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(A) Density = \[
\frac{\text{Total number of individuals}}{\text{Total number of quadrats studied}}
\]

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

(C) Frequency (%) = \[
\frac{\text{Total number of quadrats of occurrence}}{\text{Total number of quadrats studied}} \times 100
\]

(D) Relative Frequency (RF) = \[
\frac{\text{Number of occurrence of a species}}{\text{Number of occurrence of all species}} \times 100
\]

(E) Abundance = \[
\frac{\text{Total number of individuals}}{\text{Number of quadrats of occurrence}}
\]

(F) A/F Ratio

The distribution pattern of different species was studied using the ratio of abundance to frequency (A/F) following (Curtis and Cotton, 1956). This ratio indicates regular (less than 0.025), random (0.025-0.05) and contagious (more than 0.05) distribution of species.

\[
A/F = \frac{\text{Abundance}}{\text{Frequency}}
\]

(G) Basal area: The basal area of tree/ shrub species was calculated by the following formula:

\[
\text{Basal area of species} = \frac{\text{Circumference at breast height (Cbh)}^2}{4 \pi}
\]

Total basal area = Basal area of a species x density per unit area
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Total basal area of single species

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

Importance value Index (IVI): The Importance value index (IVI) of trees was calculated by using the values of the relative frequency, relative density and relative basal area:

\[ \text{Importance value index (IVI)} = \text{RF} + \text{RD} + \text{RBA} \]

Provenance value (PV) index: For herbs, the provenance value (PV) index was calculated by summing up the values of relative frequency and relative density:

\[ \text{Provenance value (PV)} = \text{RF} + \text{RD} \]

Species diversity (H'): Species diversity of trees in each forest site was calculated by using Shannon-Weiner information index (Shannon and Weiner, 1963).

\[ H' = -\sum_{i=1}^{S} \left( \frac{N_i}{N} \right) \log_2 \left( \frac{N_i}{N} \right) \]

Where \( N_i \) = Total number of individual species, \( N \) = Total number of individuals of all species.

Concentration of dominance (Cd): Concentration of dominance was measured by Simpson’s Index (Simpson 1949).

\[ Cd = \sum_i^S \left( \frac{N_i}{N} \right) \]

Where \( N_i \) is total number of individuals of a species and \( N \) is total number of individuals of all species.

2. Soil analysis

The soil characteristics i.e. physical and chemical were carried out for each forest/plantation site. The samples were collected by inserting the soil Corer at two depths i.e. 0-15, 15-30cm. Total six soil samples (02 from each depth) were collected randomly from each forest and agro forestry plantation. The collected soil samples were packed in gunny bags named with tags and brought to the laboratory for analysis. All the samples were brought separately to the laboratory in polythene bags.
for the analysis of physical and chemical properties. Physical examinations of the soil samples were determined according to Misra (1968), Lodhiyal (2000) and Lodhiyal et al. (2002). The following physical parameters were assessed:

2 (A) Physical properties of soil

(a) Soil moisture

The soil moisture content was determined by the following formula:

\[
\text{Moisture content (\%) = } \frac{\text{Fresh weight of soil} - \text{Dry weight of soil}}{\text{Dry weight of the soil}} \times 100
\]

Before taking the dry weight of soil samples, the fresh weight of soil was estimated. Thereafter, the soil samples were kept in oven at 60\(^\circ\)C for a constant weight (oven dry weight).

(b) Soil texture

The oven dry soil samples were sieved for estimation the soil texture. The soil texture such as sand, silt and clay was determined according to the particle size as given below:

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Name of soil texture</th>
<th>Size of soil particle</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Sand</td>
<td>0.02-0.20mm</td>
</tr>
<tr>
<td>2.</td>
<td>Silt</td>
<td>0.002-0.020mm</td>
</tr>
<tr>
<td>3.</td>
<td>Clay</td>
<td>less than 0.002mm</td>
</tr>
</tbody>
</table>


(c) Soil water holding capacity

The water holding capacity (WHC) of soil in each site was determined by Hilgard Cup method (Cassel and Neilson 1986). The following formula was used as given below:

\[
\text{WHC (\%)} = \frac{W_2 - W_3 - W_4}{W_3 - W_1} \times 100
\]
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Where,

\[ W_1 = \text{weight of box + filter paper} \]

\[ W_2 = \text{weight of box + filter paper + saturated soil} \]

\[ W_3 = \text{weight of box + filter paper + oven dried soil} \]

\[ W_4 = \text{water absorbed by filter paper} \]

(c) **Bulk density**

The bulk density of soil depends greatly on the mineral make up of soil and the degree of compaction. The density of quartz is around 2.65 g/cm³ but the (dry) bulk density of a mineral soil is normally about half that density, between 1.0 and 1.6 g/cm³. Soils high in organics and some friable clay may have a bulk density well below 1 g/cm³. Bulk density of soil is usually determined from a core sample which is taken by driving a metal corer into the soil at the desired depth and horizon. This gives a soil sample of known total volume. Soil bulk density was calculated by divided dry weight of soil sample by the volume of soil in corer:

\[
\text{Bulk density (g cm}^{-2}\text{)} = \frac{\text{Weight of oven dry soil (Mass)}}{\text{Volume of soil in soil corer (cm}^3\text{)}}
\]

Where mass was the oven dried weight (at 60°C) weight of soil and volume is the soil volume in soil corer.

(d) **Soil porosity**

Porosity or pore space is the amount of air space or void space between soil particles. Infiltration, groundwater movement, and storage occur in these void spaces. The porosity of soil or geologic materials is the ratio of the volume of pore space in a unit of material to the total volume of material.

Soil porosity was calculated by following formula:

\[
\text{Porosity (\%) =} \frac{(2.65 - \text{Bulk density})}{2.65} \times 100
\]

Where, particle density was 2.65 for each soil sample.
2 (B) Chemical properties of soil

The determining of soil chemical characteristic of each study forest site, the following parameter were studied i.e., soil pH, phosphorus, nitrogen, potassium, soil carbon, soil organic matter.

(a) Soil pH

The soil pH was determined by digital pH meter using 1:5 proportion of soil and distilled water.

(b) Nitrogen

Nitrogen content of the soil was estimates using the Kjel Auto Vs-KPT Nitrogen analyzer based on a micro-Kjeldahl technique Mishra (1968).

(c) Phosphorus

The phosphorus of soil was determined by Olsen et al (1954).

(c) Potassium

Potassium was extracted by neutral normal ammonium acetate method which was determined by using the flame photometer (Johnston, 1986).

(d) Organic carbon and organic matter

The total organic carbon was estimated by using the wet oxidation method (Jackson, 1958) and organic matter was obtained by multiplying the percentage of organic carbon by a factor of 1.724. This factor is based on upon the assumption that the organic matter of soil contains 58% carbon (Misra, 1968). Carbon stock in soil was calculated as follows (Joao Carlos et al., 2001).

Carbon stock of soil was determined by using the parameter such as soil depth, soil bulk density and carbon percentage of soil.

\[ \text{CS (carbon stock)} = \text{soil depth (d)} \times \text{bulk density (BD)} \times \text{carbon percentage in soil} \]

as followed by Singh and Singh (1992).

Soil organic matter (SOM) was measured by using the soil organic carbon and factor as given below- \[ \text{SOM} (%) = \text{SOC} (%) \times 1.724; \] where 1.724 is Van Bemmelen factor. The soil analysis were conducted at the district soil testing laboratory at Bhimtal (Nainital).
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3. Forest floor biomass

Forest floor biomass was collected by using quadrat methods of 1x1m size placed randomly in each forest once rainy, winter and summer season. Forest floor biomass components were categorized into (a) fresh leaf litter (b) partially and more decomposed litter (c) wood litter (including twigs, bark and branch) (d) miscellaneous litter consisting of inflorescence, flowers, fruits, other litter parts etc and (e) herbaceous litter following Rawat and Singh (1988), Chaturvedi and Singh (1987), Lodhiyal (1990), Lodhiyal et al. (1995a), Lodhiyal and Lodhiyal (1997a) and Lodhiyal and Lodhiyal (2003). In each quadrat all herbaceous standing shoots i.e. live and dead will be harvested at ground level (Green, 1959, Line, 1959, Lodhiyal, 2000, Lodhiyal and Lodhiyal, 2003). The collected material was taking to laboratory in polythene bag and after oven drying at the 60\(^0\)c to constant weight.

4. Litter fall

Litter fall was studied for one year period from November 2013 to November 2014. The litter fall was measured by 18 litter traps (3 litter traps each sub-plot) randomly placed in each studied natural forest and agroforestry plantation. Each trap was 1x1m with 15cm high wooden sides fitted with nylon net at the bottom. The samples were sorted out into leaf, wood reproductive parts and other components. The collected material was taking to laboratory in polythene bag and after oven drying at the 60\(^0\)c to constant weight estimates. The methodology will be followed as given by the Rawat and Singh (1983), Chaturvedi and Singh (1982), Lodhiyal et al. (2002) and Lodhiyal and Lodhiyal (2003).

5. Biomass and productivity

After selection of forest sites and agroforestry plantations, vegetation analysis of tree and shrub in each site was carried out. All the measured trees were divided into different diameter classes and in each diameter class three tree were also marked with yellow paint at breast height (1.37m) in order to assess diameter increment at annual interval in November, 2012. The mean girth GBH values for each species for a girth class were used in the regression equation get estimate of mean biomass. The regression equation was used in the form $y=a+b \ln x$, where $y=$dry weight of component (kg), $x=$GBH (cm), $a=$intercept, $b=$ slope or regression coefficient and
In=log natural. The estimation of biomass was carried out using the allometric equation for each tree component as developed by Rawat and Singh (1988), Chaturvedi and Singh (1987), Lodhiyal et al. (1992) and Bargali et al. (1991). Herb biomass was determined from ten, 1x1m quadrats once in September to October at the peak time of herbs. The harvested material was separate into aboveground and belowground components brought to the laboratory, oven dried and measured in dry weight. The marked trees were re-measured in November 2013 for their diameter increment. Thereafter, for each diameter class, the mean diameter increment was determined. For trees of mean diameter in different diameter classes were calculated separately from the Cbh measurement for 2012 (B1) and 2013 (B2). The net change of biomass (ΔB= B2-B1) yielded annual biomass accumulation. The sum of the ΔB values for different components yielded net biomass accretion in the trees.

6. Carbon stock and carbon sequestration

Carbon stock was determined by using the biomass value of species multiplied by factor (C= Biomass x 0.475) as given by (Magnussen and Reed, 2004; Singh and Lodhiyal, 2009; Lodhiyal, 2014; Kapkoti, 2016, Bhakuni, 2016). The total carbon was determined by summing up the respective values of each tree/shrub species occurred in each natural forest and agroforestry plantation. The carbon stock (C₁) is based on biomass in each forest/plantation was determined in 2013. After one year, the increment of carbon stock (C₂) was estimated by using the value of increased biomass in each stand/site. The net change in carbon stock (ΔC =C2-C1) yielded annual carbon accumulation. The sum of the carbon –values of different components i.e. bole, branch, twigs, foliage and roots yielded net carbon accretion in the trees and shrubs in each site.