REVIEW OF METHODS FOR VEGETATION AND SPECIES DIVERSITY ANALYSIS
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VEGETATION TYPE AND SPECIES COMPOSITION:

On the basis of preliminary reconnaissance three sites located in Hastinapur forest division were selected for analysis. One Hillock area and two plain forest sites (Block-1 and Block-2) near Pehli Nishia temple (Jain temple) were selected for study.

Sampling 30 randomly placed 10×10 m quadrats for Trees while for seedling, sapling, shrubs and herbs 60 randomly placed quadrats of each are studied carried out phytosociological analysis of tree vegetation. The size and number of quadrats were determined by Species Area Curve method (Mishra 1968), and the Running Mean Method (Kreshaw 1973). In each quadrat the tree layer was sampled by taking the circumference 1.37 M (circumference at breast height) with a measuring tape. Trees were considered to be individual with ≥ 31.5 cm Cbh (circumference at breast height) and 1.37m from ground, sapling with ≤ 31.5 cm Cbh and over 30 cm in height and seedling ≤ 30.0 cm in height. A shrub was phanerophyte which branched from the base of the stem (Muller-Dombois and Ellenberg 1974). The quadrats were laid down at plain and Hillock area.

Basal area refers to the ground actually penetrated by the stem and is readily seen when the leaves and stems are clipped at the ground surface (Hanson and Churill 1961). It is one of the chief characters determining the dominance and nature of the community (Rastogi 1999, Sharma 2003). The total basal area was expressed as cm² per 100 m². Basal area for the relative dominance was calculated as:

\[
\text{Mean basal area} = \frac{\text{Average diameter}}{2}
\]

Total basal area= Mean basal area × density
Relative basal area = \frac{\text{Total basal area}}{\text{Total basal area of all the species}} \times 100

**VEGETATION STUDY AND ANALYSIS:**

The analytical characters of plant community area were studied in terms of quantitative and qualitative structures. The data on vegetation were quantitatively analyzed for frequency, density and abundance (Curtis and McIntosh 1950).

**(a) Frequency:**

Frequency indicates the number of sampling units in which a given species occur, and thus express the dispersion or distribution of various species in community. In this no counting is involved just a record of presence or absences is made (Raunkiah 1934, Rastogi 1991, Sharma 2003).

\[
\text{Frequency (\%)} = \frac{\text{Number of quadrat with individual species}}{\text{Total number of quadrat studied}} \times 100
\]

After determining the percentage frequency of each species, various species are distributed among five frequency classes:

<table>
<thead>
<tr>
<th>Frequency (%)</th>
<th>Frequency class</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-20%</td>
<td>A</td>
</tr>
<tr>
<td>21-40%</td>
<td>B</td>
</tr>
<tr>
<td>41-60%</td>
<td>C</td>
</tr>
<tr>
<td>61-80%</td>
<td>D</td>
</tr>
<tr>
<td>81-100%</td>
<td>E</td>
</tr>
</tbody>
</table>

**(b) Density:**

Density denotes average number of individuals of a given species out of the total of samples examined in a study area however the species may or may not occur in all the quadrats (Oosting 1958, Rastogi 1999, Sharma 2003)
Density = \frac{\text{Total number of plants of individual species in all quadrats}}{\text{Total number of quadrat studied}}

(c) Abundance:

This is the number of individuals of any species per sampling units of occurrence. It is calculated as

\frac{\text{Total number of individual of a species}}{\text{Total number of individuals of all the species}}

Importance value index (IVI):

In order to express the dominance and ecological success of any species, with a single value, the concept of IVI has been developed as per Curtis and McIntosh (1950), Phillips (1959) and Mishra (1968). This index utilizes three characters viz. Relative frequency, Relative density, and Relative dominance or Basal area following Curtis (1959).

1. Relative Basal Area = \frac{\text{Total basal area of the species}}{\text{Total basal area of all the species}} \times 100

2. Relative Density = \frac{\text{Number of individuals of the species}}{\text{Number of individuals of all the species}} \times 100

3. Relative Frequency = \frac{\text{Number of occurrence of the species}}{\text{Number of occurrence of all the species}} \times 100

By adding above three values IVI were calculated. The spatial distribution of species in different forest sites has been derived from Whiteford index of A/F ratio (Whiteford 1949). The A/F ratio if below 0.025 indicates regular distribution, between 0.025 - 0.05 indicates random distribution and when \geq 0.05 indicates
contagious distribution (Curtis and Cottam 1956). Since the relation between frequency and abundance indicates the nature of species distribution. The distribution pattern of different species was studied using the ratio of A/F. Based on Chandrasekhar (1998) the tree species with GBH ≥ 10.0 cm to ≤ 30.0 cm were measured as sapling and species with ≤10.0 cm GBH were counted as seedling. As per Basha (1988) seedling were again classified into unestablished (Height below 40 cm), established (40-100 cm) and advance growth (above 100 cm height and below 10 cm GBH) to know the regeneration status of the forest community.

**Soil analysis:**

Soil samples from three different depth of soil profile i.e. surface (0-10 cm), middle (11-20 cm) and lower (21-30cm) were collected. Thus a total of 27 soil samples (3 replicates) from three different depths were analyzed for knowing soil properties.

The texture of soil was assessed following USDA (Anon 1975). The soil moisture percentage and water holding capacity was determined as per method described by Misra (1968). The reaction was assessed by a control dynamic digital PH meter, digital EC (Electrical Conductivity) meter. The organic carbon percentage was measured by the potassium dichromate reaction method and by subsequent Spectrophotometric measurement (Nelson and Sommers 1982), available nitrogen was determined by Alkaline Permagnat method as described by Subbiah and Ashiza (1956), available phosphorus by Phosphomolybdenum Blue Colorimetric method (Jackson 1967) and available potassium by flame Photometer after leaching soil with Sodium Bicarbonate (Jackson 1967).

**POPULATION STRUCTURE OF TREES:**

The diameter distribution of stem has often been utilized to study the stand structure or population structure of forest. Such studies help in distinguishing between early successional forest and mature forest and also
between even aged and varying aged stands (Goff and West 1975). The regeneration pattern of important tree species was determined for each girth class of individual species for each species in addition to seedling and sapling classes (Good and Good 1972) six more classes based on Cbh were arbitrarily established as following-

<table>
<thead>
<tr>
<th>Size class</th>
<th>Range in height/ Cbh</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seedling</td>
<td>(A) ≤ 30 cm in height</td>
</tr>
<tr>
<td>Sapling Cbh ≤ 31.5 cm</td>
<td>(B) ≥ 30 cm in height</td>
</tr>
<tr>
<td>Young tree</td>
<td>(C) 31.5 – 60.0 Cbh</td>
</tr>
<tr>
<td>Young trees</td>
<td>(D) 61.0-90.9 cm Cbh</td>
</tr>
<tr>
<td>Middle aged trees</td>
<td>(E) 91.0-120.0 cm Cbh</td>
</tr>
<tr>
<td>Middle aged trees</td>
<td>(F) 121.0-150.0 cm Cbh</td>
</tr>
<tr>
<td>Older trees</td>
<td>(G) 151.0- 180.0 Cbh</td>
</tr>
<tr>
<td>Older trees</td>
<td>(H) ≥ 180.0 cm Cbh</td>
</tr>
</tbody>
</table>

The number of individuals in each girth class for each species was divided by total number of individuals in all girth classes for that species. The resulting value was multiplied by 100 to yield percent density and plotted against corresponding girth class.

**SPECIES DIVERSITY AND RELATED PARAMETERS:**

Synthetic parameters of phytosociological studies like Dominance, Diversity, similarity Index etc. are very useful in comparison to two different communities. The species richness or with in habitat diversity (α diversity) was simply the number of species per unit area (Whittaker 1960, Pielou 1974, 1975). β diversity was calculated by formula given by Whittaker (1975).
BD = \frac{Sc}{S}

BD = Beta (\beta) diversity

Where Sc is the total number of species occurring in a set of samples counting each species only once, whether or not it occur more than once and S is average number of species per individual sample.

Species diversity index (H') determined using Shannon – Weiner Information index (Shannon – Weiner 1963) that is as follows-

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

Where N is total importance value for the species i and Ni is total importance value of the all the species in a stand. As the logarithm to the base two was used here the expression of diversity is in units of bits per individual.

Concentration of dominanace (Cd) was calculated by Simpson’s index (Simpson 1949).

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

Where, Ni and N were same as for Shannon – Weiner information index. It ranges from one. If all the individuals, belongs to one species (1 /S) if they are equally divided among the species (S). It is the inverse of diversity. Whittaker (1972) suggested that this index is appropriate for communities exhibiting strong dominance.
SPECIES RICHNESS INDEX OR VARITY INDEX (d).

At its simplest level diversity can be defined as the number of species found in a community, a measure known as species richness, indicating the mean number of species per sample (Margalef 1958) was calculated as:

\[
d = \frac{S}{\sqrt{N}}
\]

Where \( S \) = number of species.

\( N \) = number of individuals of all species.

**Evenness** was calculated following Pielou (1966), it is the relative distribution of individuals among the species present in a community.

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

Where \( H' \) = Shannon – Weiner diversity index.

\( S \) = number of individuals of all the species.

**Equitability (EC) or Species Index per log cycle** was calculated following Whittaker (1972) as:

\[
EC = \frac{S}{\log N_i - \log N_s}
\]

Where \( S \) = number of species in the site.

\( N_i \) and \( N_s \) are the diversity value of most and least important species respectively.

**Species heterogeneity** defined as the reciprocal of Simopson’s
Floristic Diversity Index (Simpson 1949) which is given as:

\[ D = 1 - \left[ \sum \left( \frac{n_i}{n} \right)^2 \right] \]

Where \( D \) = Biodiversity index.

\( n_i \) = number of individuals of in the species.

\( N \) = total number of all individuals.

THE NICHE CONCEPT:

The niche is multidimensional description of a species resource need, habitat requirement and environmental tolerances (Hutchinson 1957, Crawley 1997). The niche concept serve as a shorthand summary of species, complex suit of ecological attributes including its abiotic tolerance, its maximum relative growth rate, its Phenology, its susceptibilities to various enemies and its relative competitive abilities with other plant species.

NICHE SPACE PARTITIONING AND RESOURCE SHARING:

Species rich communities may be composed of (i) Species with narrow niches (ii) Species with more broadly overlapping niches (iii) Habitat providing 'longer' niche axis or (iv) A combination of these. **Dominance-Diversity curves** are drawn to ascertain resource apportionment by the components in the various sites for herbaceous species, wherein the IVI was used as an expressive measure of the niche or species/ resource apportionment. This is based on the assumption that there is some correspondence between the share of community resource and community space utilized by the species (Whittaker 1975, Pandey 2002). Degree of resource apportionment is considered a measure of resource conservation, Pandey (2002).

Pichi- Sermolli (1948) suggested an index for the establishment of the maturity in plant communities based on frequency percent of all species in the stand of a community. The principle is the long accepted notion that higher the
frequency percent of each species and smaller the number of sporadic species, the more mature is the community.

Adding the frequency percent of all the species in a site and dividing the sum of total number of species in the site obtain the index. The nearer to 100 the index of maturity is the more mature is the community.

ORDINATION:

Thirty quadrats of trees and 60 quadrats each of sapling, seedling and shrub were subjected to gradient analysis. The community coefficient or Indices of Similarity (IS) is also worked out (Sorenson 1948) for analysis of ordination, using the formula given below.

\[ IS = \frac{2C}{A+B} \]

Where C is the number of species common in two quadrats.
A = total number of species in one quadrat.
B = total number of species in other quaradrat.

The Community- Coefficient Values are categorized in to 5 classes as per the degree of similarity Class I (0 - 20%), Class II (21 - 40%), Class III (41 - 60%), Class IV (61 - 80%) and class V (81 - 100%). The distribution percentage of different IS classes for each locality are separately worked out.

Indices of Dissimilarity (ID) are worked out by using the formula given below.

\[ ID = 100 - IS. \]

These ID values are used for determining the spatial distance between different quadrats along an ordination axis, by the multi polar ordination technique (Bray and Curtis 1957, Whittaker 1973, Whittaker and Gauch 1973).
The indices of similarity and dissimilarity are transcribed in to a correlation matrix for the construction of first ordination axis (X-axis) by the formula:

\[
X = L^2 + \frac{(dA^2 - dB^2)}{2L}
\]

Where L is the length of the axis depicting the ID values between the most dissimilar quadrats (terminal quadrat) A and B. dA and dB depicting the minimum and maximum ID values of quadrat A and B respectively. All the quadrats are similarly ordinated along the X-axis; it is very likely that quadrat showing close similarity may be quite apart because of multidimensional floristic similarities (Muller-Dombois and Ellenberg 1974). The next step is to separate the stand in a second dimension by constructing Y-axis (Beals 1960). The terminal stand was selected as poorest fit on the X-axis, taking into consideration of the respective correlation and modification in the selection (Swan and Dix 1966, Newsome and Dix 1968). Such a poorly fitted stands would be one that share especially high ID values with terminal stands. The X-axis fit of each species is indicated by 'e'. The poorest fit could be noted from highest ex^2 value using the formula,

\[
ex^2 = dA^2 - x^2
\]

And the terminal stands were selected for Y axis ordination. The Y values thus obtained are also plotted to show the position of each stand.

A third dimension of the ordination axis, Z axis is worked out to study further segregation of quadrats (Beals 1960), here the terminal quadrats were selected from the poorest fit on the x axis and y axis using the formula given below.

\[
ez^2 = ex^2 + ey^2
\]

Where, ex^2 and ey^2 are the fitness value of x axis and y axis respectively. The Z axis values are tabulated and also plotted to show the position of each.

Since the ordination graph are a mere geometric approximation for showing
the dissimilarity value, it was also necessary to test the efficiency of these graphs by using standard indices with known probability distribution (Quenoquille 1950). This is done by comparing ID values between selected releve pairs with their ordination intervals (OI). The ordination intervals are calculated as:

\[
OI = \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2 + (z_1 - z_2)^2}
\]

Where \(x\), \(y\) and \(z\) are respective ordination values. The correlation coefficient, (Muller-Domboks and Ellenberg 1974).

\[
\begin{align*}
    r &= \frac{Sxy - (sx sy)}{n \sqrt{(sx^2 - (sx)^2/n) (sy^2 - (sy)^2/n)}} \\
    Sxy &= \sum (x - \bar{x})(y - \bar{y})
\end{align*}
\]

Where \(sx\), \(sy\) are summed values of the respective and \(n\) is the number of selected relevés, significance of \(r\) values were also tested by the formula given below (Moroney 1954).

\[
t = \frac{r \sqrt{n-2}}{\sqrt{1-r^2}}
\]

And \(t\) values again are compared with values in \(t\) table at 0.5% and 1% level of significance. ID values are plotted over the ordination interval in to a scatter diagram and to these data a straight line is fitted as \(Y = a + bx\) (Moroney 1954). Where \(x\) is ordination interval that corresponds, \('Y'\) is the ID values, \('a'\) is the point of intersection on \(Y\) axis and \('b'\) is the slope of the line.