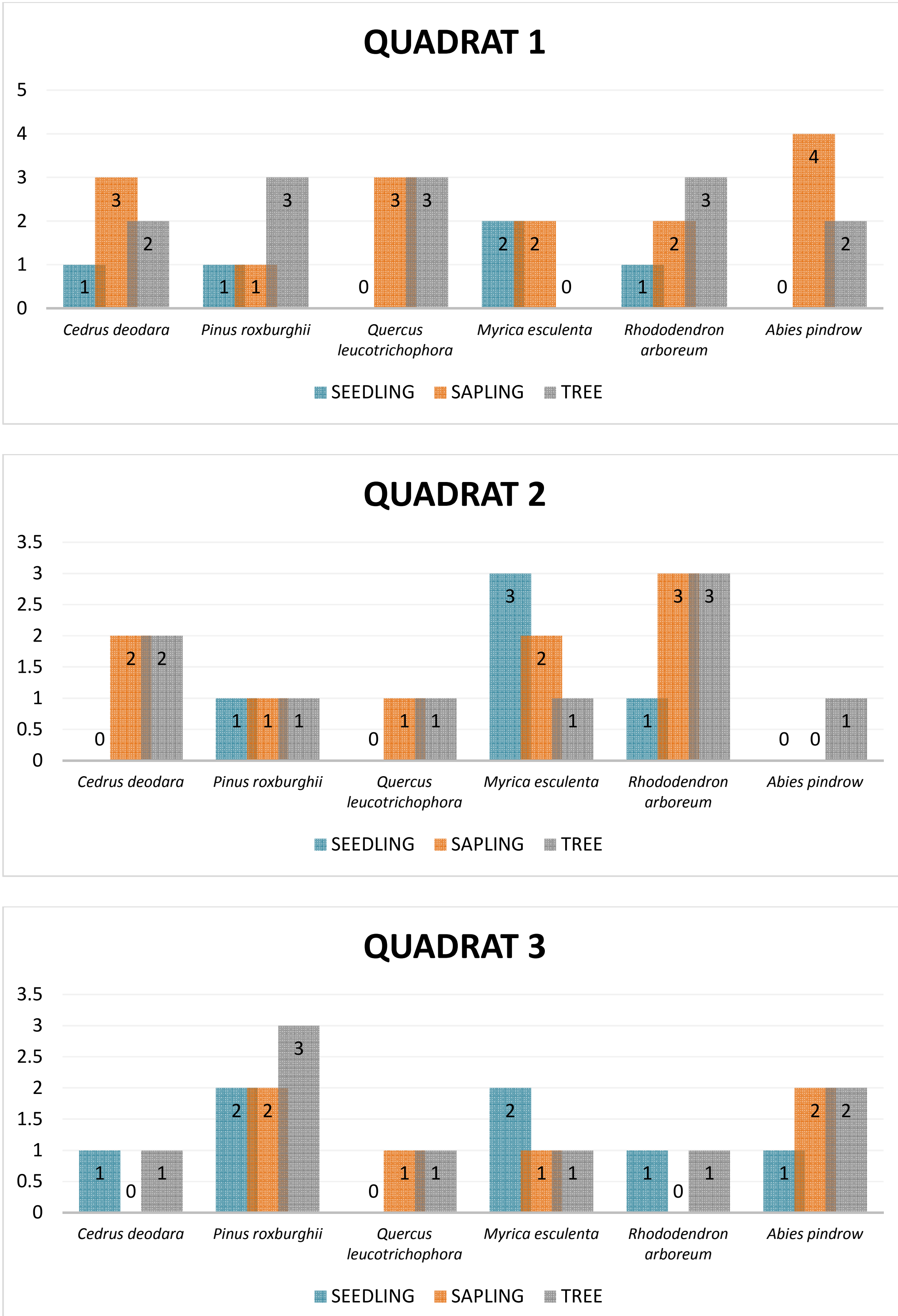


Figure 4.3: Tree species distribution (per 100 m²) in Site II (Hill Slope)

Table 4.3: Frequency, density and abundance of tree species in Site II (Hill Slope)

Species	Seedling			Sapling			Adult		
	Frequency (%)	Density (ind. per 100 m²)	Abundance	Frequency (%)	Density (ind. per 100 m²)	Abundance	Frequency (%)	Density (ind. per 100 m²)	Abundance
Cedrus deodara	66.7	0.67	1	66.7	1.67	2.5	100	1.67	1.67
Pinus roxburghii	100	1.33	1.33	100	1.33	1.33	100	2.33	2.33
Quercus leucotrichophora	0	0	0	100	1.67	1.67	100	1.67	1.67
Myrica esculenta	100	2.33	2.33	100	1.67	1.67	66.7	0.67	1
Rhododendron arboreum	100	1	1	66.7	1.67	2.5	100	2.33	2.33
Abies pindrow	33.3	0.33	1	66.7	2	3	100	1.67	1.67

In **Site II** (hill slope) highest frequency of 100% was recorded for seedlings in *Pinus roxburghii*, *Myrica esculenta* and *Rhododendron arboreum* while the lowest frequency of zero percent was estimated in *Quercus leucotrichophora*. Similarly, in sapling stage the highest frequency was estimated to be 100% of *Pinus roxburghii, Quercus leucotrichophora and Myrica esculenta* while in adults, except *Myrica esculenta* all other tree species possessed a frequency of 100%.

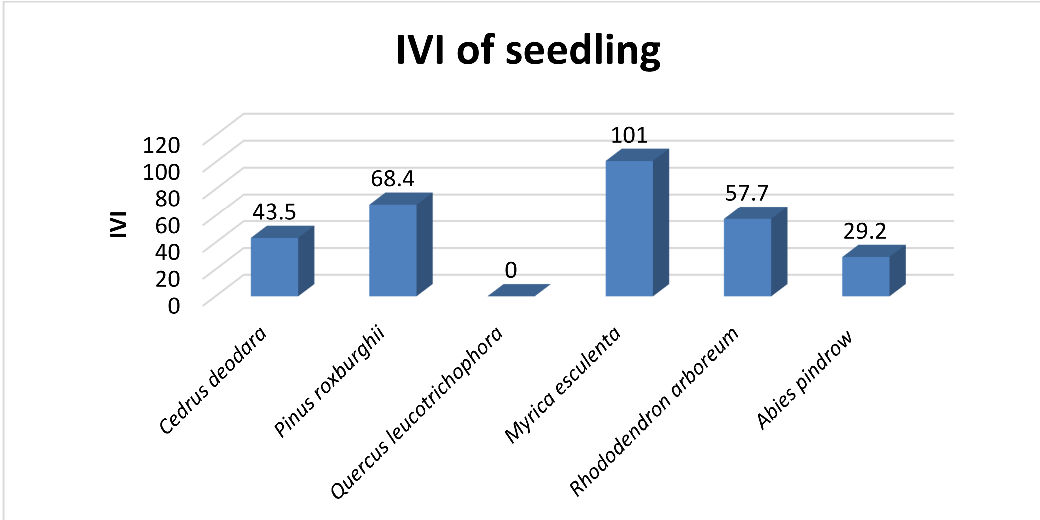
The greatest density in seedlings was recorded in *Myrica esculenta* of 2.33 individuals per 100 m² while in the sapling layer, Abies pindrow possessed the highest density of 2 individuals per 100 m² while all other tree species showed a density of 1.67 individuals per 100 m² except *Pinus roxburghii*, that had a density of 1.33 individuals per 100 m². In adults, the highest density was shared by *Pinus roxburghii* and *Rhododendron arboreum* with 2.33 individuals per 100 m² while the lowest density of 0.67 individuals per 100 m² was observed in *Myrica esculenta*.

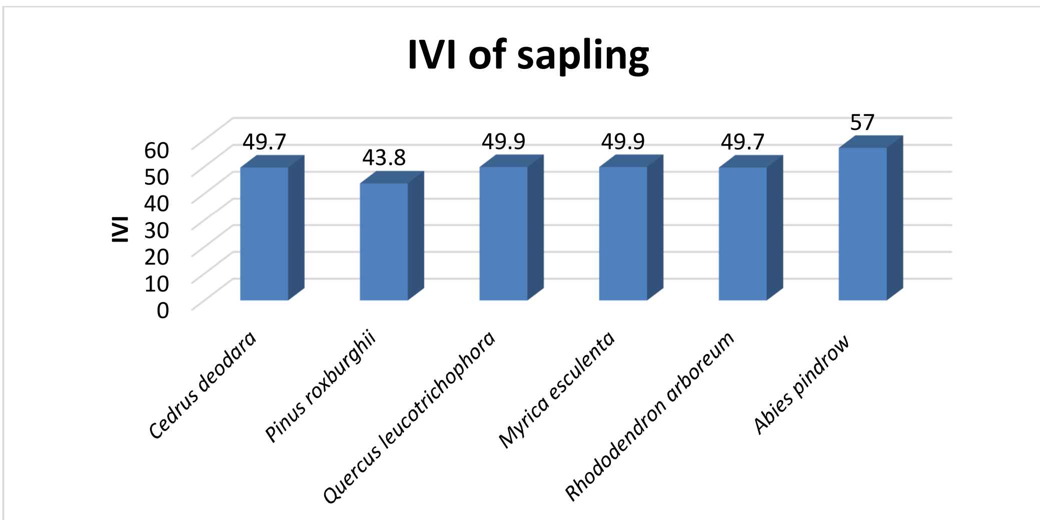
Abundance in seedlings was again highest in *Myrica esculenta* with 2.33 individuals per 100 m² while is saplings, the highest abundance was possessed by *Abies pindrow* with 3 individuals per 100 m². Similar to the density in adults, the highest abundance in adults was recorded to be 2.33 individuals per 100 m² for the same above species.

Table 4.4: Important Value Index of tree species in site II (Hill Slope)

SPECIES	SEEDLING				SAPLING				ADULT			
	Relative Frequency	Relative Density	Relative Abundance	IVI	Relative Frequency	Relative Density	Relative Abundance	IVI	Relative Frequency	Relative Density	Relative Abundance	IVI
HILL SLOPE												
Cedrus deodara	16.7	11.8	15.0	43.5	13.3	16.7	19.7	49.7	17.7	16.1	15.7	49.5
Pinus roxburghii	25.0	23.5	19.9	68.4	20.0	13.3	10.5	43.8	17.7	22.6	21.8	**62.1**
Quercus leucotrichophora	0	0	0	0	20.0	16.7	13.2	49.9	17.7	16.1	15.7	49.5
Myrica esculenta	25.0	41.1	34.9	**101**	20.0	16.7	13.2	49.9	11.8	6.5	9.4	27.7
Rhododendron arboreum	25.0	17.7	15.0	57.7	13.3	16.7	19.7	49.7	17.7	22.6	21.8	**62.1**
Abies pindrow	8.3	5.9	15.0	29.2	13.3	20.0	23.7	**57.0**	17.7	16.1	15.7	49.5

Myrica esculenta dominated the seedling stage of site II with the highest IVI of 101 while *Quercus leucotrichophora* had an IVI of zero which may be due to the wild herbivore animals that feed on soft, young leaves of plants and trees. The sapling layer of forest was dominated by *Abies pindrow* with the highest IVI of 57 while other species had minor differences in the IVI. *Pinus roxburghii* and *Rhododendron arboreum* shared the greatest value of IVI of 62.1 in adults. *Myrica esculenta* that dominated the seedling stage, possessed the least IVI of 27.7 in adults.





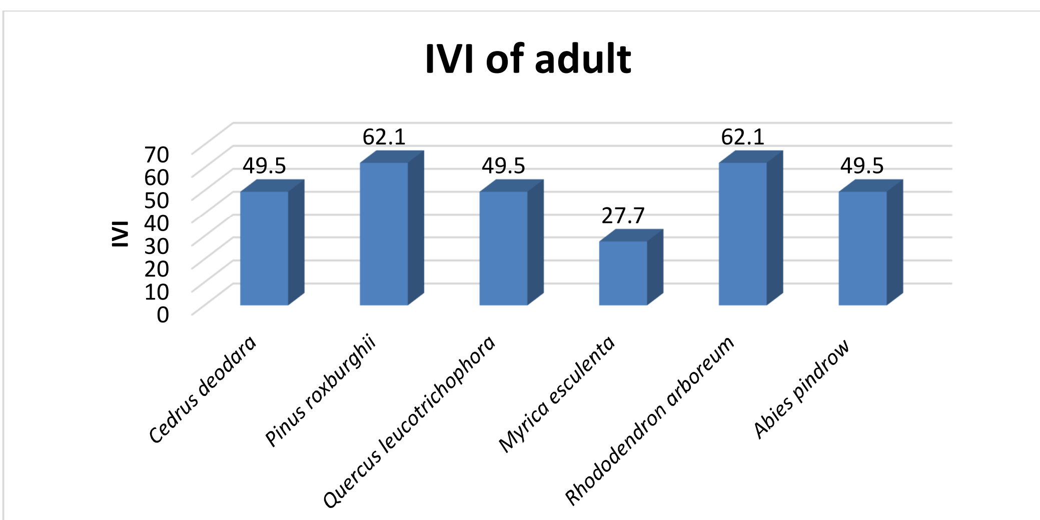


Figure 4.4: IVI of seedling, sapling and adults of tree species in Site II (Hill Slope)

4.1.1.3 Site III – Hill Base

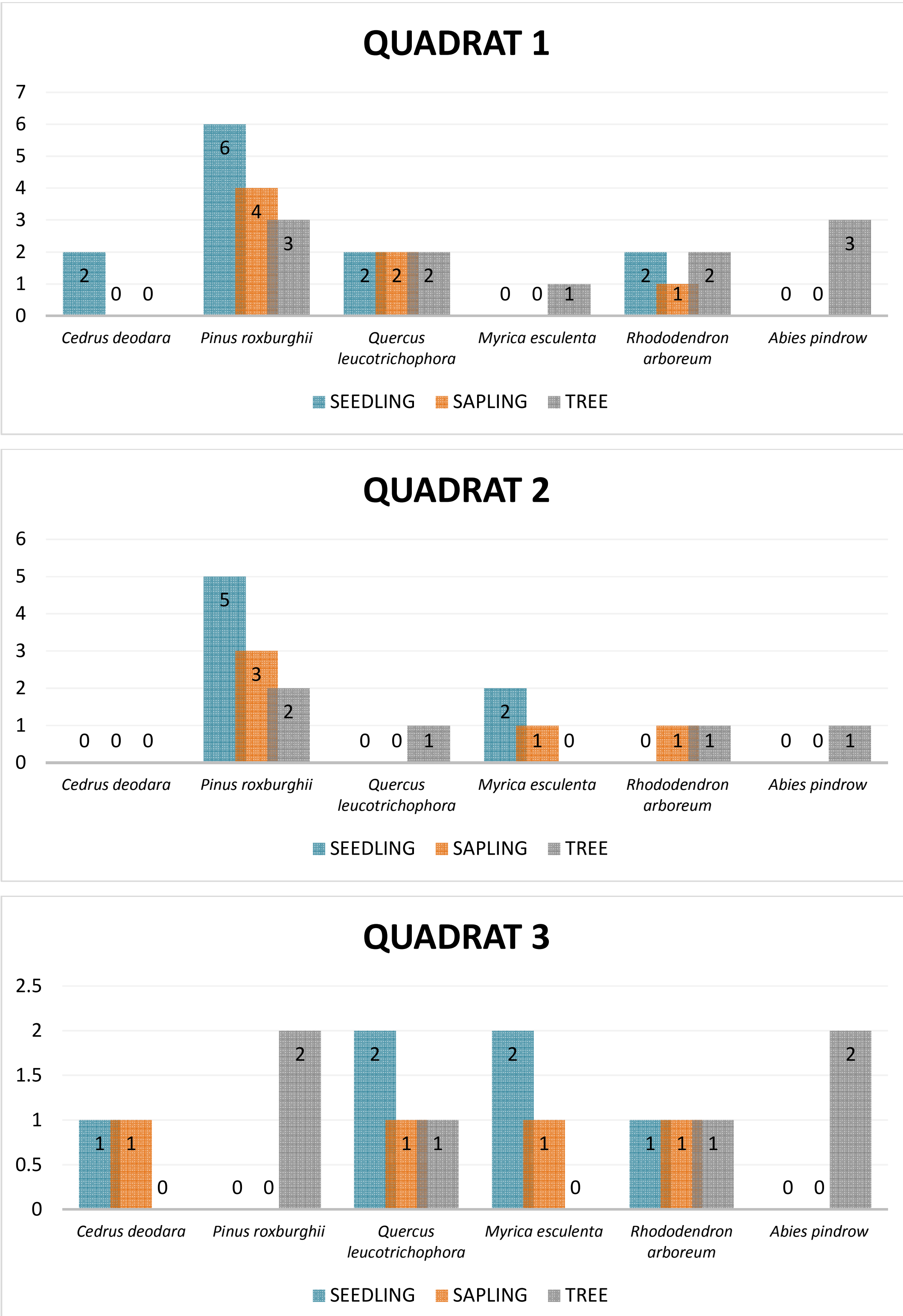


Figure 4.5: Tree species distribution (per 100 m²) in Site III (Hill Base)

Table 4.5: Frequency, density and abundance of tree species in Site III (Hill Base)

Species	Seedling			Sapling			Adult		
	Frequency (%)	Density (ind. per 100 m²)	Abundance	Frequency (%)	Density (ind. per 100 m²)	Abundance	Frequency (%)	Density (ind. per 100 m²)	Abundance
Cedrus deodara	66.7	1	1.5	33.3	0.33	1	0	0	0
Pinus roxburghii	66.7	3.67	5.5	66.7	2.33	3.5	66.7	2.33	2.33
Quercus leucotrichophora	66.7	1.33	2	66.7	1	1.5	66.7	1.33	1.33
Myrica esculenta	66.7	1.67	2.5	66.7	1	1.5	66.7	0.67	1
Rhododendron arboreum	66.7	1	1.5	100	1	1	100	1.33	1.33
Abies pindrow	0	0	0	0	0	0	100	2	2

In **Site III** (hill base) all the tree species in seedling stage possessed same frequency of 66.7% except *Abies pindrow* with zero frequency. The highest frequency of 100% was recorded for both saplings and trees in *Rhododendron arboreum*. *Cedrus deodara* exhibited a decreasing frequency of 66.7, 33.3 and 0 in seedling, sapling and adult respectively. The frequency estimated for *Pinus roxburghii* and *Quercus leucotrichophora* were same same i.e., 66.7% in all three layers.

Pinus roxburghii exhibited the highest density of 3.67 individuals per 100 m² in seedlings, 2.33 individuals per 100 m² in saplings and 2.33 individuals per 100 m² in adults.

Similar to the density, abundance too was found highest in *Pinus roxburghii* with 5.5 individuals per 100 m² in seedling stage, 3.5 individuals per 100 m² in sapling stage and 2.33 individuals per 100 m² in adults.

Table 4.6: Important Value Index of tree species in site III (Hill Base)

SPECIES	SEEDLING				SAPLING				ADULT			
	Relative Frequency	Relative Density	Relative Abundance	IVI	Relative Frequency	Relative Density	Relative Abundance	IVI	Relative Frequency	Relative Density	Relative Abundance	IVI
HILL BASE												
Cedrus deodara	20.0	11.5	11.5	43.0	9.9	5.9	11.8	27.6	0	0	0	0
Pinus roxburghii	20.0	42.3	42.3	**104.6**	20.0	41.2	41.2	**102.4**	16.7	30.4	29.2	**76.3**
Quercus leucotrichophora	20.0	15.4	15.4	50.8	20.0	17.7	17.7	55.4	16.7	17.4	16.7	50.8
Myrica esculenta	20.0	19.2	19.2	58.4	20.0	17.7	17.7	55.4	16.7	8.7	12.5	37.9
Rhododendron arboreum	20.0	11.5	11.5	43.0	29.9	17.7	11.8	59.4	24.9	17.4	16.7	59.0
Abies pindrow	0	0	0	0	0	0	0	0	24.9	26.1	25.0	76.0

In case of IVI, the highest IVI value is exhibited by *Pinus roxburghii* in all the three growth stages of trees. In seedling layer, the IVI value estimated is 104.6 and in sapling layer, the value of IVI is 102.4 which is way more than any other species studied **(Table 4.6) (Figure 4.6).** In adult zone too, highest IVI recorded is 76.3 for *Pinus roxburghii*. This shows the growing, germinating, climatic and water condition of the tree as well as the forest area. Pine tree needs less water, comparatively warmer climate and wind plays a major role as a carrier of its seeds.

While the hill base showed dominance of *Pinus roxburghii*, *Abies pindrow* and *Cedrus deodara* showed nil IVI in seedling/sapling and adult stages respectively. This may be due to altitude as these trees grow on comparatively higher altitude and the other factor can be rainfall and temperature differences.

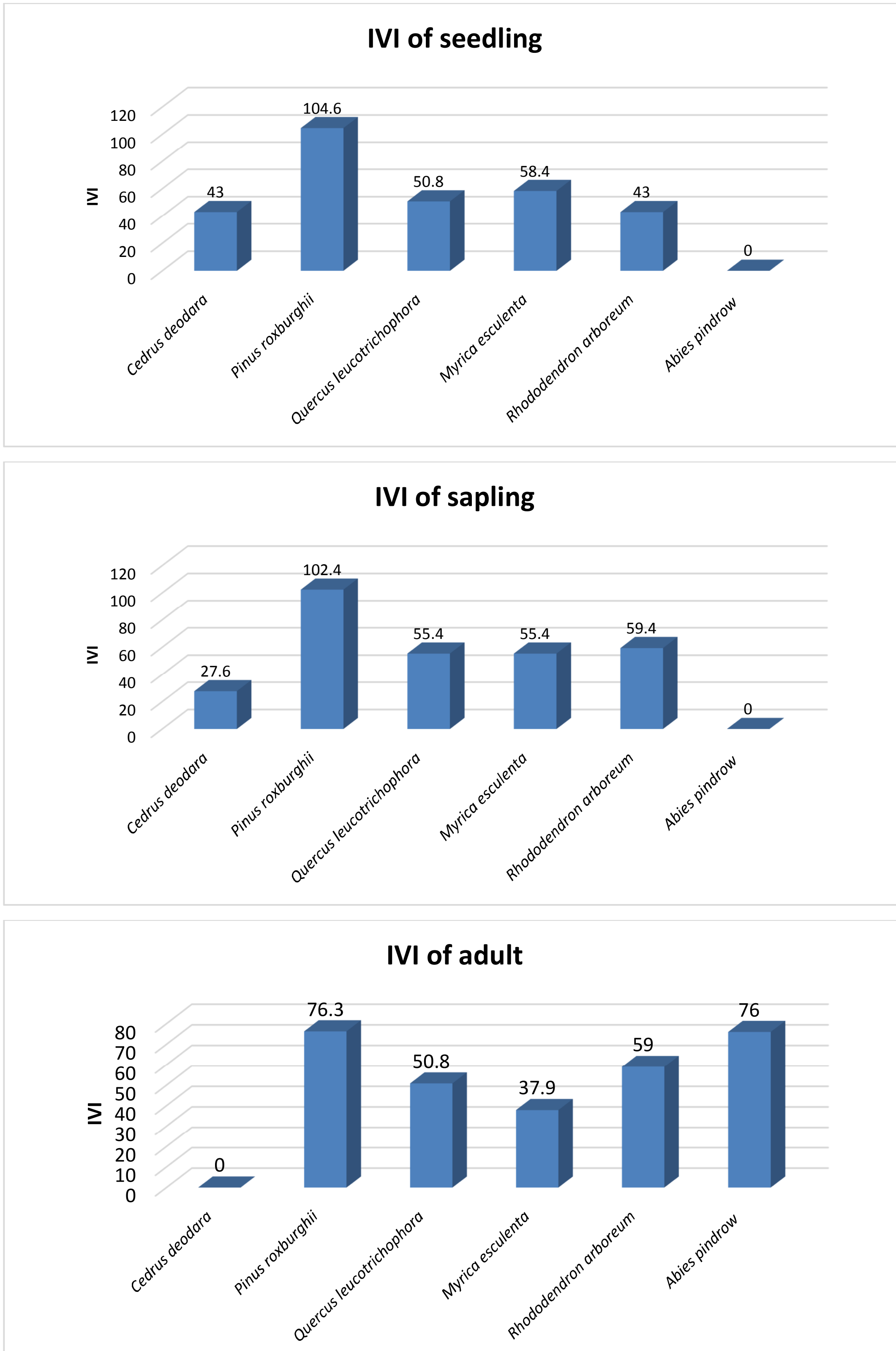


Figure 4.6: IVI of seedling, sapling and adults of tree species in Site III (Hill Base)

4.1.2 Tree species composition in disturbed forest

Same as the protected forest site, three sites were taken based on different elevations i.e., hill top, hill slope and hill base. All six species of trees were studied along the tree sites.

4.1.2.1 Site I - Hill Top

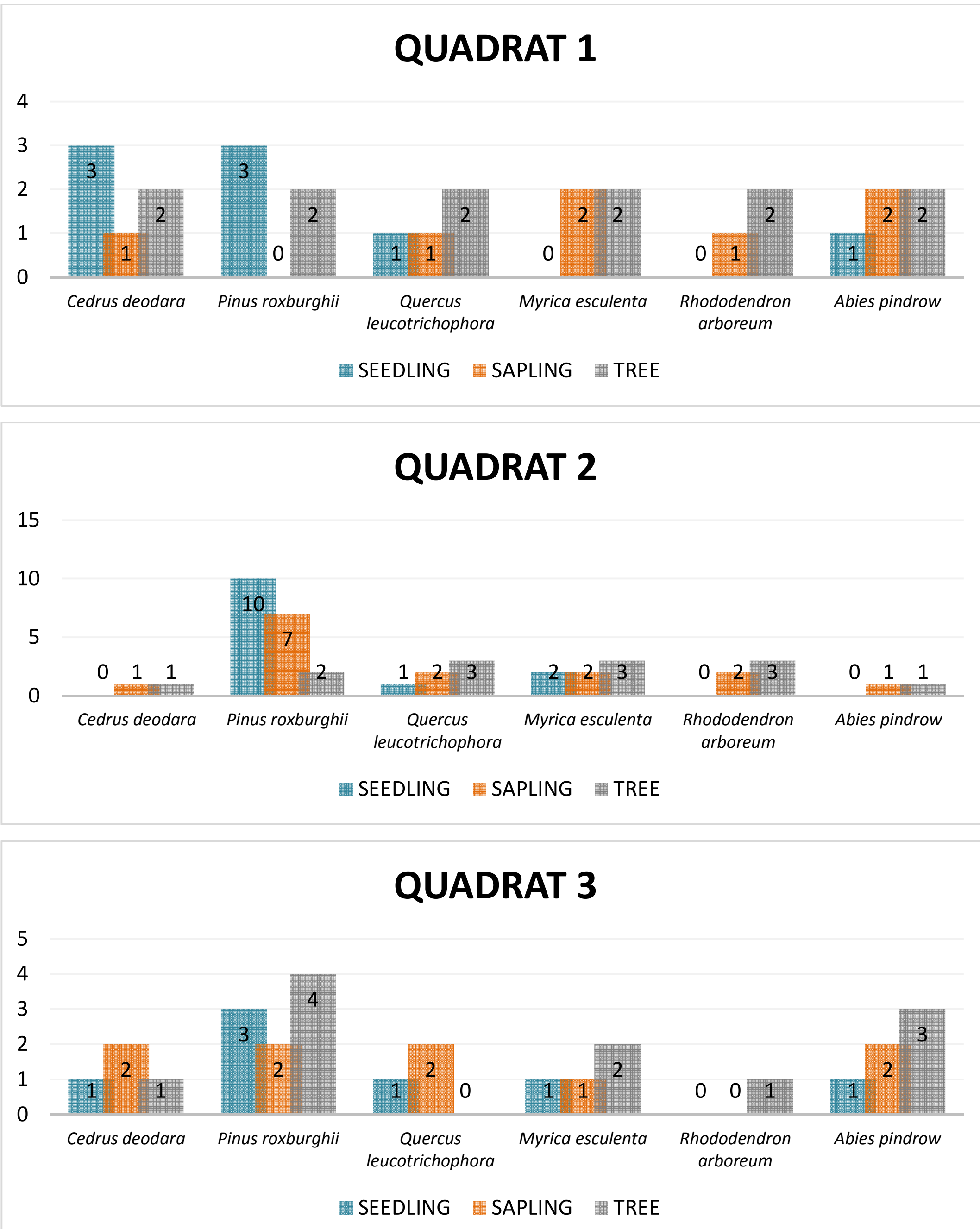


Figure 4.7: Tree species distribution (per 100 m²) in Site I (Hill Top)

Table 4.7: Frequency, density and abundance of tree species in Site I (Hill Top)

Species	Seedling			Sapling			Adult		
	Frequency (%)	Density (ind. per 100 m²)	Abundance	Frequency (%)	Density (ind. per 100 m²)	Abundance	Frequency (%)	Density (ind. per 100 m²)	Abundance
Cedrus deodara	66.7	1.33	2	100	1.33	1.33	100	1.33	1.33
Pinus roxburghii	100	5.33	5.33	66.7	3	4.5	100	2.67	2.67
Quercus leucotrichophora	100	1	1	100	1.67	1.67	66.7	1.67	2.5
Myrica esculenta	66.7	1	1.5	100	1.67	1.67	100	2.33	2.33
Rhododendron arboreum	0	0	0	66.7	1	1.5	100	2	2
Abies pindrow	66.7	0.67	1	100	1.67	1.67	100	2.67	2.67

In **Site I** (hill top) highest frequency of 100% was recorded for seedlings in *Pinus roxburghii* and *Quercus leucotrichophora* while all the other species possessed 66.7% frequency except *Rhododendron arboreum* with zero frequency. *Cedrus deodara, Myrica esculenta* and *Abies pindrow* exhibited 100% frequency in sapling and adult zones. *Rhododendron arboreum* and *Pinus roxburghii* shared same frequency of 66.7% and 100% in seedling and adult respectively.

Pinus roxburghii exhibited the greatest density of 5.33 individuals per 100 m² and 3 individuals per 100 m² in seedlings and saplings respectively. The highest no. of individuals in adults were found to be 2.67 individuals per 100 m² in *Pinus roxburghii* and *Abies pindrow*.

Abundance was highest for *Pinus roxburghii* with similar 5.33 individuals per 100 m² in seedlings while it was recorded 4.5 individuals per 100 m² in saplings. Similar to the density in adults, highest abundance is also shared by both *Pinus roxburghii* and *Abies pindrow* with 2.67 individuals per 100 m².

Table 4.8: Important Value Index of tree species in site I (Hill Top)

SPECIES	SEEDLING				SAPLING				ADULT			
	Relative Frequency	Relative Density	Relative Abundance	IVI	Relative Frequency	Relative Density	Relative Abundance	IVI	Relative Frequency	Relative Density	Relative Abundance	IVI
HILL TOP												
Cedrus deodara	16.7	14.3	18.5	49.5	18.8	12.9	10.8	42.5	17.7	10.5	9.9	38.1
Pinus roxburghii	24.9	57.1	49.2	**131.2**	12.5	29.0	36.5	**78.0**	17.7	21.0	19.8	58.5
Quercus leucotrichophora	24.9	10.7	9.2	44.8	18.8	16.1	13.5	48.4	11.8	13.2	18.5	43.5
Myrica esculenta	16.7	10.7	13.9	41.3	18.8	16.1	13.5	48.4	17.7	18.4	17.3	53.4
Rhododendron arboreum	0	0	0	0	12.5	9.7	12.2	34.4	17.7	15.8	14.8	48.3
Abies pindrow	16.7	7.1	9.2	33.0	18.8	16.1	13.5	48.4	17.7	21.1	19.8	**58.6**

Pinus roxburghii was recorded as dominant species in seedling as well as the sapling zone with the highest IVI of 131.2 and 78 respectively. *Rhododendron arboreum* displayed an IVI of zero (in seedlings) which shows the poor growth of that species. In sapling stage, *Quercus leucotrichophora, Myrica esculenta* and *Abies pindrow* exhibited equal and second highest IVI of 48.4. While in the adults, *Abies pindrow* possessed the highest IVI of 58.6 preceding *Pinus Roxburghii* with 0.1 that has the second highest IVI of 58.5.

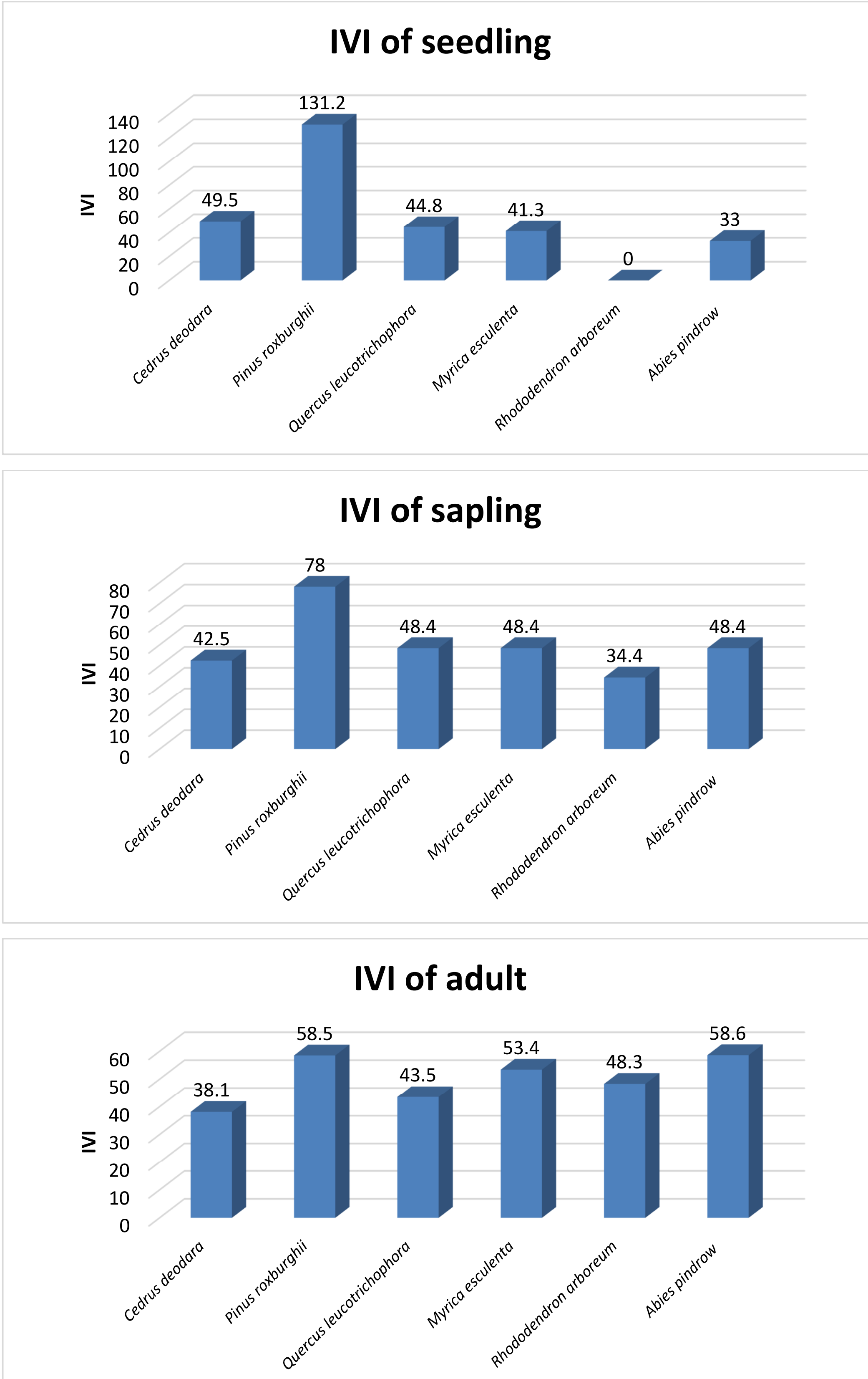
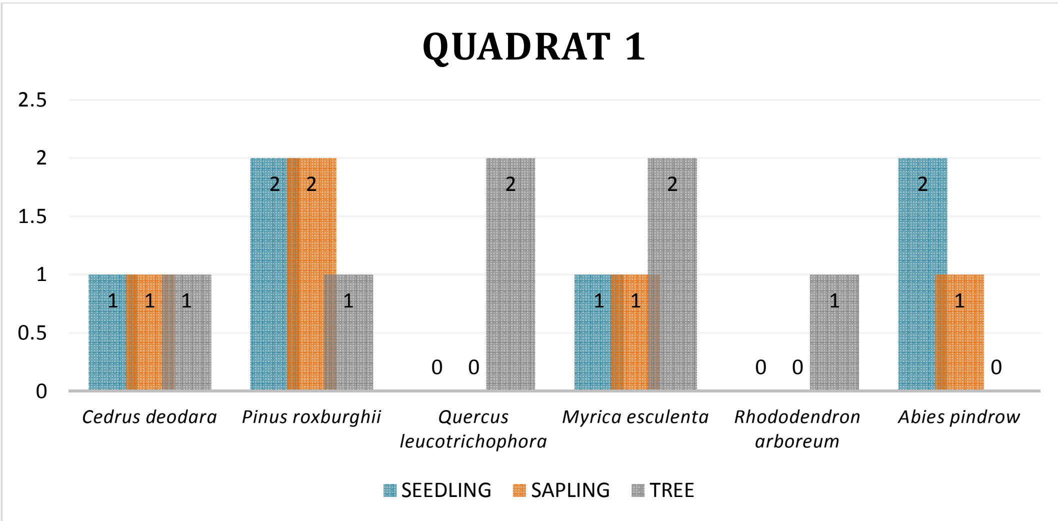
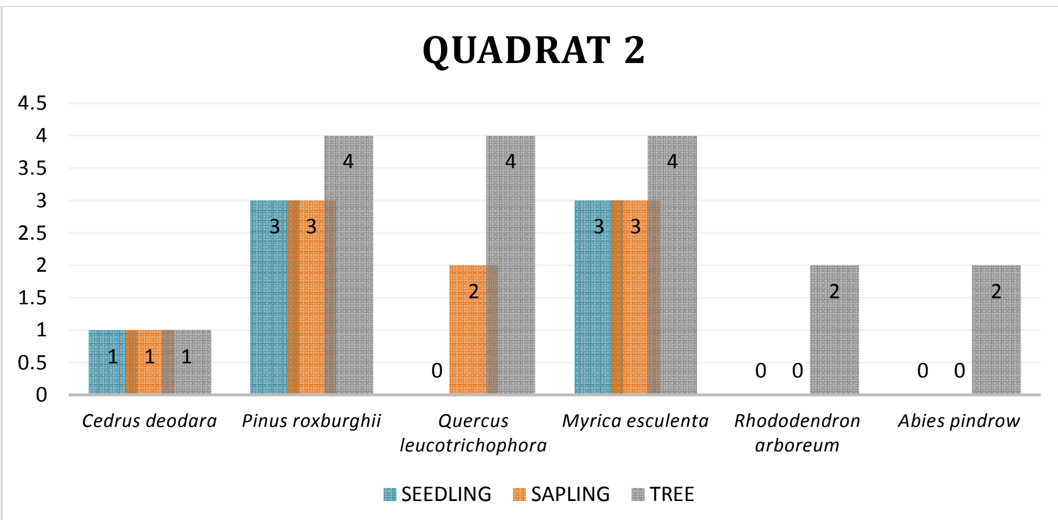


Figure 4.8: IVI of seedling, sapling and adults of tree species in Site I (Hill Top)

4.1.2.2 Site II - Hill Slope





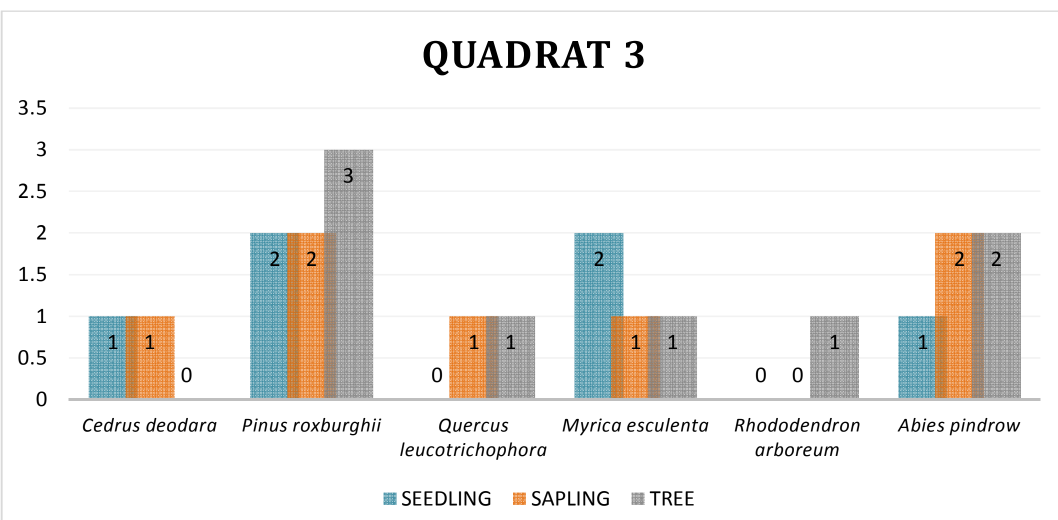


Figure 4.9: Tree species distribution (per 100 m²) in Site II (Hill Slope)

Table 4.9: Frequency, density and abundance of tree species in Site II (Hill Slope)

Species	Seedling			Sapling			Adult		
	Frequency (%)	Density (ind. per 100 m²)	Abundance	Frequency (%)	Density (ind. per 100 m²)	Abundance	Frequency (%)	Density (ind. per 100 m²)	Abundance
Cedrus deodara	100	1	1	100	1	1	66.7	0.67	1
Pinus roxburghii	100	2.33	2.33	100	2.33	2.33	100	2.67	2.67
Quercus leucotrichophora	0	0	0	66.7	1	1.5	100	2.33	2.33
Myrica esculenta	100	2	2	100	1.67	1.67	100	2.33	2.33
Rhododendron arboreum	0	0	0	0	0	0	100	1.33	1.33
Abies pindrow	66.7	1	1.5	66.7	1	1.5	66.7	1.33	2

In **Site II** (hill slope) highest frequency of 100% was recorded for seedlings, saplings and adults in *Pinus roxburghii* and *Myrica esculenta*. *Cedrus deodara* possessed 100% frequency in seedlings and sapling zones while *Rhododendron arboreum* was not found in the same zones. *Quercus leucotrichophora* and *Rhododendron arboreum* exhibited 100% frequency in adults but zero frequency in seedlings.

Pinus roxburghii demonstrated the greatest density in all the three levels. The highest density recorded was 2.33 individuals per 100 m² in seedling, 2.33 individuals per 100 m² in saplings and 2.67 individuals per 100 m² in adults too.

Alike density, the abundance in all the three zones was highest of *Pinus roxburghii* with 2.33 individuals per 100 m² in seedlings and saplings, and 2.67 individuals per 100 m² in adults.

Table 4.10: Important Value Index of tree species in site II (Hill Slope)

SPECIES	SEEDLING				SAPLING				ADULT			
	Relative Frequency	Relative Density	Relative Abundance	IVI	Relative Frequency	Relative Density	Relative Abundance	IVI	Relative Frequency	Relative Density	Relative Abundance	IVI
HILL SLOPE												
Cedrus deodara	27.3	23.1	14.6	65.0	23.1	14.3	12.5	49.9	12.5	6.3	8.6	27.4
Pinus roxburghii	27.3	53.9	34.1	**115.3**	23.1	33.3	29.1	**85.5**	18.8	25.0	22.9	**66.7**
Quercus leucotrichophora	0	0	0	0	15.4	14.3	18.8	48.5	18.8	21.9	19.9	60.6
Myrica esculenta	27.3	46.2	29.3	102.8	23.1	23.8	20.9	67.8	18.8	21.9	19.9	60.6
Rhododendron arboreum	0	0	0	0	0	0	0	0	18.8	12.5	11.4	42.7
Abies pindrow	18.2	23.1	21.9	63.2	15.4	14.3	18.8	48.5	12.5	12.5	17.2	42.2

Pinus roxburghii was found the most dominant species in **site II** (hill slope). It exhibits the highest IVI of 115.3 in seedings preceding *Myrica esculenta* with an IVI of 102.8, highest IVI of 85.5 in saplings preceding *Myrica esculenta* again that possessed IVI of 67.8 and highest IVI of 66.7 in adults too.

Rhododendron arboreum exhibited nil IVI that signifies that the seedlings and saplings are absent which represents that the species is in a poor condition with almost no capacity to germinate or grow. This can be due to the heavy human interferences, overgrazing or other anthropogenic activities.

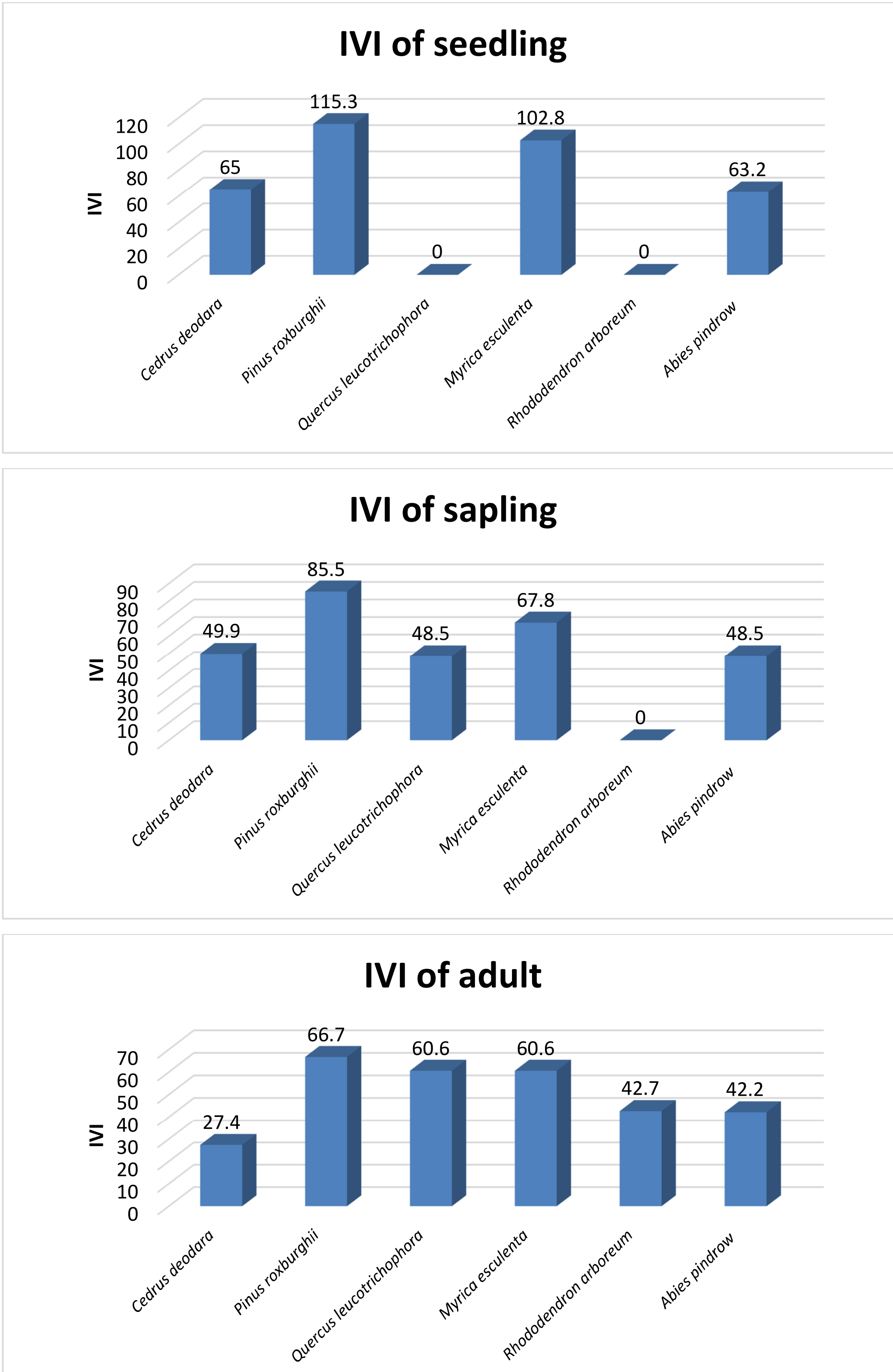
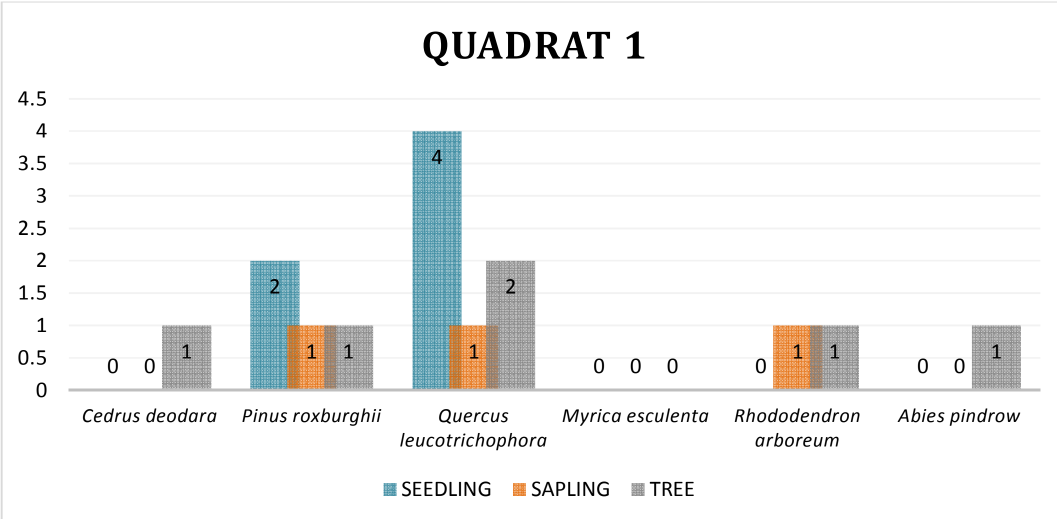
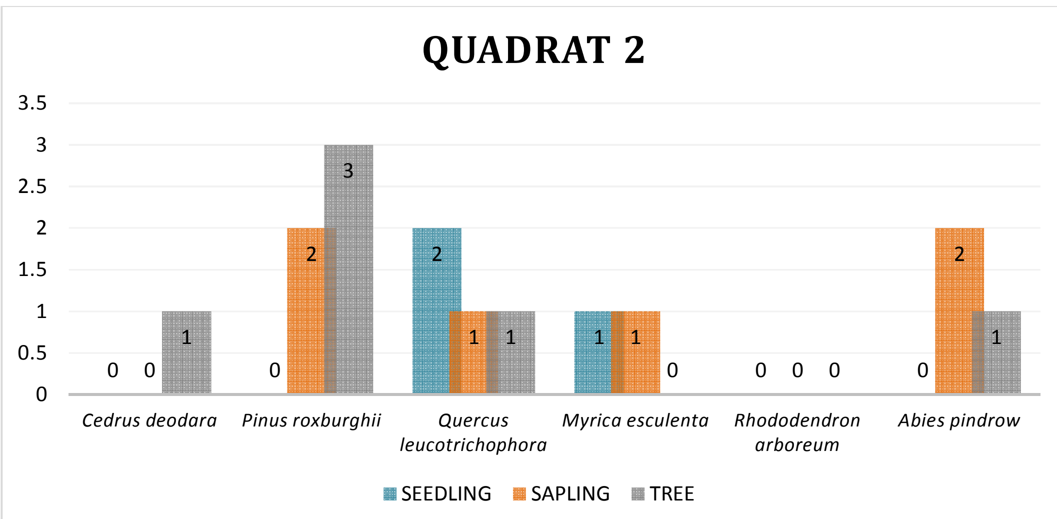


Figure 4.10: IVI of seedling, sapling and adults of tree species in Site II (Hill Slope)

4.1.2.3 Site III - Hill Base





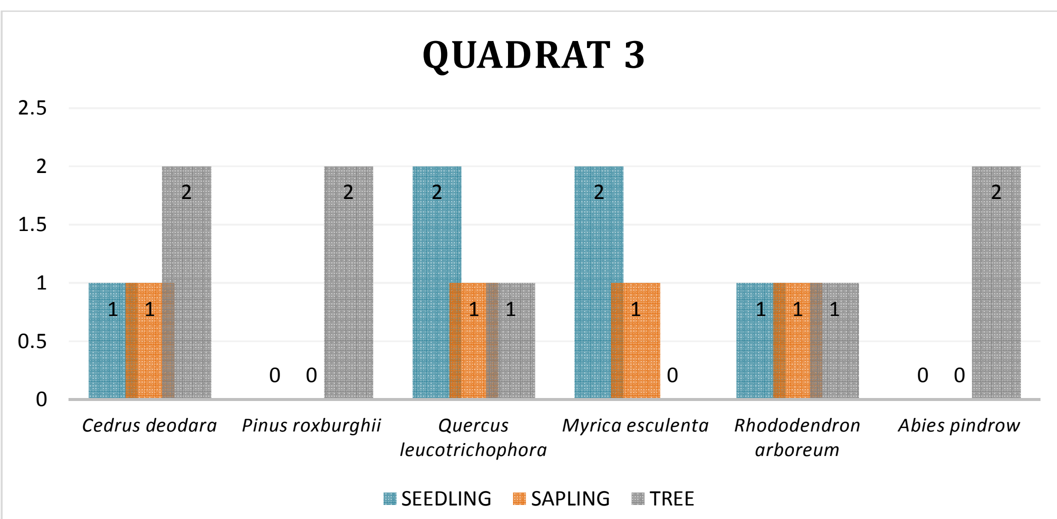


Figure 4.11: Tree species distribution (per 100 m²) in Site III (Hill Base)

Table 4.11: Frequency, density and abundance of tree species in Site III (Hill Base)

Species	Seedling			Sapling			Adult		
	Frequency (%)	Density (ind. per 100 m²)	Abundance	Frequency (%)	Density (ind. per 100 m²)	Abundance	Frequency (%)	Density (ind. per 100 m²)	Abundance
Cedrus deodara	33.3	0.33	1	33.3	0.33	1	100	1.33	1.33
Pinus roxburghii	33.3	0.67	2	66.7	1	1.5	100	2	2
Quercus leucotrichophora	100	2.67	2.67	100	1	1	100	1.33	1.33
Myrica esculenta	66.7	1	1.5	66.7	0.67	1	0	0	0
Rhododendron arboreum	66.7	0.33	1	66.7	0.67	1	66.7	0.67	1
Abies pindrow	0	0	0	33.3	0.67	2	100	1.33	1.33

In **Site III** (hill base) highest frequency of 100% for all seedling, sapling and adult zone was only recorded in *Quercus leucotrichophora*. *Rhododendron arboreum* possessed a frequency of 66.7% for all three zones while *Pinus roxburghii* displayed an increasing frequency of 33.3%, 66.7% and 100% from seedling to adults. All the species in adult zone exhibited 100% frequency except *Myrica esculenta* (0%) and *Rhododendron arboreum* (66.7%). *Abies pindrow* also exhibited zero frequency in seedlings.

In terms of density, highest number of individuals as seedlings and saplings i.e., 2.67 individuals per 100 m² and 1 individual per 100 m² respectively were witnessed in *Quercus leucotrichophora*. *Pinus roxburghii* possessed equally highest density in saplings i.e., 1 individual per 100 m² while in adults, highest density was of *Pinus roxburghii* with 2 individuals per 100 m².

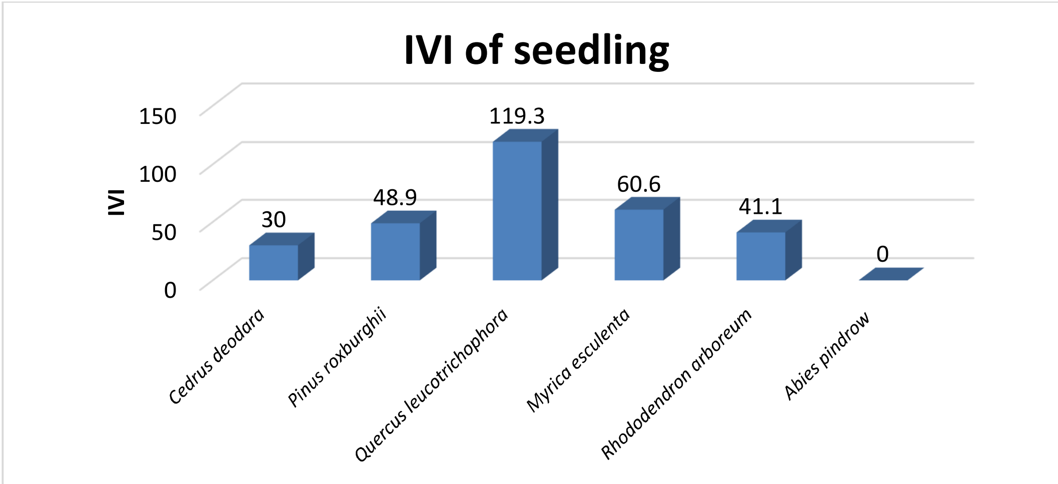
Abundance in seedlings was recorded highest in *Quercus leucotrichophora* of 2.67 individuals per 100 m². *Abies pindrow* and *Pinus roxburghii* exhibited the highest abundance in sapling and adult zone respectively with a count of 2 individuals per 100 m².

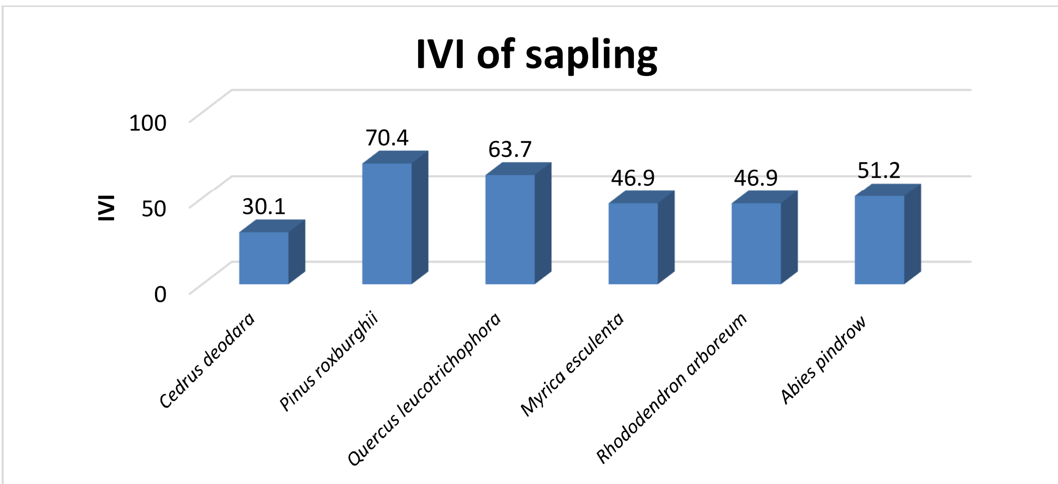
Table 4.12: Important Value Index of tree species in site III (Hill Base)

SPECIES	SEEDLING				SAPLING				ADULT			
	Relative Frequency	Relative Density	Relative Abundance	IVI	Relative Frequency	Relative Density	Relative Abundance	IVI	Relative Frequency	Relative Density	Relative Abundance	IVI
HILL BASE												
Cedrus deodara	11.1	6.7	12.2	30.0	9.1	7.7	13.3	30.1	21.4	20.0	19.0	60.4
Pinus roxburghii	11.1	13.3	24.5	48.9	27.3	23.1	20.0	**70.4**	21.4	30.0	28.6	**79.8**
Quercus leucotrichophora	33.3	53.3	32.7	**119.3**	27.3	23.1	13.3	63.7	21.4	20.0	19.0	60.4
Myrica esculenta	22.2	20.0	18.4	60.6	18.2	15.4	13.3	46.9	0	0	0	0
Rhododendron arboreum	22.2	6.7	12.2	41.1	18.2	15.4	13.3	46.9	14.3	10.0	14.3	38.6
Abies pindrow	0	0	0	0	9.1	15.4	26.7	51.2	21.4	20.0	19.0	60.4

In case of IVI, the highest value is 119.3 exhibited by *Quercus leucotrichophora* in the seedling zone. *Pinus roxburghii* displayed the dominance in sapling and adult zone with the highest IVI value of 70.4 and 79.8 respectively.

Abies pindrow (seedlings) and *Myrica esculenta* (adults) showed zero IVI count that is due to the absence of seedlings and adults of the particular species respectively. This can be due to over exploitation of forests by man in the name of increasing tourism, activities like trekking, camping, fire nights, picnics and other anthropogenic activities.





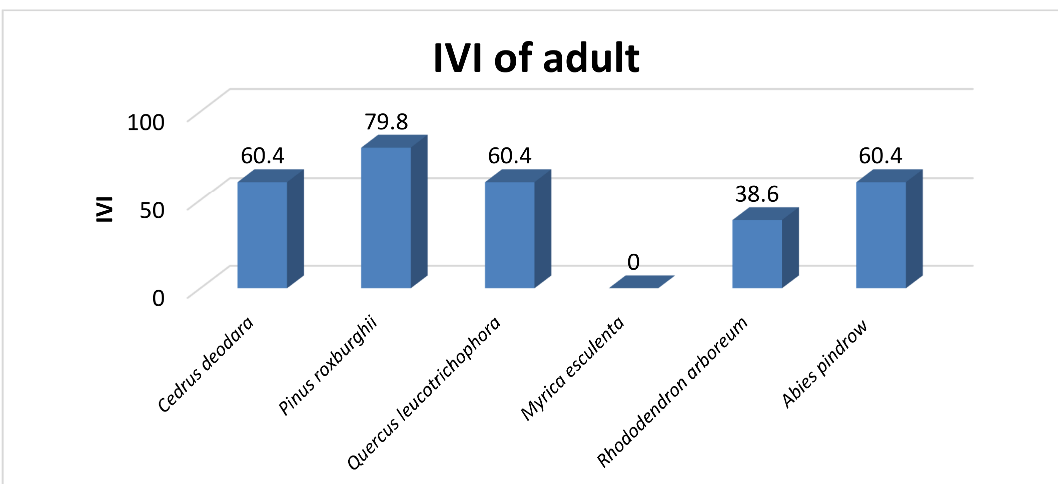


Figure 4.12: IVI of seedling, sapling and adults of tree species in Site III (Hill Base)

4.2 Measurement of biodiversity

The diversity index is a quantitative degree which reveals about how many discrete species of plants is present in the dataset and how uniformly the individuals of the species are distributed in the area.

Biodiversity values are used to demonstrate the community composition and arrangement or to concentrate on conservation policy decisions. The biodiversity value will depend not only on the habitat surveyed and the species assessed, but on the measurement used. There are many different indices of biodiversity. **(Kempton, 1979)**

Diversity indices are important statistical measure used to characterize richness (the number of species) and evenness (how uniform abundant species are in a sample) of the species in the community (**Magurran, 1988**) and is used as a tool for determining the health of an ecosystem.

4.2.1 Biodiversity in protected forest

The figure below demonstrates the distribution of seedlings, saplings and adults in three different altitudinal sites or zones.

The distribution of species among seedlings, saplings and adults in protected forest patch along the altitude was almost similar. In site I i.e., the **Hill Top**, the seedlings were estimated to have the highest diversity with diversity index (H`) of 0.96 that is 34% while the seedlings and adults shared equal proportion of 33% with diversity index of 0.94 and 0.95 respectively.

Similar to the site I, in site II i.e., the **Hill Slope**, saplings diversity was found the highest with 35% which had the diversity index of 0.99 which was trailed by adults with the value of 0.96 (34%). The seedlings in this zone showed minimum diversity index of just 0.88 which was 31%. In site III i.e., Hill Base, the seedlings and saplings shared equal percentage of diversity with 33% with almost equal diversity index of 0.91 and 0.90 respectively while the adults showed highest diversity index of 0.95 (34%). The reason for such similar sort of diversity in seedlings, saplings and adults of the various tree species is due to the negligible interference of humans in the forest ecosystem.

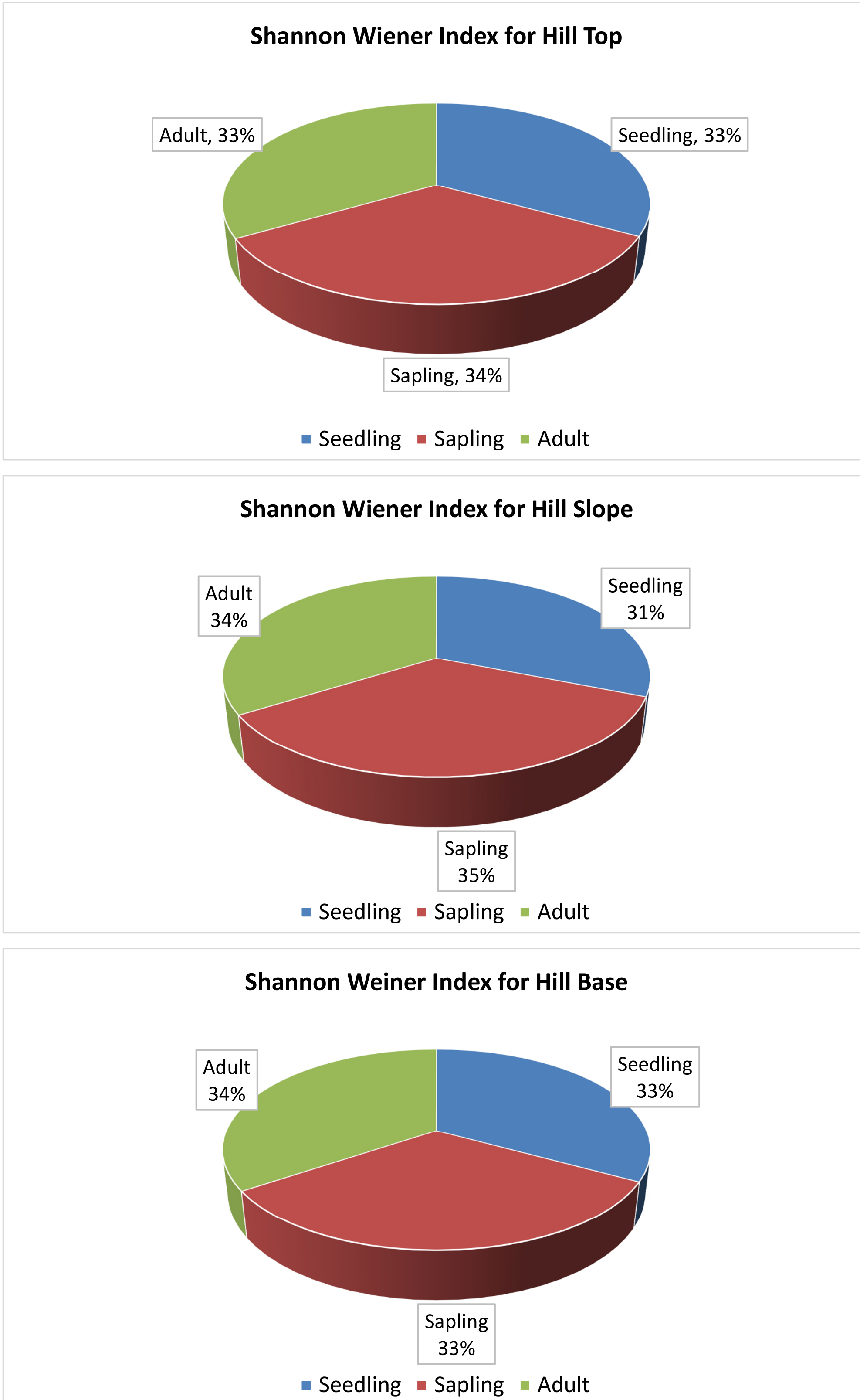
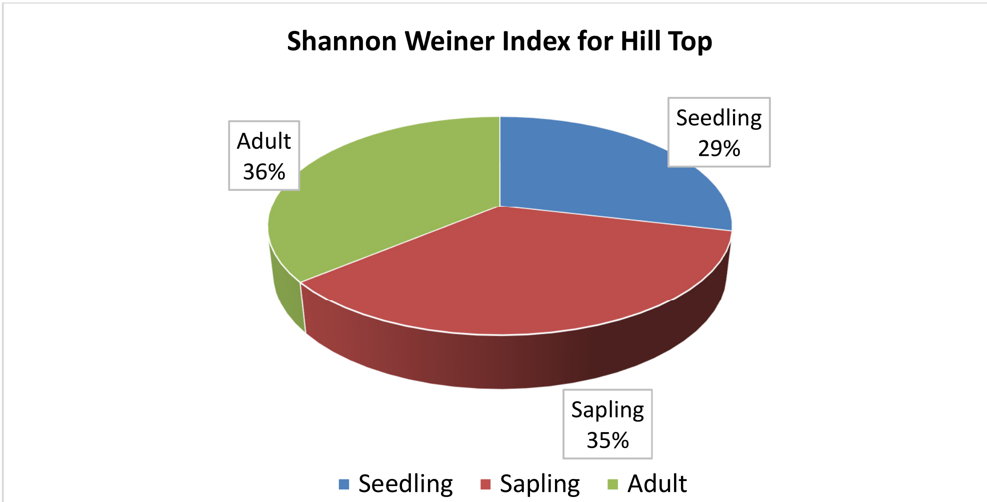
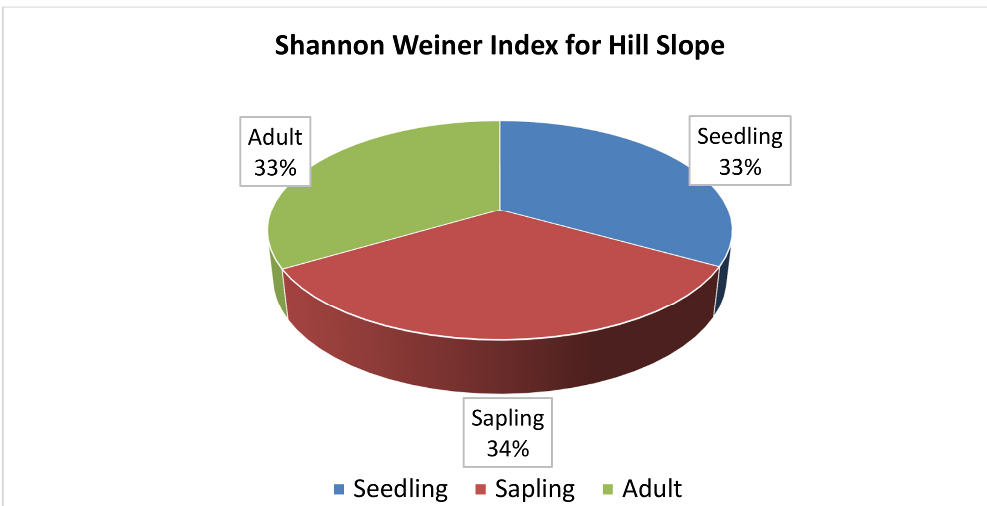


Figure 4.13: Shannon-Weiner Index for different study sites in protected forest

4.2.2 Biodiversity in disturbed forest





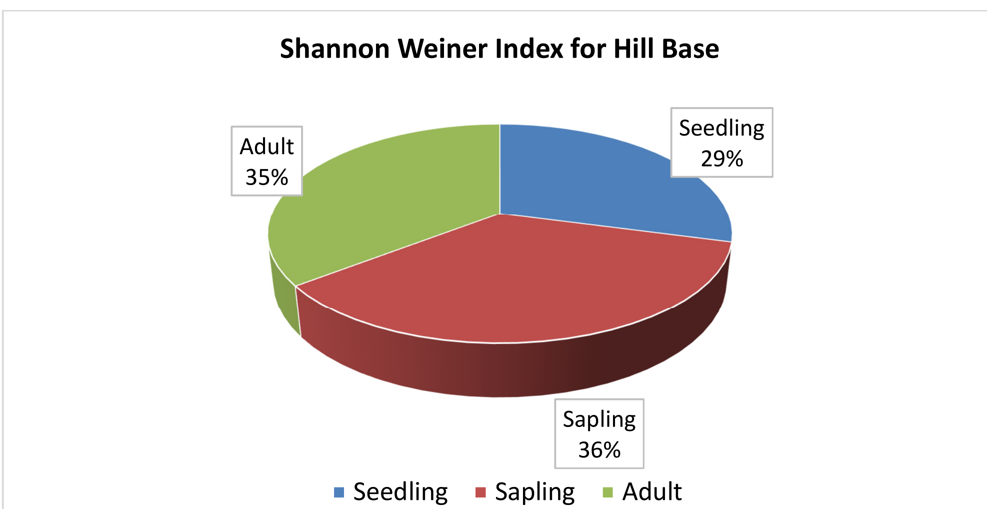


Figure 4.13: Shannon-Weiner Index for different study sites in disturbed forest

The distribution of saplings and adults along the altitude was quite similar in all three sites but the seedlings showed comparatively significant differences. In site I i.e., the **Hill Top**, the highest diversity was owned by the adults with the diversity index of 0.98 (36%) and the least diversity was exhibited by the seedlings with a value of just 0.78 (29%).

All the three growth stages of a tree species i.e., seedlings, saplings and adults displayed similar diversity with an index of 0.94 (33%), 0.95 (34%) and 0.94 (33%) respectively in **Hill Slope** (site II) while the seedlings in site III **(Hill Base)** a low diversity index of just 0.79 as compared to both saplings and seedlings with equal diversity index value of 0.96. This could be due to anthropogenic activities, over grazing, forest fire during summer, increasing tourism and their sports and activities like fire camping and trekking.

4.3 Regeneration status of forests

Regeneration status of any plant species offers us an idea about the growth, development and health of a forest. It reveals to us about how the plant or tree species are growing in an area, what are the human or natural disturbances that may cause harm to the species which may lead to the deterioration of not only a single specie nut the whole community or forest.

Regeneration of forest or any tree species can be estimated by the density (individuals per unit area) of seedlings, saplings and adults. The higher the number of individuals of seedlings as compared to saplings and adults, the better is the regeneration status of that species. In this section of the chapter, the regeneration status of protected and disturbed forests is discussed.

4.3.1 Regeneration in protected forest

The protected forest of Ranikhet is maintained by the Cantonment Board, Ranikhet which restricts the illegal trespassing of humans for any reason at all.

Regeneration was studied in three sites i.e., Hill Top (Site I), Hill Slope (Site II) and Hill Base (Site III). The species that were analysed were *Cedrus deodara*, *Pinus roxburghii*, *Quercus leucotrichophora, Myrica esculenta, Rhododendron arboreum* and *Abies pindrow*.

Table 4.13: Regeneration status of tree species in Hill Top (Site I)

Tree Species	Seedling (Ind. per hectare)	Sapling (Ind. per hectare)	Adult (Ind. per hectare)	Regeneration Status
Cedrus deodara	78	44	33	**GOOD**
Pinus roxburghii	89	56	100	FAIR
Quercus leucotrichophora	44	78	67	FAIR
Myrica esculenta	67	67	111	FAIR
Rhododendron arboreum	0	22	44	**POOR**
Abies pindrow	22	56	89	FAIR

In **site I** i.e., the Hill Top, *Cedrus deodara* showed good regeneration as the number of individuals of seedlings (78 individuals per hectare) was highest as compared to its saplings (44 individuals per hectare), while the density of saplings was still greater than adults (33 individuals per hectare). The good regeneration in *Cedrus deodara* might be due to good high altitude, cold humid climate and no large-scale human disturbances.

While all other species showed a fair regeneration condition, *Rhododendron arboreum* showed poor regeneration in the same site with no seedlings growing at all. The individuals per hectare counted for its saplings and adults were 22 and 44 respectively. The poor regeneration may be due to height, deep shades caused due to large tress that inhibit the seedlings to grow and proliferate and wild herbivores that feed on it.

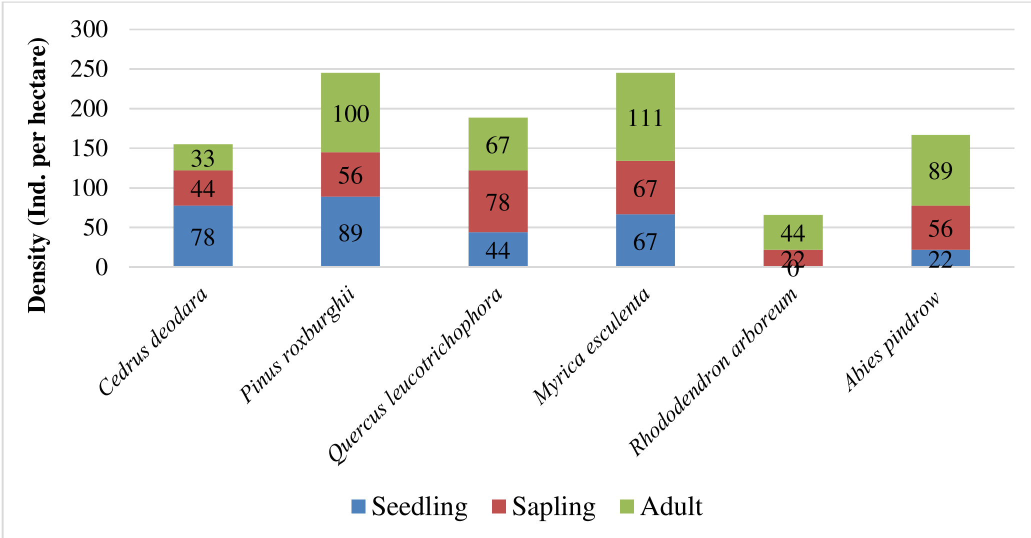


Figure 4.15: Regeneration status of tree species in Hill Top (Site I)

Table 4.14: Regeneration status of tree species in Hill Slope (Site II)

Tree Species	Seedling (Ind. per hectare)	Sapling (Ind. per hectare)	Adult (Ind. per hectare)	Regeneration Status
Cedrus deodara	22	56	56	FAIR
Pinus roxburghii	44	44	78	FAIR
Quercus leucotrichophora	0	56	56	**POOR**
Myrica esculenta	78	56	22	**GOOD**
Rhododendron arboreum	33	56	78	FAIR
Abies pindrow	11	67	56	FAIR

In **site II**, the Hill Slope, *Myrica esculenta* displayed a good regeneration level with high number of seedlings i.e., 78 individuals per hectare followed by saplings with 56 individuals per hectare and adults with 22 individuals per hectare.

As all the other tree species exhibited a fair regeneration status, *Quercus leucotrichophora* possessed poor regeneration with no seedlings and approximately equal density of 56 individuals per hectare in both saplings and adults. This may be due to wild animals feeding on the soft, young seedlings of the species or due to inappropriate weather condition.

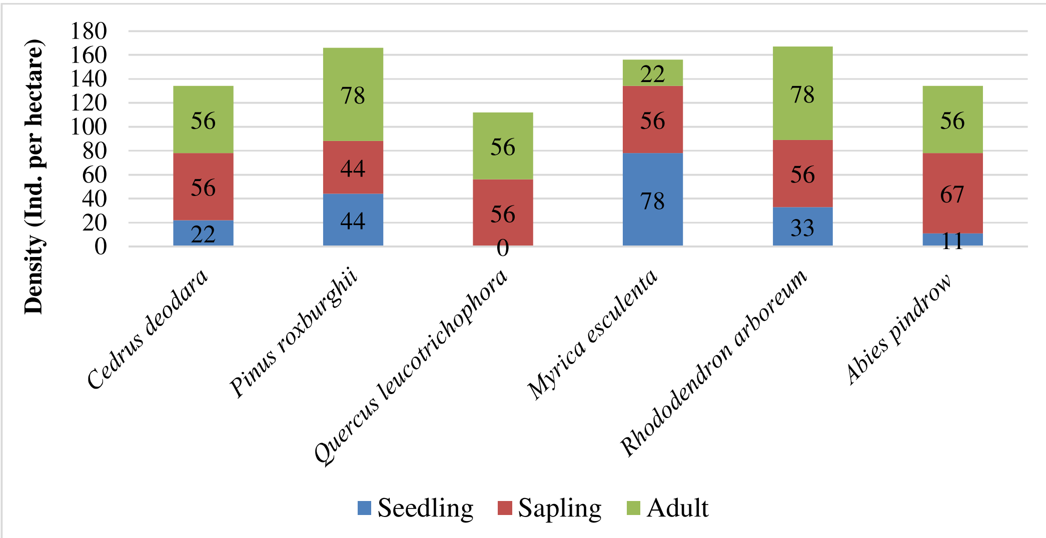


Figure 4.16: Regeneration status of tree species in Hill Slope (Site II)

Table 4.15: Regeneration status of tree species in Hill Base (Site III)

Tree Species	Seedling (Ind. per hectare)	Sapling (Ind. per hectare)	Adult (Ind. per hectare)	Regeneration Status
Cedrus deodara	33	11	0	**NEW**
Pinus roxburghii	122	78	78	FAIR
Quercus leucotrichophora	44	33	44	FAIR
Myrica esculenta	56	33	22	**GOOD**
Rhododendron arboreum	33	33	44	FAIR
Abies pindrow	0	0	67	**NO**

The **site III** i.e., the Hill Base showed quite different results of regeneration. *Cedrus deodara* showed new regeneration at the hill base with seedlings (33 individuals per hectare) and saplings (11 individuals per hectare) and no adults in count. This may be due to better climatic condition, cold humid weather low wind pressure and no disturbance by not only human but wild animals too.

Catching on to the same yet little different pattern, *Myrica esculenta* displayed a good regeneration grade with high number of seedlings (55 individuals per hectare) followed by 33 and 22 individuals of saplings and adults respectively. Unlike these two, *Abies pindrow* exhibited no regeneration at the hill base which may be due to low altitude, warmer conditions. It had no seedlings or saplings, only an adult density of 67 individuals per hectare. All other species showed fair regeneration in site Ⅲ.

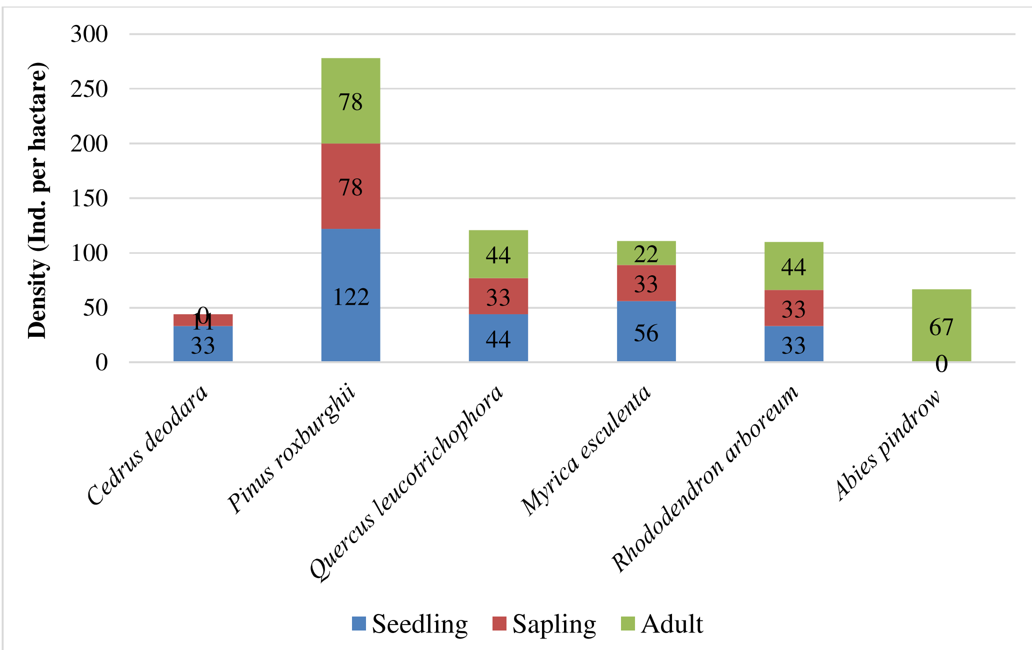


Figure 4.17: Regeneration status of tree species in Hill Base (Site III)

4.3.1 Regeneration in disturbed forest

The disturbed forest of Ranikhet is a very important source of raw materials like fire wood, fodder for domestic animals and other resources for man.

Similar to the prior study, regeneration was studied in three sites i.e., Hill Top (Site I), Hill Slope (Site II) and Hill Base (Site III). The species that were analyzed were *Cedrus deodara, Pinus roxburghii, Quercus leucotrichophora, Myrica esculenta, Rhododendron arboreum* and *Abies pindrow*.

Table 4.16: Regeneration status of tree species in Hill Top (Site I)

Tree Species	Seedling (Ind. per hectare)	Sapling (Ind. per hectare)	Adult (Ind. per hectare)	Regeneration Status
Cedrus deodara	44	44	44	FAIR
Pinus roxburghii	178	100	89	**GOOD**
Quercus leucotrichophora	33	56	56	FAIR
Myrica esculenta	33	56	78	FAIR
Rhododendron arboreum	0	33	67	**POOR**
Abies pindrow	22	56	89	FAIR

The regeneration level of tree species in **site I** i.e., Hill Top was fair for all the species other than *Pinus roxburghii* that displayed good regeneration with higher number of seedling density (178 individuals per hectare) in comparison to saplings and adults` density of 100 individuals per hectare and 89 individuals per hectare respectively. This may be because the pine trees need no utmost care and their seeds germinate easily. They have light seeds which are carried away with wind for pollination and germination at a new virgin place.

Rhododendron arboreum acquired poor regeneration with no seedlings and 33 and 67 individuals per hectare of saplings and adults respevtively. This may be due to greater altitude and higher and longer exposure to the sun.

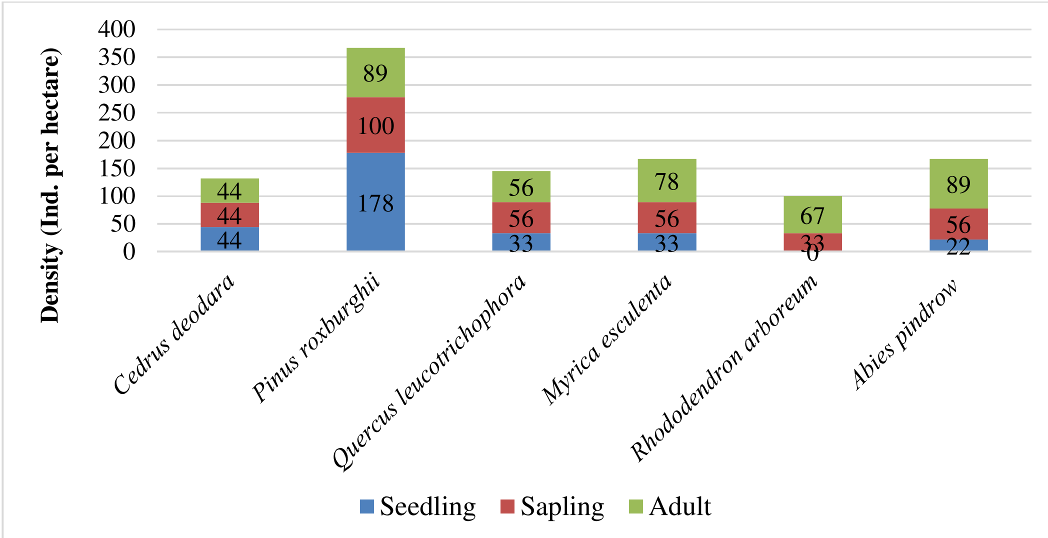


Figure 4.18: Regeneration status of tree species in Hill Top (Site I)

Table 4.17: Regeneration status of tree species in Hill Slope (Site II)

Tree Species	Seedling (Ind. per hectare)	Sapling (Ind. per hectare)	Adult (Ind. per hectare)	Regeneration Status
Cedrus deodara	33	33	22	FAIR
Pinus roxburghii	78	78	89	FAIR
Quercus leucotrichophora	0	33	78	**POOR**
Myrica esculenta	67	56	78	FAIR
Rhododendron arboreum	0	0	44	**NO**
Abies pindrow	33	33	44	FAIR

In **site II**, i.e., the Hill Slope, the fair type of regeneration was found to be the supreme regeneration in all the tree species. No tree species exhibited new or even good regeneration. Apart from this, *Quercus leucotrichophora* possessed a poor regeneration with no seedlings trailing to *Rhododendron arboreum* that depicted no regeneration at all with neither any seedlings nor saplings.

This condition of poor, just fair and no regeneration in this site may be due to higher disturbances. The site contains construction of roads, trespassing of humans with their animals and automobiles, tourists for jungle safari experiences and a lot more.

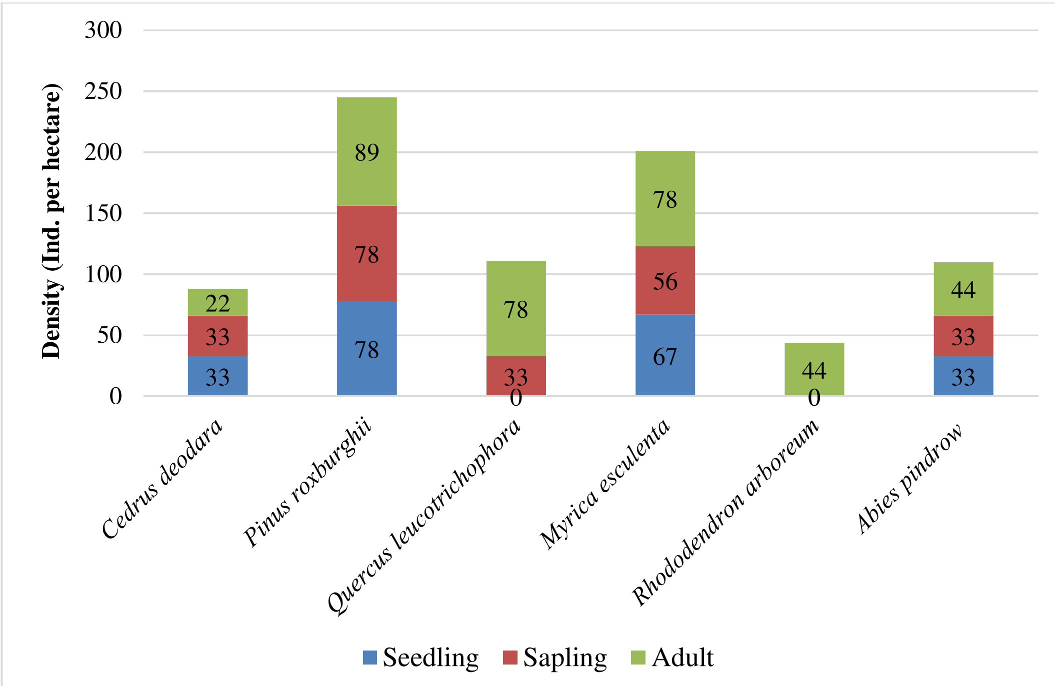


Figure 4.19: Regeneration status of tree species in Hill Slope (Site II)

Table 4.18: Regeneration status of tree species in Hill Base (Site III)

Tree Species	Seedling (Ind. per hectare)	Sapling (Ind. per hectare)	Adult (Ind. per hectare)	Regeneration Status
Cedrus deodara	11	11	44	FAIR
Pinus roxburghii	22	33	67	FAIR
Quercus leucotrichophora	89	33	44	FAIR
Myrica esculenta	33	22	0	**NEW**
Rhododendron arboreum	11	22	22	FAIR
Abies pindrow	0	22	44	**POOR**

In the last site that was the Hill Base (**site III**), only *Myrica esculenta* showed new regeneration with no adults and 33 individuals of seedlings and 22 individuals of saplings per hectare. While all other species demonstrated a fair type of regeneration, *Abies pindrow* displayed a poor regeneration with no seedlings and 22 saplings and 44 adults per hectare. This may be due to comparatively low altitude for the species to grow properly with less water and moisture, poor soil condition and warmer temperature.

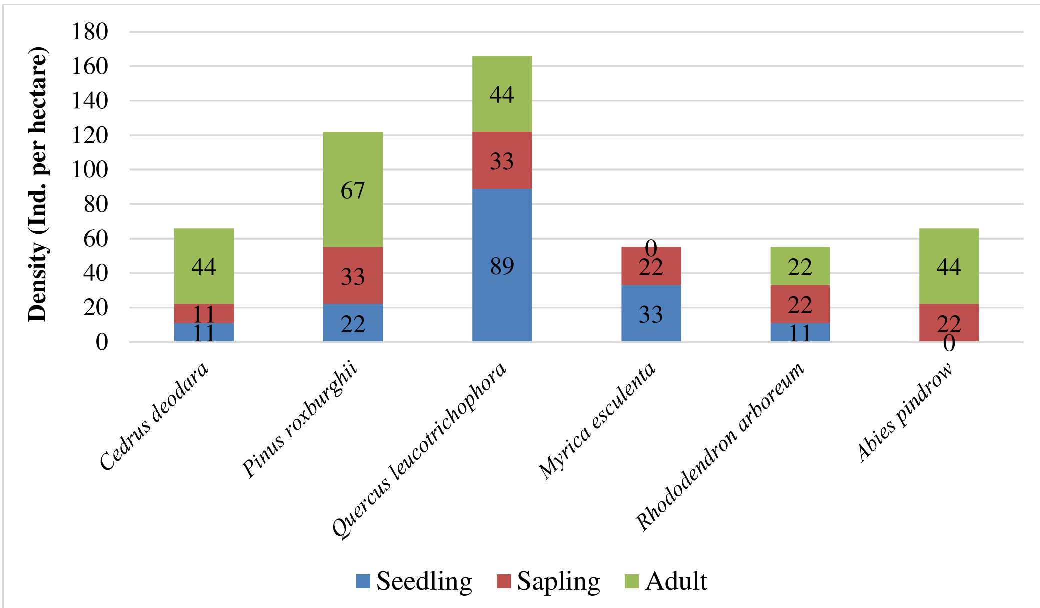


Figure 4.20: Regeneration status of tree species in Hill Base (Site III)

4.4 Forest Survey Analysis and Interpretation

The ecologically-sensitive state Uttarakhand is although endowed with rich flora and fauna but there is increase in pressure on its natural ecosystem from the past decades. The state ranks sixth in terms of recorded forest area in percentage and its forest cover with rich biodiversity is considered its major wealth. Ranikhet, which is the cantontment town located in the Almora district of Uttarakhand was our main study site which also holds an array of biodiversity. Most of the area in Ranikhet comes under the reserved forest area and is surrounded by Betalghat block towards south, Bhikiyasain block towards west, Dwarahat block towards north and Hawlbag block towards east. In order to determine various causes that influence species richness and distribution and affect their regeneration potential, a survey was being done with the local communities residing in this area. The main aim behind conducting this survey was to gather information related to major problems that led to the decline of the major forest species, to know the alteration in the plant life history, to examine the extent of dependence of local communities in the forest for the procurement of forest resources and also to know the forest department interventions towards protecting and conserving the forest. The survey was carried out by filling of the questionnaire comprised of three sections namely demographic information, assessing dependence on forest and forest related awareness by personally interacting with local people.

Through this survey, it was observed and identified that Forest fires are the most common and deadly cause for the loss of forest in this region. This massive forest fire during summer results in depletion of groundwater table also and causes severe water crisis in this hill area. This is because the fissures through which rainwater percolates have been blocked with ash as a result the groundwater does not get recharged. Moreover, due to rapid urbanization the number of oak trees in the Almora region has declined. It sounds more devastating when you are aware of the fact that the natural oak forest is alone responsible for retaining around 31% of rainwater. According to the locals, though any sort of procurement from the Cantt managed forest area is prohibited by the forest department but the procurement of fuelwood and fodder and cutting of trees for commercial purpose are being done secretly by the tribal or local communities residing in the forest. The government also finds it a bit difficult to manage the forest due to limited capacity of forest department and burgeoning human population around the protected areas.

In an attempt to balance the ecosystem and to reduce the effect of deforestation, time to time manual transplantation or afforestation is being done by the Forest department here. While, deforestation cannot be avoided completely, adapting practices such as clear cutting and selective cutting is also taken into account. To protect against the forest fire, the forest officials take precautions and implement necessary steps by making fire lanes, clearing out dry leaves of the trees and by also having the provision of employing firewatchers. For water conservation, locally evolved rain water harvesting technique such as Khal khampi is also practiced.

4.5 Statistical Analysis

ANOVA technique revealed that the differences in densities (number of individuals per 100 m^2) among the six species as well as the altitude (hill top, slope and base) in the protected forests were statistically non-significant.

While in the case of disturbed forest, the same two-way ANOVA technique revealed that the densities (number of individuals per 100 m^2) among the species and altitude were statistically significant.

Summary and Conclusions

SUMMARY AND CONCLUSION

Ranikhet is one of the most beautiful hill stations of Uttarakhand. Due to decent altitude of 1869 metres above sea level, suitable environment and appropriate weather conditions, Ranikhet enjoys a diverse forest cover. The forest is divided into disturbed and protected forest. The Cantonment Board of Ranikhet maintains the protected forest. The results examined by the above assessment for both protected and disturbed forests provide us an idea of the most dominant and most abundant tree species as well as their regeneration potential.

The study site was divided into three altitudinal zones i.e., hill top, hill slope and hill base. Each tree species was studied in context of their seedlings, saplings and adults. All the three zones showed difference in terms of various phytosociological attributes viz. density, frequency, abundance, IVI etc. The overall tree density in protected forest land varied between 444 ind. ha^{-1} (hill top) to 255 ind. ha^{-1} (hill base). The overall tree density in disturbed forest land varied between 423 ind. ha^{-1} (hill top) to 221 ind. ha^{-1} (hill base).

In protected forest, *Myrica esculenta* was found as dominant tree species with the highest IVI of 66.3 at hill top while *Pinus roxburghii* was dominant at hill slope and hill base with the highest IVI of 62.1 and 76.3 respectively. In the seedling layer, *Pinus roxburghii* was found dominant with highest IVI of 79.6 and 104.6 at hill top and hill base respectively while *Myrica esculenta* was dominant at hill slope with highest IVI of 101. In the sapling layer, *Quercus leucotricophora* was found dominant with IVI of 65.1 at hill top while *Abies pindrow* and *Pinus roxburghii* were found dominant with highest IVI of 57 and 102.4 at hill slope and hill base respectively.

In disturbed forest, *Abies pindrow* was found as dominant tree species with the highest IVI of 58.6 at hill top while *Pinus roxburghii* was dominant at hill slope and hill base with the highest IVI of 66.7 and 79.8 respectively. In the seedling layer, *Pinus roxburghii* was found dominant with highest IVI of 131.2 and 115.3 at hill top and hill slope respectively while *Quercus leucotricophora* was dominant at hill base with highest IVI of 119.3. In the sapling layer, *Pinus roxburghii* was found dominant at all the three sites with highest IVI of 78, 85.5 and 70.4 at hill top, hill slope and hill base respectively.

Cedrus deodara exhibited good regeneration at hill top of protected forest patch while *Rhododendron arboretum* had poor regeneration. At hill slope, *Myrica esculenta* and *Quercus leucotrichophora* possessed good and poor regeneration, respectively. *Cedrus deodara* was found as new in the hill base while *Myrica esculenta* and *Abies pindrow* showed good and no regeneration, respectively.

The good regeneration at the hill top of disturbed forest was observed in *Pinus roxburghii* while *Rhododendron arboretum* displayed poor regeneration. At hill slope, maximum four species were recorded with fair regeneration followed by *Quercus leucotrichophora* and *Rhododendron arboretum* having poor and no regeneration, respectively. Similarly, *Myrica esculenta* was found as new at the hill base while *Abies pindrow* showed poor regeneration.

The results raise concern as the regeneration of some species has been very poor. The reason is high disturbances caused by both nature and humans. Natural problems like landslides and soil runaway during monsoons also have an effect on forest cover. Several human activities like unlawful cutting down of trees for wood and fodder for animals, over exploitation of forest resource, illegal trespassing, increasing tourism and their activities like trekking, camping, jungle safaris have not only degraded the forest cover but also destroyed the natural habitats of various wild animals. This results in the migration of wild cats like leopards, tigers towards the town. The biggest challenge in today's time is the uncontrollable forest fire. The fire not only wipes out the small flora, herbs, shrubs and seedlings & saplings of trees but also destroy the adult trees.

The forest department has taken various initiative to conserve the floral richness of not only the protected forest but also to prevent the disturbed forests to get more deteriorated. The afforestation is practiced at different barren forest sites and the tradition of sustainable forest development is brought into existence in which the value of forest and its products is raised and improved. Its high time now and people need to get aware and educated, otherwise a time will come when the world will be jam-packed with concrete jungles only.

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Appendices

ANOVA: Two-Factor (Without Replication) for Protected Forest

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows(species)	251.3333	5	50.26667	2.29878	0.123028	3.325835
Columns (altitude)	76	2	38	1.737805	0.225039	4.102821
Error	218.6667	10	21.86667			
Total	546	17				

ANOVA: Two-Factor (Without Replication) for Disturbed Forest

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows (species)	452.2778	5	90.45556	4.101259	0.027553	3.325835
Columns (altitude)	200.1111	2	100.0556	4.536524	0.039619	4.102821
Error	220.5556	10	22.05556			
Total	872.9444	17				

VITA

The author was born on 17 February 1997 in Almora district of Uttarakhand. He successfully completed his High School in 2012 from Army Public School, Ranikhet, Almora, Uttarakhand with 9.0 CGPA (First class with Distinction) and Intermediate in 2014 from the same institution with 67% marks (First class). The author passed his B.Sc. Life Science degree in 2017, from Kumaun University, Nainital, Uttarakhand with 59.8% (Second class). Thereafter, the author joined the College of Post Graduate Studies in 2017 in Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, Uttarakhand, India, for the degree of M.Sc. in Environmental science.

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ABSTRACT

The present study was conducted in the forests of Ranikhet, a cantonment town in Almora district of Uttarakhand located at an altitude of 1,869 meters (6,132 ft) above mean sea level and within sight of western peak of Himalayas. The study area is located between 29.65^0 N and 79.42^0 E. The cantonment is spread across two ridges, the former one called the Ranikhet ridge that is situated at an elevation of 5,983 ft and later one is the Chaubatia ridge at an elevation of 6,942 ft. The purpose of the study was to understand the growth behavior of tree species in the Cantonment protected and disturbed forests of Ranikhet in terms of dominance, diversity, regeneration dynamics and biomass at different altitude levels. Plot design was used to analyse quantitatively and qualitatively the tree, sapling and seedling vegetation. The entire forest regime reflected a dominance of Pine *(Pinus roxburghii)*, Oak *(Quercus leucotrichophora)* and Deodar *(Cedrus deodara)* trees. Other trees are Kafal (*Myrica esculenta*), Buransh (*Rhododendron arboreum*) and sub-alpine fir (*Abies pindrow*). The overall tree density in protected forest varied from 444 trees ha^{-1} (at hill top) to 346 trees ha^{-1} (at hill slope) to 255 ind. ha^{-1} (at hill base) while in disturbed forest, it varied between 423 trees ha^{-1} (at hill top) to 355 trees ha^{-1} (at hill slope) to 221 trees ha^{-1} (at hill base). Variations in forest composition, structure and their regeneration status are also influenced by the climatic condition of this area. *Cedrus deodara* and *Myrica esculenta* exhibited good regeneration in protected forest while *Pinus roxburghii* was the only species having comparatively better regeneration in disturbed forest. The regeneration status was found comparatively good in the protected forest maintained by the cantonment board as compared to the disturbed forest as the anthropogenic activities such as fodder and fuel wood collection, frequent forest fire, overgrazing, activities like trekking, jungle safari, fire camping and rapidly growing tourism has resulted in poor regeneration of forest communities. The Forest Management department of Ranikhet has taken many initiatives to protect the forests. Afforestation and sustainable forest management is practiced. The study seeks to understand the current forest composition, regeneration potential and the dynamics of forest management in Ranikhet.

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शोध शीर्षक : ''उत्तराखण्ड के रानीखेत में स्थित संरक्षित तथा असंरक्षित वनों के पुनर्जनन अवस्था का मूल्यांकन''

सलाहकार : डा0 उमा मेलकानिया

सारांश

वर्तमान अध्ययन उत्तराखंड के अल्मोड़ा जिले में स्थित सैनिक छावनी परिषद, रानीखेत क वनों में संचालित किया गया। यह स्थान हिमालय के पश्चिमी शीर्ष की संकरी चोटी के अंदर समुद्र तल से 1869 मीटर (6132 फिट) की ऊँचाई पर स्थित है। प्रस्तुत अध्ययन क्षेत्र सैनिक छावनी के दोनों ओर 29.65^{o} उत्तर तथा 79.42^{o} पूर्व अक्षांश में फैला हुआ है। यह परिक्षेत्र दो भागों में बटा है, जो कि पूर्व में रानीखेत परिक्षेत्र कहा जाता है, जो 5983 फिट की ऊँचाई पर स्थित है, जबकि दूसरा परिक्षेत्र चौबटिया परिक्षेत्र कहलाता है, जो 6942 फिट की ऊँचाई पर स्थित है। इस अध्ययन का मूल उद्देश्य रानीखेत परिक्षेत्र में छावनी द्वारा संरक्षित तथा असंरक्षित क्षेत्र में विद्यमान वृक्षों की प्रजातियों के विकास, वर्चस्व, विविधता, पुनर्जनन, गतिशीलता और बायोमास के संदर्भ में विकास व्यवहार को समझना है। प्रस्तुत अध्ययन हेतु छोटे–छोटे से परिक्षेत्रों का प्रयोग करके वृक्षों के बीजों, पौधों तथा पादपों के प्रतिदर्श (नमूने) एकत्र कर उनके विकास, गुणवत्ता तथा परिमाणों का विश्लेषण किया गया। समूचा वन क्षेत्र विभिन्न प्रकार की प्रजातियों, जैसे– चीड़ (*Pinus roxburghii*), बाँज (*Quercus leucotrichophora*) तथा देवदार (*Cedrus deodra*) के वृक्षों से मिश्रित है। इसके अतिरिक्त अन्य दूसरे वृक्षों में काफल (*Myrica esculenta*), बुराँश (*Rhododendron arboreum*) तथा अल्पाइन देवदार (*Abies pindrow*) उपलब्ध हैं। संरक्षित जंगल में वृक्षों की सघनता पहाड़ी चोटी पर 444 वृक्ष प्रति हे0, पहाड़ी ढलान पर 346 वृक्ष प्रति हे0 तथा पहाड़ी आधार 255 वृक्ष प्रति हे0 पायी गयी, जबकि असंरक्षित जंगल में वृक्षों की सघनता पहाड़ी चोटी पर 423 वृक्ष प्रति हे0, पहाड़ी ढलान पर 355 वृक्ष प्रति हे0 तथा पहाड़ी आधार 221 वृक्ष प्रति हे0 पायी गयी। वनों में पाये गये वृक्षों की मात्रा, आकार तथा उनके पुनर्जनन पर उस क्षेत्र की जलवायु की वर्तमान स्थिति का भी प्रभाव पाया गया। संरक्षित वन क्षेत्रों में देवदार तथा काफल के वृक्षों के पुनर्जनन की अवस्था अच्छी पायी गयी, जबकि असंरक्षित वन क्षेत्रों में चीड़ के वृक्षों का पुनर्जनन अपेक्षाकृत बहुत अच्छा पाया गया। छावनी द्वारा अनुरक्षीत संरक्षित वन क्षेत्रों में वृक्ष समुदाय की पुनर्जनन अवस्था अच्छी पायी गयी परन्तु असंरक्षित वन क्षेत्रों में कुछ मानवजनित गतिविधियों, जैसे– पशु–चारा, ईधन हेतु लकड़ी एकत्रित करना, जंगलों में आग लगना, जानवरों द्वारा चरना व अन्य गतिविधियाँ, जैसे– ट्रेकिंग, जंगल सफारी, फायर कैम्प अभियान व द्रुत गति से बढ़ती हुई पर्यटन व्यवस्था के फलस्वरूप जंगलों के विनाश तथा जंगलों के कटान जैसे कार्यो की अधिकता के कारण वृक्ष समुदाय के पुनर्जनन, प्रकार्यो की स्थिति दयनीय पायी गयी। रानीखेत के वन व्यवस्थापक विभाग द्वारा जंगलों के संरक्षण हेतु अनेकों सराहनीय कदम उठाये गये हैं, जिसके अंतर्गत वृक्षारोपण, वृक्षों की समुचित देखभाल तथा उन्हें सुरक्षित रखने का भी कार्य किया जा रहा है। प्रस्तुत अध्ययन में रानीखेत के वनों की वर्तमान संरचना, पुनर्जनन क्षमता और वन प्रबन्धन की गतिशीलता को समझने का प्रयास किया गया है।

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