The present investigations entitled “Study on dynamics of plant bioresources in Chail wildlife sanctuary of Himachal Pradesh” was conducted during 2011-2014 in Chail Wildlife sanctuary, which falls in the Solan District of Himachal Pradesh. The general description of the site under investigation has been detailed under the following heads/sub-heads:

### 3.1 GENERAL DESCRIPTION OF THE STUDY AREA

The present study was carried out in Chail Wildlife Sanctuary in Himachal Pradesh. It lies in Kandaghat Sub-Division of Solan district and part of this also falls under the jurisdiction of Shimla Sub-Division of Shimla District. Total area of the sanctuary is 10,853.16 ha (108 sq km) having eleven beats. It is somewhat rectangular in shape and surrounded by Choma and Bhalwag of Shimla Forest Division in the North, Ashwani Khad between Kannola village and Nalla Janerghat in the North-west, Ashwani Khad in the South-west and Giri river its confluence at Gaura with Ashwani Khad in the South-east (Figure 2).

#### 3.1.1 Location and Extent

It is situated along 900 - 2,275 m between Latitude 30°53’36” to 31°00’42” N and Longitude 77°07’20” to 77°16’44” E. Formerly, it was the private game reserve of the Maharaja of Patiala. The sanctuary is known to have an exceptional variety of wildlife. The Sanctuary has, within its boundaries, Chail town and numerous villages, and is connected by a forest corridor to the Shimla Water Catchment Sanctuary (an IBA) in the north. It comprises part of the catchment area of a tributary of the Giri River. The forest cover of the Sanctuary includes Himalayan Subtropical Pine Forest, Ban Oak Forest and Moru Oak Forest, according to the forest classification by Champion and Seth (1968). The dominant forest tree is Ban Oak (*Quercus leucotrichophora*), mixed with Chir Pine (*Pinus roxburghii*) at lower altitudes. *Rhododendron arboreum* forms pure stands in places and Cedar (*Cedrus deodara*) and Blue Pine (*Pinus wallichiana*) have been planted in some areas. There is little mature forest, and much secondary growth due to disturbance.
(Gaston and Singh, 1980). Reference to the habitat map in Garson (1983) shows that the forest is largely confined to the northern half of the sanctuary (Singh et al., 1990).

Figure 2: Map of Study Area

3.1.2 Faunal Biodiversity

At least 139 bird species have been reported from the site (Naim Akhtar pers. comm. 2003), including five species of pheasants, i.e. Cheer (Catreus wallichii), Koklass (Pucrasia macrolopha), Kaleej (Lophura leucomelanos), Peafowl (Pavo cristatus) and Red Junglefowl (Gallus gallus). While Cheer Pheasant occurs only in grassland, Kaleej and Koklass occur in oak forest. In the late 1970s, Gaston and Singh (1980) and Gaston et al. (1981) estimated 40 to 60 pairs, while in March 1983, Garson (1983) estimated a minimum of 32 pairs. The Cheer Pheasant (Catreus wallichii) is categorized as ‘Vulnerable’ and White-rumped Vulture (Gyps bengalensis) is categorized ‘Critically Endangered’ according to the IUCN red list of threatened species.

3.1.3 Climate

The climate of Chail Wildlife Sanctuary is temperate to sub-tropical with cold winters; rainfall is received in monsoon. The rainfall pattern is typical
monsoon type with rainfall concentrated from July to September. During winters precipitation is in the form of snowfall that has reduced considerably over the years. Dry conditions occurs during April, May, and June just before the start of monsoons and in October and November which sometime results in fire hazard in the lower elevations of the sanctuary. The perennial streams are also affected during the dry periods. The study area is adjoining the Shimla city; the averages of temperature and rainfall for the years 2011-2014 recorded from IMD Shimla Station, is given in Annexure I to IV and Fig. 3-6.

The monthly mean minimum temperature was recorded 2.53°C (January, 2011), 0.82°C (February, 2012), 2.78°C (January, 2013) and 2.68°C (February, 2014), whereas the mean maximum temperature was 26.02°C (May, 2011), 28.20°C (June,
As far as precipitation is concerned, a total precipitation 1265.6 mm was recorded during the first year, out of which maximum 338.4 mm was recorded in the month of August. In the second year maximum precipitation (350.6 mm) was recorded in the month of July which ultimately leads to a total annual precipitation of 1232.4 mm. During the third year of study, total precipitation was 1446.9 during this year highest precipitation was recorded during June (319.6 mm). During fourth year the maximum precipitation was recorded in the month of July (561.5 mm) during this year total precipitation was 1624.8 mm.

3.1.4 Edaphic Factors

The parent material consists of shale, schist, slate and quartzite. The sanctuary is drained by a number of seasonal streams which eventually converge into perennial streams. The terrain of Chail Wildlife Sanctuary is moderate to steep and precipitous at places. All the streams of the sanctuary form the catchment of Ashwini Khad which ultimately drains into the Giri river, a tributary of river Yamuna.

3.2 METHODOLOGY

The detailed methodology adopted for the field survey, data collection and analysis of the information collected as per the requirements of the study has been elaborated under the followings headings:

3.2.1 FLORISTIC SURVEY

Reconnaissance survey was taken up initially to record and find out floristically rich as well as different types of vegetations was undertaken in the entire study area during first year of the study. Informal discussions on specific issue pertaining to the same were also held with concerned staff of the forest and wildlife departments and also with the local people as well. After building upon this informal and basic information, a detailed plan was developed for botanizing the area by regular field collection trips in special locations with rich floral wealth, covering microhabitats, various types of vegetations in different areas at different altitudes. Each area was visited at least three times i.e. during April to June to record the flora of spring and pre-monsoon, during July to September to enumerate the monsoon flora and during October to November to cover plants of autumn season. During survey, relevant details of the data pertaining to the
habitat, micro-habitat characteristics and phenological period of each of the species were collected. Photographs of the important plants in their natural habitats, some unique vegetation types were also taken as part of the documentation and presented in the thesis as coloured plates.

3.2.1.1 Collection of Specimens

Plant specimens were collected with flowers, fruits or both. The herbaceous plants were collected with underground parts to show their special character. In case of woody plants, the branches or twigs of suitable sizes were collected. The plant specimens as collected during the survey were numbered and labeled with field labels using field books and then placed in different polythene bags of sizes suitable for a particular species thereby avoiding mixing and spoiling of the specimens. These bags were then closed immediately with the rubber band to avoid excessive desiccation and wilting. For delicate and very small plant specimens, field press was used where these specimens were put in this press immediately after their collection. During field work, observations on habit, phenology, characteristic diagnostic features of the plant and associated plants species were recorded. Preliminary identification of the specimens was done with the help of available local floras.

3.2.1.2 Identification and Nomenclature

Plant specimens from field were identified by using the available local floras (Collett, 1902; Nair, 1976; Chowdhery and Wadhwa, 1984; Polunin and Stainton, 1984; Kaur and Sharma, 2004). Final identification of the plant specimens was done after consulting relevant literature. Identifications were confirmed by comparing the materials with authentic specimens’ sheets at the Herbarium of Himalayan Forest Research Institute, Shimla, FRI Herbarium Dehradun, Forest Survey of India Herbarium and the Herbarium of Botanical Survey of India, Northern Circle, Dehra Dun.

3.2.1.3 Presentation of Data

In the present work vascular plants like angiosperms and gymnosperms have been critically described with identification keys up to species level and arranged in a sequence of families.
3.2.1.4 Preparation of Keys

Dichotomous indented keys were provided for the families and under each family to the genera and genera to species level occurring in the study area. Prior to the identification of the families, some broader groups made, chiefly based on carpel features (number, fused, free carpels; ovules number and arrangement) supported with stamens, leaves and habit characteristics (Linnaeus, 1753; Bentham and Hooker, 1862-1883; Hutchinson, 1967, 1973; Cronquist, 1981; Takhtajan, 1980). Keys to the genera were based on various macroscopic features with different priorities of characters applicable to the plants included in the present flora only. A brief account was provided for each family, depicting the main family characters followed by brief information of the genera and species. In case of monotypic genera, since the description is based on a single species, has been avoided. The key to the families has been primarily designed to assist in the preliminary identification of the only the plants reported herein. Similarly, the key to the genera and species applies mostly to the plants included in the present study.

3.2.1.5 Arrangement of Families

Keeping in view arrangement of families in major Indian herbaria and important floras as published in the country, the Bentham and Hooker’s system of classification of angiosperms as given in Genera Plantarum (1862-1883) has been followed. However, deviations at the family level have been made in certain cases in which Hutchinson’s (1959) concept regarding splitting of families was followed without violating the superstructure of the said system. To the families of gymnosperms, the modern scheme of classification proposed by Melchior and Werdermann (1954) has been followed. Family names with author citation are followed as per Nomina Familiorum Conservanda of International Code of Botanical Nomenclature (ICBN). The name of the family is given along with author citation, common name of the family.

3.2.1.6 Plant Enumeration

The identified plant species have been arranged alphabetically. Description starts with botanical name of the plant given in bold italics. Description of the species includes habit and habitat followed with salient
vegetative and floral characters with each species general occurrence in various types of habitat.

3.2.2 PHYTOSOCIOLOGICAL STUDIES

The present study was carried out in 3 different altitudinal zones of Chail Wildlife Sanctuary in District Solan, Himachal Pradesh. The methodology employed for quantitative assessment of the plant species has been elaborated as below:

3.2.2.1 Selection of study sites

As the sanctuary lies between 900m-2275m amsl., the study area was divided into 3 different altitudinal zones i.e. Zone I: 900m-1400m; Zone II: 1400m to 1900m and Zone III: 1900m to 2275m amsl (Table 3.1). Sites were selected on each and every accessible aspect between 900m to 2275m amsl. The habitats were identified based on the physical characters and dominance of the vegetation. The sites facing high anthropogenic pressure were considered as degraded habitats and sites having closed canopy with high percent of humus and moisture were considered as moist habitat whereas low percent of the same as dry habitat.

<table>
<thead>
<tr>
<th>Zone</th>
<th>Altitude range (m)</th>
<th>Latitude</th>
<th>Longitude</th>
<th>No. of Plots (50m X 50m) laid within</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>900-1400</td>
<td>$30^\circ$ 53.651’ to $30^\circ$ 59.797’ N</td>
<td>$77^\circ$ 10.096’ to $77^\circ$ 12.406’ E</td>
<td>22</td>
</tr>
<tr>
<td>II</td>
<td>1400-1900</td>
<td>$30^\circ$ 54.867’ to $30^\circ$ 59.792’ N</td>
<td>$77^\circ$ 10.009’ to $77^\circ$ 13.106’ E</td>
<td>38</td>
</tr>
<tr>
<td>III</td>
<td>1900-2275</td>
<td>$30^\circ$ 57.128’ to $30^\circ$ 59.719’ N</td>
<td>$77^\circ$ 10.914 to $77^\circ$ 14.077’ E</td>
<td>42</td>
</tr>
</tbody>
</table>

The site having >50% boulders of the ground cover were considered as bouldery habitat. Latitudes, longitudes and altitude were measured with the help of Global Positioning System (GPS) and slope with the help of Abney’s Level.

3.2.2.2 Vegetation sampling

The field surveys were conducted during different seasons within the selected zones and habitats for the quantitative assessment of vegetation. In each zone, plots of 50x50m was laid. Trees were sampled by randomly laid 10, 10x10m quadrate; shrubs and sapling by 20, 5x5m quadrate and herbs and
seedling by 20, 1x1m quadrate. For the collection of data from these quadrats standard ecological methods (Saxena and Singh, 1982; Singh and Singh, 1992; Dhar et al., 1997; Joshi and Samant, 2004; and Samant and Joshi, 2004) were followed. The circumference at breast height (cbh at 1.37m from ground) for each tree individual was recorded. The individuals with (cbh ≥ 31.5 cm), were considered as trees, (cbh 10.5-31.4 cm) saplings and (cbh <10.5 cm) seedlings. Shrubs were considered as the woody species having several branches arising from their base (Osmaston, 1927; Saxena and Singh, 1982).

3.2.2.3 Quantitative analysis

For the ecological analysis of data Curtis and McIntosh (1950); Grieg-Smith (1957); Kersaw (1973); Mueller-Dombois and Ellenberge (1974); Singh and Singh (1992); Dhar et al. (1997); Samant et al. (2002a and b); Samant and Joshi (2004) and Joshi and Samant (2004) have been followed. Communities were identified based on the Importance Value Index (IVI). The IVI was calculated as sum of relative frequency, relative density and relative basal area. The abundance data of different sites were pooled to get community averages in terms of Density, Total Basal Area and IVIs.

**Density:** Density quantifies the strength of species in the community and therefore, considered as one of the prime important character in determining community structure.

\[
\text{Density} = \frac{\text{Total number of individuals of a species}}{\text{Total number of quadrat studied}}
\]

**Relative Density (RD):** This provides for numerical strength of a particular species in relation to total number of individuals of all species.

\[
\text{Relative Density (RD)} = \frac{\text{Number of individuals of the species}}{\text{Number of individuals of all species}} \times 100
\]

**Frequency:** Frequency of an individual species denotes its spatial pattern, importance as also the evenness of spatial distribution in community. For comparison of different vegetation units frequency is expressed in terms of various species in a community.
Frequency (%) = \( \frac{\text{Number of quadrats in which the species occur}}{\text{Number of quadrats studied}} \times 100 \)

Relative Frequency (%) = \( \frac{\text{Number of occurrences of a species}}{\text{Number of occurrences of all species}} \times 100 \)

**Basal Area/Dominance:** This is regarded as an index of dominance of a species. Higher basal area of a species indicates greater dominance. The average basal area and the relative basal area were calculated from the average diameter of the stem at breast height (diameter at breast height- DBH) for trees.

\[
\text{Basal area} = \pi r^2 \quad \text{where} \quad \pi = 3.1415; \ r = \text{radius}
\]

Relative Dominance (R Dom.) = \( \frac{\text{Total basal area of a species}}{\text{Total basal area of all species}} \times 100 \)

**Importance Value Index (IVI):** A total picture of the ecological status of a species with respect to a community structure can be obtained by summing up relative density, relative frequency and relative dominance as Importance Value Index (Curtis, 1959).

\[
\text{Importance Value Index (IVI)} = \text{Relative Density} + \text{Relative Frequency} + \text{Relative Dominance}
\]

**Abundance (A):** This is a measure of the number of individuals of a species in a community per quadrat in which it occurred. Species distribution and abundance can vary both temporally and spatially and may therefore, differ regionally in response to the species life history, habit characteristics, resource availability and as well as based on natural and anthropogenic disturbances.

\[
\text{Abundance (A)} = \frac{\text{Total number of individuals of the species}}{\text{Total number of quadrats of occurrence}}
\]
**Distribution pattern (A/F Ratio):** The Abundance to percentage frequency ratio (A/F) provides information about the nature of distribution of species. The ratio being less than 0.025 indicates regular, 0.025 to 0.050 random and above 0.050 is contiguous distribution pattern (Curtis and Cottam, 1956).

**Species Diversity:** Species diversity of trees, shrubs and herbs were determined with the Shannon-Wiener diversity index (Shannon and Wiener, 1963).

\[
H' = -\sum_{i=1}^{s} \frac{n_i}{N} \ln \frac{n_i}{N}
\]

Where, \( H' \) = Shannon-Wiener Diversity Index of species diversity; \( n_i \) = Importance value of a species and \( N \) = Total importance value of all the species

**Dominance Index:** This is calculated to evaluate the level of dominance of a species within a community. This is expressed by Simpson’s Index (1949).

\[
C = \sum_{i=1}^{s} \left( \frac{n_i}{N} \right)^2
\]

Where, \( C \) is Concentration of dominance; \( n_i \) = importance value of a species and \( N \) = Total importance value of all the species

**Species Evenness Index (E):** This is calculated as per Hill (1973).

\[
E = \frac{H'}{\ln S}
\]

Where, \( H' \) is the Shannon-Wiener diversity index and \( S \) is the total number of species in the community.

**Species Richness (S):** It is the total number of species in the community.

### 3.2.3 UNDERSTANDING THE DYNAMICS OF PLANT GENETIC RESOURCES

Addressing the current state of plant genetic resources, measure of the changes in the status of diversity over time and perspective of genetic vulnerability are important aspect to study the dynamics of plant bioresources (Brown and Hodgkin, 2015).
A total of 209 informants were interviewed during the study. Informants were classified between III different age groups i.e. Group – I was of 18-30 years, Group – II was 30-55 years and Group III was of 55 and above aged people to gain maximum information (Table 3.2). The data through semi-structured questionnaire, individual contacts and group discussion between different age groups was taken for the present stratus of plant genetic resources including crops wild relatives and landraces, existing cropping patterns in and around sanctuary and shift and loss of PGR was assessed spatially and temporally. Crops grown between May to October are categorized as *Kharif* Crops and crops grown between November to April are categorized as *Rabi* crops. The change in cropping patterns and genetic erosion was assessed over years, i.e. the current scenario (2014-2015) was compared to 1990, which was kept as base year because most significant changes in agricultural land-use started towards the end of 80s. The increase/decrease in area under different crops was calculated as \(N - \frac{N1}{N} \times 100\); where \(N\) is the area under particular crop in 1990; \(N1\) the area under same crop in 2014-215 (Ford-Lloyd *et al*., 2006 and Rana *et al*., 2010) and the checklist of plant genetic resources for food and agriculture (PGRFA) was prepared in terms of threats and vulnerability as per Brown, 2008 and Brown and Hodgkin, 2015.

**Genetic erosion:** It is the measure of a gradual disappearance of various forms of cultivated species and of its wild relatives over space and time. The assessment was made on the number of traditional crops and also in term of decrees in area under these crops (Ford-Lloyd *et al*., 2006).

(I) Genetic erosion at varietal level: It was calculated as

\[
\frac{\text{Traditional crops / varieties at present}}{\text{Traditional crops / varieties before ‘N’ number of years}} \times 100
\]

Here ‘N’ is considered as base year for calculating the genetic erosion i.e. 1990.
(II) **Genetic erosion at species level**: It was calculated as

\[
\text{Number of crops in an area at present} \times 100 \div \text{Number of crops in an area before ‘N’ number of years}
\]

Here ‘N’ is considered as base year for calculating the genetic erosion i.e. 1990.

### 3.2.4 ETHNOBOTANICAL STUDIES

The ethnobotanical study was conducted in 9 panchayats around the Chail wildlife sanctuary. The information regarding the usage of medicinal plants, wild edible, aromatic, timber, fuel wood, fodder etc. available in the study area was collected by using a questionnaire survey, semi-structured interviews and discussions with key informants. A range of ethnobotanical information including plant local names, uses, parts used, and mode of utilization were covered.

Ethnobotanical survey was conducted in 121 villages (Figure 7) in 9 panchayats within the sanctuary among 209 informants (Table 3.2). The interview was focused on basic questions concerning the informant’s knowledge of the uses of local plants. A typical question would be: which local plants do you know and/or use? To help assure that the information was unbiased as possible, efforts were made to avoid the presence of other people during the interviews.

**Table: 3.2: Indigenous people interviewed among different age groups within Chail Wildlife Sanctuary, Himachal Pradesh**

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Panchayats</th>
<th>Farmers Interviewed</th>
<th>Age groups (Years)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>18-30</td>
</tr>
<tr>
<td>1</td>
<td>Chail</td>
<td>16</td>
<td>7</td>
</tr>
<tr>
<td>2</td>
<td>Sakori</td>
<td>23</td>
<td>14</td>
</tr>
<tr>
<td>3</td>
<td>Banjani</td>
<td>21</td>
<td>11</td>
</tr>
<tr>
<td>4</td>
<td>Jhajha</td>
<td>26</td>
<td>6</td>
</tr>
<tr>
<td>5</td>
<td>Nagali</td>
<td>25</td>
<td>8</td>
</tr>
<tr>
<td>6</td>
<td>Balog</td>
<td>30</td>
<td>16</td>
</tr>
<tr>
<td>7</td>
<td>Janedghat</td>
<td>19</td>
<td>9</td>
</tr>
<tr>
<td>8</td>
<td>Dhangil</td>
<td>27</td>
<td>15</td>
</tr>
<tr>
<td>9</td>
<td>Hinner</td>
<td>22</td>
<td>6</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>9</strong></td>
<td><strong>209</strong></td>
<td><strong>92</strong></td>
</tr>
</tbody>
</table>
Figure 7: Distribution of villages within Chail Wildlife Sanctuary