Original Research Article

Assessment of Richness of Diversity between Various Species of vegetation type and their Threat status in Mukundpur Forest Area, Satna District, Madhya Pradesh, India

ABSTRACT: ***Mukundpur forest range is situated in Amarpatan Tahsil in Satna district of Madhya Pradesh India. The species of 58 trees, 28 shrubs, 08 lianas, 20 herbs and 19 grasses (total 133) had been found by using vegetation sampling. By evaluating IVI (Important Value Index) for the species of various vegetation types, the threat and conservation status was assessed by Normal Distribution Principle. The richness of species of study area was assessed by taking the two parameters i.e. number of species and their average IVI between various vegetation types and threat and conservation categories. The result of richness of diversity in numbers and their IVI for different vegetation types were expressed in terms of significant or non significant. The present study provided the procedure for designing species diversity in a forest area by developing various alternative strategies to assess the number of species and their IVI between various vegetation types with optimum species diversity and minimizing the threat parameters simultaneously.***

The optimal number species of 58 tree, 28 shrubs, 30 lianas, 20 herbs, 19 grasses (Total 155) and optimal average IVI between threat and conservation category 1 were assessed as 23.073, 19.284, 9.085, 25.321 and 10.067 within trees, shrubs, lianas, herbs and grasses respectively with total of 86.83 were assessed to make the significant diversity and at the same time maintaining the non significant status of threat and conservation status. The number of lianas species should be increased from 8 to 30 which lowered the average IVI of the species from 44.125 to the average value of 9.085.

Keywords: *Analysis of Variance, Frequency Class, IVI, Level of Significance, Normal Distribution Principle, Optimization Technique, Significant and Non Significant, Threat and Conservation Categories.*

1. INTRODUCTION

The study and analysis has been carried out with the purpose of conservation, propagation of diversity of vegetation with an innovative methodology employing modern statistical tool, for more meticulous and precise information on species diversity in terms of number and IVI with respect to different kinds of vegetation.

There are two popular diversity indices [1, 2]. These indices do not represent the species which are responsible threatening status in particular ecosystem. About 42% of world forests are dry forest [3] at global level. At national level, India accounts for 8% of the global biodiversity with only 2.4% of the total land area & the world [4, 5]. The tropical dry forests occupy 38% of the total forest area in India [6]. Tropical forests are often referred to as one of the most species diverse terrestrial ecosystems [7]. An Assessment of threatened plants of India has been made by [8]. Conservation and economic evaluation of biodiversity has been done by [9]. At regional level, threat assessment of Vindhyan region of Madhya Pradesh has been made by [10, 11, 12, 13, 14].

Mukundpur Range situated in Amarpatan Tahsil of Satna district in Madhya Pradesh, India. The first white Tiger safari is established at this village. The Mukundpur range is surrounded by mining areas of Bauxite and Limestone. The nearby located cement factories are always in search of new areas, besides exploiting existing known areas. Thus area is encountering impact of temperature rise, industrialization, desertification, shifting in the growing seasons of plants, loss of pollinators and seed dispersers, causing extinction of precious plants.

Looking towards the ecological stress in study area, the threat and conservation status between various vegetation types trees [15], shrubs [16], lianas [17], herbs [18] and grasses [19] had done in study area.

In the present work richness of plant diversity is assessed by the Analysis of Variance (ANOVA) between various species of vegetation types and their threat categories in terms of kinds of species and their IVI. This work also discusses the various alternative strategies to find the number of species between various vegetation types to make the species diversity optimum in the study area at the same time reducing the threat parameters which is providing a procedure for ecological modeling. This study will help in future research on the vegetation and allied conservation measures of various species with higher degree of precision and accuracy.

2. STUDY AREA:

Mukundpur region mainly comprises the present area of Mukundpur range of Satna forest division and lies between north latitude of $24^0$11'35" N to $24^0$26'25" N and longitude of $81^0$6'35" E to $81^0$22'20" E. The range has geographical area of 589.71 km^2 with forest area 111.55 km^2 as discussed by Singh, 2018. Northern boundary lies with Beehar River demarcating Satna and Rewa district. The forest of Mand reserve is situated in this area where first white tiger safari is established. Eastern boundary lies mainly with the district boundaries bifurcating Rewa and Satna districts. The famous Charaki ghati forms one of its boundaries. Southern boundary lies mainly with submerged area of Son River and it extends to district boundaries of Shahadol and Satna districts. The average annual rainfall in study area was noticed from 354.1 mm to 1748.4 mm with mean annual rainfall of 1074.26 mm. The area receives nearly 51 rainy days in year. South western mansoon plays the active role of precipitation in study area starting form middle of June month. The average highest daily temperature ranges within 24.06^0 C to 41.73^0 C with mean temperature of 32.24^0 C. The highest daily temperature recorded was 47.7^0 C Similarly the average lowest daily temperature was 8.85^0 C to 27.72^0 C with minimum daily temperature of 1.7^0 C.

3. MATERIAL AND METHOD:

For the assessment of biodiversity of Mukundpur region, the vegetation sampling was done for the trees, shrubs, herbs, lianas and grasses. Stratified systematic random sampling method was used for sampling for the vegetation Anon [26]. For determining minimum number of sample points, the formula used is $n = z^2 \frac{pq}{E^2}$ where E= difference between population proportion mean and sample proportion average, p = population proportion, q= 1- p, z=1.96 for a level of significance of 95% [21].

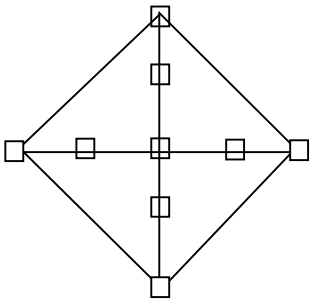
Based on the secondary data from Mukundpur range and Satna forest division, the sample size for various tree parameters i.e. number of trees per hectare, volume of trees per hectare and established regeneration per hectare was calculated at 10% error (E) between population and sample proportion at 95% level of significance keeping in view time and other resources [22].

Minimum 95 numbers of sample points were calculated from the above formula to assess the vegetation. The forest maps of Mukundpur range on survey of India topo sheet is

of the scale of 1:15000. The grids at 35"x 35" and 30"x30" intervals are drawn by trial and error, for systematic random sampling. The 111 and 151 random points were recorded on above grid. The 151 sample points at 30"x 30" were selected on safer side, so that points may fall in river bed, submergence and encroachments. The longitudes and latitudes of 151 points were noted from topo sheets and list of 151 points are prepared.

Each sample points were located on ground with the help of GPS.

Figure 1- sample plot with their Quadrat



sample plot area 0.16 or 0.1 ha

Quadrat of size 2 m x 2m, 9 in number

At each sample points, the layout of sample plot of 0.16 hectare with 9 quadrat of 2 ×2 m on ground as shown in **figure 1** was done with the help of prismatic compass Anon [20]. At these points recording of data of the girth and species of the trees, along with species of shrubs and lianas (numbers) were taken on whole sample plot of 0.16 hectare and data for species of herbs, grasses and established regeneration was recorded at each 9 quadrat of 2 ×2 m. The results were analyzed by developing a Microsoft access program to calculate the number, regeneration of trees per hectare and volume in m^3 per hectare by using local volume table, prepared for Satna forest division. The calculations for the density, frequency, basal area and IVI of the all species of trees have been done with same program [23]. The name and number of shrubs, lianas herb plants and established regeneration of plant species was also evaluated. For grasses, only the names of the species and their presence were recorded, in each quadrate. All the IVI for all the vegetation type species have been summarized in decreasing order and analyzed further to assess the conservation and protection status of species by using the NORMAL DISTRIBUTION PRINCIPLE [24] as represented in **figure 2**, normal distribution curve of IVI values. Principle is as under:

μ = mean of IVI of all species, σ= standard deviation of IVI,

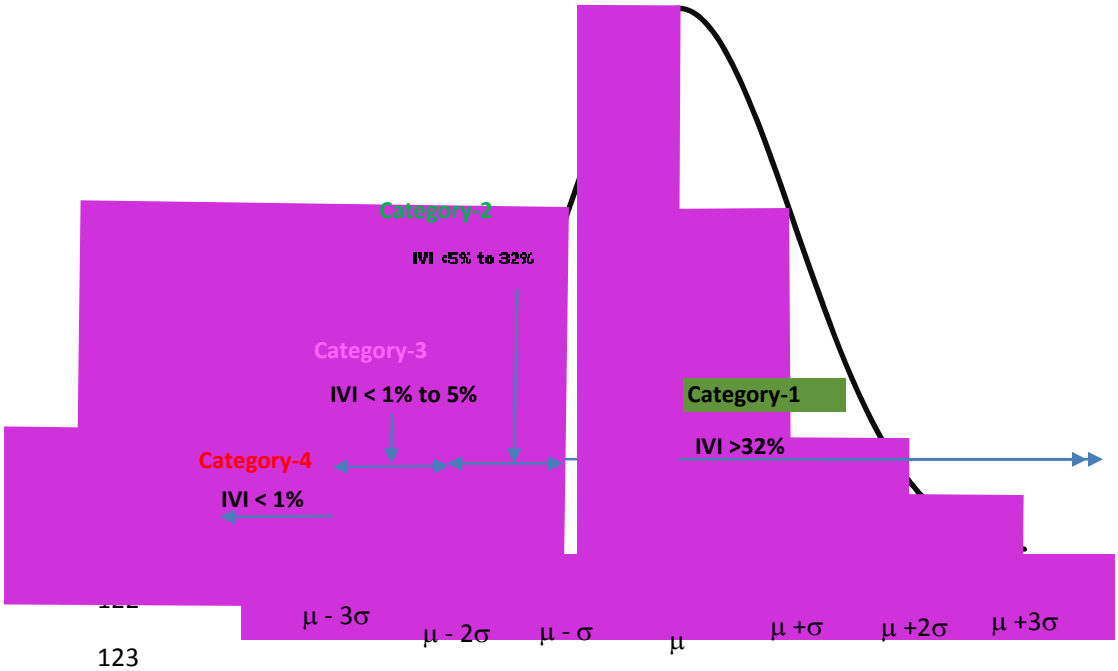
Then normal distribution principal states that there should be:-

(a) 68% of total number of species whose IVI is between $\mu + \sigma$and $\mu - \sigma$.

(b) 95% of the total number of species whose IVI is between $\mu + 1.96\sigma$ and $\mu - 1.96\sigma$.

(c) 99% of the total number of species whose IVI is between $\mu + 2.58\sigma$ and $\mu - 2.58\sigma$.

Figure 2- Normal distribution curve of IVI values



For safer evaluation for IVI, for conditions (b) and (c) $\mu - 2\sigma$ to $\mu + 2\sigma$and $\mu - 3\sigma$ to $\mu + 3\sigma$ have been calculated and used in further study. Now again here, μ is the population mean and is equivalent to sample average and $\sigma$is population standard deviation and here for sample it is replaced by $\sigma/\sqrt{n}$ i.e. standard error(SE).

Now, with the help of this principle [25], categorization is done as follows:

$IVI < \mu - 3\sigma$ (species having IVI less than 1%) - category 4.

$\mu - 3\sigma \leq IVI < \mu - 2\sigma$ (species having IVI between 1 to 5%) - category 3.

$\mu - 2\sigma \leq IVI < \mu - \sigma$ (species having IVI between 5 to 32%) - category 2.

$IVI \geq \mu - \sigma$ (species having IVI greater than 32%) - category 1.

The species in category 4 require highest degree of protection. The species in category 3 require lesser protection than category 4. The species in category 2 require lesser protection than category 3. The species in category 1 require least protection and are available in plenty and they are available for harvesting. The species wise results for trees [15], shrubs [16], lianas [17], herbs [18] and grasses [19] have been discussed for various threat and conservation categories for the study area.

After analyzing the above results have been tabulated between numbers of various species and their average IVI of different vegetation types and their number of species and average IVI for conservation and threat categories. After the tabulation the Null and alternate

hypothesis have been formulated at 5% level of significance for the variance of number of different species and variance of average IVI between various vegetation types and their threat and conservation categories.

The two way Analysis of Variance (ANOVA) has been done by using 'F statistics' at 5% level of significance. At 5% level of significance, the testing of hypothesis has been done by following decision rules:

1. If $F_{calculated} < F_{tabulated}$, Null hypothesis is not rejected. It means there is no significant difference in variance of number of species and average IVI between various vegetation types and between various threat and conservation categories.
2. If $F_{calculated} > F_{tabulated}$, Null hypothesis rejected. It means there is a significant difference in variance of number of species and average IVI between various vegetation types and between various threat and conservation categories.

After testing the significance, our objective is to optimize the variance in number and their average IVI of the species between various vegetation types and tries to reduce the same between various threat and conservation categories. The optimization technique is used to find out the number an average IVI of the species between various vegetation types (Trees, Shrubs, Lianas, Herbs and Grasses) by making the variance significant. The same technique is used to reduce the threat status between various threat and conservation categories by making the variance of number and average IVI of the species as non significant.

The optimization technique, [26] uses the iterative processes which consist of first designing a basic feasible solution and proceed towards OPTIMAL SOLUTION and testing the each feasible solution for optimality to know whether the solution on hand is optimal or not. If not an optimal, redesign the program and test for optimality until the test confirms the OPTIMALITY. The iterative steps are repeated until a finite optimal solution, if exists, is found.

4. RESULT AND DISCUSSION:

4.1 The results for the 58 species of trees, for various threat and conservation categories are as follows:-

1. Category 4 No species exists in this category.

2. Category 3 The species in this category are *Bridelia squamosa*, *Holoptelia integrifolia*, *Bombax ceiba*, *Bauhinia racemosa*, *Mitragyna parvifolia*, *Albizia procera*, *Sterculia urens*, *Carissa opaca*, *Ficus benghalensis*, *Solanum amricanum*, *Pterocarpus marsupiun*, *Dalbergia sissoo*, *Boswellia serrata*, *Ziziphus mauritiana*, *Ficus religiosa*, *Schleichera oleosa*, *Dendrocalamus strictus*, *Ficus benjamina, Annona squamosa*, *Acacia leucophloea*, *Grewia tilaefolia*, *Gardenia latifolia*, *Woodfordia fruticosa*, *Careya arborea*, *Lannea coromandalica*, *Semecarpus anacardium*, *Gardenia resinfera*, *Terminalia arjuna*, *Ixora arborea*, *Vitex negundo*, *Cordia macleodii*, *Acacia ferruginea, Kydia calycina* (33 species with average IVI of 0.531).

These species requires improvement in presence, density and basal area as a management strategy.

3. Category 2 The species in this category are *Miliusa tomentosa*, *Shorea robusta*, *Phyllanthus emblica*, *Azadirachta indica*, *Holarrhena pubescens*, *Ziziphus xylopyrus, Albizia odoratissima*, *Cassia fistula*, *Cassine glauca*, *Terminalia alata*, *Aegle marmelos*, *Feronia elephantum*, *Garuga pinnata*, *Terminalia bellirica* and O*ugeinia oojeinensis* (14 species with average IVI of 2.039).

4. Category 1 The species in this category are *Diospyros melanaxylon*, *Lagerstroemia parviflora*, *Tectona grandis*, *Butea monosperma*, *Anogeissus latifolia*, *Wrightia tinctoria*, *Ailanthus excelsa, Strychnos potatorum*, *Buchanania lanzan*, *Acacia catechu* and *Madhuca longifolia* (11 species with average IVI of 23.073).

4.2 The results for 28 species of shrubs, for various threat and conservation categories are as follows:-

1. **Category 4** No species exists in this category.
2. **Category 3** There are 11 species with average IVI of 0.557. These are *Grewia tilifolia*, *catunaregam spinosa*, *Nyctanthes arbor-tristis*, *Terminalia arjuna*, *Leucaena leucocephala*, *Bridelia squamosa*, *Anogeissus pendula*, *Jatropha curcas*, A*brus precatorius*, *Buchanania lanzan* and *Terminalia bellirica*.
3. **Category 2** The 8 species are observed with average IVI of 2.536. These species are *Aegle marmelos*, *Ziziphus xylopyrus, Ziziphus mauritiana*, *Cassia fistula*, *Artemisia vulgaris*, *Feronia elephantum*, *Miliusa tomentosa* and *Annona squamosa*.
4. **Category 1** The 9 species are observed with average IVI of 19.284. The species are *Lantana camara*, *Helicteres isora*, *Carissa opaca*, *Dendrocalamus strictus*, *Holarrhina pubescens, Woodfordia fruticosa*, *Chloroxylon swietenia*, *Alanium* spp, and *Solanum nigrum*.

Some of the species of trees are also appearing as a shrub in the results.

4.3 The results for 08 species of lianas, for various threat and conservation categories are as follows:-

1. **Category 4** There are 3 species with average IVI of 2.69 are under this category. They are *Bauhinia vahlii*, *Bauhinia purpurea* and *Butea superba*.
2. **Category 3** Only one species with average IVI of 15.5 is found in this category i.e. *Asparagus racemosus*.
3. **Category 2** No species are found in this category.
4. **Category 1** There are 4 species with average IVI of 44.125 in this category. These are *Hemidesmus indicus*, *Acacia donaldi*, *Clitoria ternatea* and *Cocculus hirsutus*.

4.4 The results for 20 species of herbs, for various threat and conservation categories are as follows:-

1. **Category 4** There are no species under this category.

2. **Category 3** There are 5 species with average IVI of 0.414 are classified under this category. These are *Mimosa pudica*, *Sida veronicaefolia*, *Sida cordifolia*, *Solanum virginianum* and *Rauvolfia serpentina*.
3. **Category 2** There are 8 species with average IVI of 2.583 are found in this category. These are *Cyperus rotundus*, V*igna trilobata*, *Tribulus terrestris*, *Coleus barbatus*, *Andrographis paniculata*, *Enicostemma littorale*, C*oix lacryma jobi* and *Gymnema sylvestre*. These species require more protection than category 1 species, though they have little threat to extinct.
4. **Category 1** There are 7 species with average IVI of 25.321 in this category. These species are *Ocimum basilicum*, C*onvolvulus microphyllus*, *Phyllanthus amarus*, *Aconitum chasmanthum*, *Eclipta alba*, *Borreria articularis* and *Bacopa monnieri*.

4.5 The results for 19 species of grasses for various threat and conservation categories are as follows:-

1. **Category 4** There are 6 species with average IVI of 0.12 under this category which require highest degree of protection. These species are *Dichanthium annulatum*, V*igna trilobata*, *Paspalidium punctatum*, *Peucedanum dhana*, Grewia hirsuta and *Ziziphus oenoplia*.
2. **Category 3** There are 3 species with average IVI of 1.75 in this category. These are *Setaria intermedia*, *Ipomea reniformis* and *Saccharum spontaneum*.
3. **Category 2** There are only one species with average IVI of 3.42 are found in this category i.e. *Eragrostis tenella*.
4. **Category 1** There are 9 species with average IVI of 10.067 in this category. These are *Heteropogon contortus*, *Cenchrus ciliaris*, *Euphorbia thymifolia*, *Aristida funiculata*, *Cynodon dactylon*, *Oxalis* spp, *Paspalum* spp, *Dichanthium annulatum* and *Cassia tora*.

4.6 The results for number of species in various vegetation types (R_1, R_2, R_3 R_4 and R_5) and their threat and conservation categories (C_1, C_2, C_3 and C_4)

From 4.1, 4.2, 4.3, 4.4 and 4.5 the number of various trees, shrubs, lianas, herbs and grasses with their threat and conservation status is presented in table 1.

Table 1:- Number of species in various vegetation types and their threat and conservation categories

Vegetation type	Threat and conservation category				
	category 1 (C_1)	category 2 (C_2)	category 3 (C_3)	category 4 (C_4)	Total
Trees (R_1)	11	14	33	0	58
Shrubs (R_2)	9	8	11	0	28
Lianas (R_3)	4	0	1	3	8
herbs (R_4)	7	8	5	0	20

Grasses (R_5)	9	1	3	6	19
Total	40	31	53	9	133 (Grand Total)

Correction Factor (CF) = 133^2 / 20 = 884.45

Total Sum of Squares = $11^2+9^2+4^2+7^2+9^2+14^2+8^2+0^2+8^2+1^2+33^2+11^2+1^2+5^2+3^2+0^2+0^2+3^2+0^2+6^2$ -- 884.45 = 1078.55

Sum of Squares between Conservation Categories = $C_1^2/5 + C_2^2/5 + C_3^2/5 + C_4^2/5$ -- 884.45

= 205.75

Sum of Squares between Vegetation Types = $R_1^2/4 + R_2^2/4 + R_3^2/4 + R_4^2/4 + R_5^2/4$ -- 884.45

= 358.80

For table 1 the following hypothesis at 5% level of significant is formulated:

A. Between conservation and threat categories:

1. **Null hypothesis (H_0)**: There is no significant difference in the variance of number of species.
2. **Alternate hypothesis (H_i):** There is significant difference in the variance of number of species.

B. Between various vegetation types:

1. **Null hypothesis (H_0)**: There is no significant difference in variance of number of species.
2. **Alternate hypothesis (H_i):** There is significant difference in variance of number of species.

The results of two ways analysis for table 1 is presented below in **table 2**:

Table 2 :- **ANOVA table for table 1**

Source of Variation	Sum of squares	Degree of freedom	Mean Sum of Square	$F_{calculated}$	$F_{tabulated}$ at 5% level of significance
Between conservation category	205.75	4 -1 = 3	68.583	1.601172	$F_{(3,12)} = 3.49$
Between vegetation type	358.8	5 - 1 = 4	89.7	2.09418	$F_{(4,12)} = 3.26$
Residuals	514	19 - 7 = 12	42.833		
Total	1078.55	20 - 1 = 19			

For variance of the number of species between conservation and threat categories $F_{calculated} < F_{tabulated}$, null hypothesis is accepted. It means there is no significant difference in variance of the number of species between threat and conservation category.

For variance of the number of species between various vegetation type $F_{calculated} < F_{tabulated}$, null hypothesis is accepted. It means there is no significant difference in variance of the number of species between various vegetation types.

The above result indicates that variance of the number of species between various vegetation types of trees, shrubs, lianas, herbs and grasses are not significant at 5% level of significance. The study area is poor in number of species between trees, shrubs, lianas, herbs and grasses. The number of species between threat and conservation category are also good in study area. The area is dominated by majority of tree species which are restricting the growth of shrubs, lianas, herbs, grasses and tubers. The species of *Lantana camara* and *Ocimun basilicum* are invading the study area. These species are appearing as weeds which are checking the growth of other species in the area. The various tree species are not converting into trees due to excessive invasion of *Lantana camara* as majority of species remaining in bushy form. The invasion of *Ocimun basilicum* as a weed, is limiting the growth of herbs and grass species.

In order to make the significant species diversity the $\mathbf{F_{calculated} > 3.26}$, say $\mathbf{F_{calculated} = 3.3}$. For making the significant diversity in number of species ANOVA **table 2** is redesigned by backward calculation for mean sum of squares and total sum of squares between various vegetation types and it is expressed in bold and small brackets and modified ANOVA table is presented in **table 3**.

Table 3 :- Modified ANOVA table for significant diversity in number of species

Source of Variation	Sum of squares	Degree of freedom	Mean Sum of Square	$F_{calculated}$	$F_{tabulated}$ at 5% level of significance
Between conservation category	205.75	4 -1 = 3	68.583	1.601172 (**2.68**)	$F_{(3,12)} = 3.49$
Between vegetation type	358.8 (**565.4**)	5 - 1 = 4	89.7 (**141.35**)	2.09418 (**3.3**)	$F_{(4,12)} = 3.26$
Residuals	514 (**307.4**)	19 - 7 = 12	42.833 (**25.62**)		
Total	1078.55	20 - 1 = 19			

Thus modified mean sum of squares = 42.833 * 3.3 = 141.35 and modified sum of squares between various vegetation types = 141.35 * 4 = 565.4 by maintaining the total sum of square same value = 1078.55 and correcting the value of residuals (1078.55&565.4 & 205.75=307.4). To check it for no significant variance in numbers between various threat and conservation categories, modified mean some of squares between residuals = 307.4/12 = 25.62. Then modified $\mathbf{F_{calculated}} = 2.68 < \mathbf{F_{tabulated}}$ **(3.49).** Hence both the objectives are satisfied by making the variance in number of species between threat and conservation

categories non significant as well as making the variance of number of species between various vegetation types significant.

Thus to make the variance of number of between various vegetation types to be significant the necessary and sufficient condition is,

Sum of squares between various vegetation type = 565.4

$$R_1^2/4 + R_2^2/4 + R_3^2/4 + R_4^2/4 + R_5^2/4 - 884.45 = 565.4$$

$$R_1^2 + R_2^2 + R_3^2 + R_4^2 + R_5^2 = 4*(565.4+884.45)$$

$$R_1^2 + R_2^2 + R_3^2 + R_4^2 + R_5^2 = 4* 1449.85 = 5799.4$$

To find out the number of species in each vegetation type we have developed the criteria by assuming the existing value of four categories and calculating the other one thus five criteria have been developed which are as follows:

Criteria 1:- R_1 is calculated assuming $R_2 = 28$, $R_3 = 8$, $R_4 = 20$, $R_5 = 19$

$$R_1^2 + 28^2 + 8^2 + 20^2 + 19^2 = 5799.4 \text{ or } R_1 = 64$$

Criteria 2:- R_2 is calculated assuming $R_1 = 58$, $R_3 = 8$, $R_4 = 20$, $R_5 = 19$

$$58^2 + R_2^2 + 8^2 + 20^2 + 19^2 = 5799.4 \text{ or } R_2 = 40$$

Criteria 3:- R_3 is calculated assuming $R_1 = 58$, $R_2 = 28$, $R_4 = 20$, $R_5 = 19$

$$58^2 + 28^2 + R_3^2 + 20^2 + 19^2 = 5799.4 \text{ or } R_3 = 30$$

Criteria 4:- R_4 is calculated assuming $R_1 = 58$, $R_2 = 28$, $R_3 = 8$, $R_5 = 19$

$$58^2 + 28^2 + 8^2 + R_4^2 + 19^2 = 5799.4 \text{ or } R_4 = 35$$

Criteria 5:- R_5 is calculated assuming $R_1 = 58$, $R_2 = 28$, $R_3 = 8$, $R_4 = 20$

$$58^2 + 28^2 + 8^2 + 20^2 + R_5^2 = 5799.4 \text{ or } R_5 = 35$$

Thus there are five alternative criteria's, which are expressed in **table 4**, are available to explain the number of species to be maintained the variance in number of species between various vegetation types to be significant as well as maintaining non significant status of variance in number between various threat and conservation categories.

Table 4 :- Various alternative criteria's for different vegetation types

Vegetation type	Number of species of vegetation types					Existing No. of species
	Criteria 1	Criteria 2	Criteria 3	Criteria 4	Criteria 5	
Trees	**64**	58	58	58	58	58
Shrubs	28	**40**	28	28	28	28
Lianas	8	8	**30**	8	8	8
herbs	20	20	20	**35**	20	20
Grasses	19	19	19	19	**35**	19
Total	139	145	**155**	148	149	133

Criteria 3 are the feasible solution for optimality as this gives the highest **total number of species of 155.** Thus 58 tree species, 28 shrubs, 30 lianas, 19 grass species (Total 155) are

required to make the significant diversity in number. Thus the 22 number of more lianas species are required to enrich the study area for significant variance in number of species as well as non significant status between threat and conservation categories.

4.7 The results for average IVI of species in various vegetation types (R_1, R_2, R_3, R_4 and R_5) and their threat and conservation categories (C_1, C_2, C_3 and C_4)

From 4.1, 4.2, 4.3, 4.4 and 4.5 the IVI of various trees, shrubs, lianas, herbs and grasses with their threat and conservation status is presented in table 5.

Table 5: - Average IVI of species in various vegetation types and their threat and conservation categories

Vegetation type	Threat and conservation category for Average IVI				
	category 1 (C_1)	category 2 (C_2)	category 3 (C_3)	category 4 (C_4)	Total
Trees (R_1)	23.073	2.039	0.531	0	25.643
Shrubs (R_2)	19.284	2.536	0.557	0	22.377
Lianas (R_3)	44.125	0	15.5	2.69	62.315
herbs (R_4)	25.321	2.583	0.414	0	28.318
Grasses (R_5)	10.067	3.42	1.75	0.12	15.357
Total	121.87	10.578	18.752	2.81	154.01

Correction Factor (CF) = 154.01^2 / 20 = 1185.95

Total Sum of Squares = 23.073^2+19.284^2+44.125^2+25.321^2+10.067^2+2.039^2+2.536^2+0^2+ 2.583^2+3.42^2+0.531^2+0.557^2+15.5^2+0.414^2+1.75^2+0^2+0^2+2.69^2+ 0^2+0.12^2--1185.95 = 2688.083

Sum of Squares between Conservation Categories = $C_1^2/5 + C_2^2/5 + C_3^2/5 + C_4^2/5$ -- 1185.95

= 1878.795

Sum of Squares between Vegetation Types = $R_1^2/4 + R_2^2/4 + R_3^2/4 + R_4^2/4 + R_5^2/4$ -- 1185.95

= 333.85

For table 2 the following hypothesis at 5% level of significant is formulated:

A. Between conservation and threat categories:

1. **Null hypothesis (H_0)**: There is no significant difference in variance of the average IVI of the species.
2. **Alternate hypothesis (H_i):** There is significant difference in variance of the average IVI of the species.

B. Between vegetation types:

1. **Null hypothesis (H_0)**: There is no significant difference in variance of the average IVI of the species.
2. **Alternate hypothesis (H_i):** There is significant difference in variance of the average IVI of the species.

The results of two ways analysis is presented below in **table 6**:

Table 6 :- ANOVA for table 5

Source of Variation	Sum of squares	Degree of freedom	Mean Sum of Square	$F_{calculated}$	$F_{tabulated}$ at 5% level of significance
Between conservation category	1878.795	4 -1 = 3	626.265	15.807	$F_{(3,12)} = 3.49$
Between vegetation type	333.85	5 - 1 = 4	83.463	2.107	$F_{(4,12)} = 3.26$
Residuals	475.438	19 - 7 = 12	39.620		
Total	2688.083	20 - 1 = 19			

For variance of the average IVI of species between conservation and threat categories $F_{calculated} > F_{tabulated}$, null hypothesis is rejected. It means there is a significant difference in variance of the average IVI of species between threat and conservation category.

For variance of the average IVI of species between various vegetation type $F_{calculated} < F_{tabulated}$, null hypothesis is accepted. It means there is no significant difference in variance of the average IVI of species between various vegetation types.

Thus, when the variance of average IVI between various vegetation types is taken, there is no richness of species diversity in study area. But there is a significant difference in variance of average IVI of the species between the threat and conservation categories. Hence average IVI of the species is an important parameter as IVI of particular species includes the frequency, density and dominance in itself. Thus, the study area does not show the richness in species diversity but it shows the high stress in threat category. To improve the richness in species diversity the variance in the average IVI of threat category should be reduced and variance in the average IVI between various vegetation types should be increased. For that the different types of species and their population and frequency and basal area should be increase by management intervention in the study area.

In order to improve the richness of the diversity in study area more introduction of trees, shrubs, lianas, herbs, grasses and tubers should be made by ex-situ conservation. The number of species between threat and conservation category are also good in study area.

In order to make the significant species diversity and making the threat and conservation categories for average IVI of the species, non significant the $\mathbf{F_{calculated} < 3.49}$, say **F calculated = 3.49**. For making the non significant threat and conservation category in average IVI, ANOVA **table 6** is reformulated by backward calculation for mean sum of

squares and total sum of squares between various vegetation types and it is expressed in bold and small brackets and modified ANOVA table is presented in **table 7**.

Table 7:- Modified ANOVA table for non significant diversity for average IVI between threat and conservation categories

Source of Variation	Sum of squares	Degree of freedom	Mean Sum of Square	$F_{calculated}$	$F_{tabulated}$ at 5% level of significance
Between conservation category	1878.795 (**414.81**)	4 -1 = 3	626.265 (**138.27**)	15.807 (**3.49**)	$F_{(3,12)} = 3.49$
Between vegetation type	333.85 (**1797.835**)	5 - 1 = 4	83.463 (**449.46**)	2.107 (**11.344**)	$F_{(4,12)} = 3.26$
Residuals	475.438	19 - 7 = 12	39.620		
Total	2688.083	20 - 1 = 19			

Between threat and conservation categories the mean sum of squares = 39.620 * 3.49 = 138.27 and sum of squares = 138.27 * 3 = 414.81, by maintaining the total sum of square same value = 2688.083 and correcting the value of Sum of squares between various vegetation types (2688.083&414.81 & 475.438 = 1797.835).

Thus modified Mean Sum of Square between vegetation types = 1797.835/4 = 449.46

To check the variance of average IVI between various vegetation types $\mathbf{F_{calculated} = 449.46/39.62 = 11.344 > F_{tabulated}}$ **(3.26).** Hence maintaining the variance of average IVI of the species non significant between threat and conservation categories, the variance of average IVI between various vegetation types is significant as **11.344 >3.26** Thus both the objectives are full filled by making the variance of average IVI of the species between threat and conservation categories as **non significant** as well as the variance of average IVI between various vegetation types as **significant**.

Thus the necessary and sufficient condition for average IVI to be non significant between threat and conservation categories:

Sum of squares between threat and conservation category = 414.81

$$\mathbf{C_1^2/5 + C_2^2/5 + C_3^2/5 + C_4^2/5 \ \& \ 1185.95 = 414.81}$$

$$\mathbf{C_1^2 + C_2^2 + C_3^2 + C_4^2 = 5*(1185.95 + 414.81)}$$

$$\mathbf{C_1^2 + C_2^2 + C_3^2 + C_4^2 = 8003.6}$$

To find out the average IVI between threat and conservation categories, four criteria's have been developed by assuming the three existing value of average IVI of threat and conservation categories to be constant and calculating the other one, these alternative criteria are:

Criteria 1:- $\mathbf{C_1}$ is calculated assuming $\mathbf{C_2}$ = 10.578, C_3 = 18.578, C_4 = 2.81,

$$\mathbf{C_1^2 + 10.578^2 + 18.578^2 + 2.81^2 = 8003.6 \text{ or } C_1 = 86.83}$$

Criteria 2:- $\mathbf{C_2}$ is calculated assuming $\mathbf{C_1}$ = 121.87, C_3 = 18.578, C_4 = 2.81,

$$\mathbf{121.87^2 + C_2^2 + 18.578^2 + 2.81^2 = 8003.6 \text{ or } C_2 = \text{Imaginary}}$$

Criteria 3:- $\mathbf{C_3}$ is calculated assuming $\mathbf{C_1}$ = 121.87, C_2 = 10.578, C_4 = 2.81,

$$\mathbf{121.87^2 + 10.578^2 + C_3^2 + 2.81^2 = 8003.6 \text{ or } C_3 = \text{Imaginary}}$$

Criteria 4:- $\mathbf{C_4}$ is calculated assuming $\mathbf{C_1}$ = 121.87, C_2 = 10.578, C_3 = 18.578,

$$\mathbf{121.87^2 + 10.578^2 + 18.578^3 + C_4^2 = 8003.6 \text{ or } C_4 = \text{Imaginary}}$$

Thus average IVI between threat and conservation categories in C_2, C_3 and C_4 are not feasible and criteria 1 is important for non significant average IVI between threat and conservation categories i.e. C_1= 86.83. Thus threat and conservation category 1 is very important category for average IVI of the species. The average IVI of the species in threat and conservation category 1 should be reduced by increasing the number of species between various vegetations types.

Thus to find out the average IVI within various vegetation types and between threat and conservation category 1 different alternatives are assessed by assuming the existing value of average IVI of within four vegetation types to be constant and calculating the other one, thus five alternative criteria have been developed, which are as follows:

$$\mathbf{R_1 + R_2 + R_3 + R_4 + R_5 = 86.83}$$

Criteria 1:- $\mathbf{R_1}$ is calculated assuming $\mathbf{R_2}$ = 19.284, $\mathbf{R_3}$ = 44.125, $\mathbf{R_4}$ = 25.321, $\mathbf{R_5}$ = 10.067

$$\mathbf{R_1 + 19.284 + 44.125 + 25.321 + 10.067 = 86.83 \text{ or } R_1 = \text{Negative}}$$

Criteria 2:- $\mathbf{R_2}$ is calculated assuming $\mathbf{R_1}$ = 23.073, $\mathbf{R_3}$ = 44.125, $\mathbf{R_4}$ = 25.321, $\mathbf{R_5}$ = 10.067

$$\mathbf{23.073 + R_2 + 44.125 + 25.321 + 10.067 = 86.83 \text{ or } R_2 = \text{Negative}}$$

Criteria 3:- $\mathbf{R_3}$ is calculated assuming $\mathbf{R_1}$ = 23.073, $\mathbf{R_2}$ = 19.284, $\mathbf{R_4}$ = 25.321, $\mathbf{R_5}$ = 10.067

$$\mathbf{23.073 + 19.284 + R_3 + 25.321 + 10.067 = 86.83 \text{ or } R_3 = 9.085}$$

Criteria 4:- $\mathbf{R_4}$ is calculated assuming $\mathbf{R_1}$ = 23.073, $\mathbf{R_2}$ = 19.284, $\mathbf{R_3}$ = 44.125, $\mathbf{R_5}$ = 10.067

$$\mathbf{23.073 + 19.284 + 44.125 + R_4 + 10.067 = 86.83 \text{ or } R_4 = \text{Negative}}$$

Criteria 5:- $\mathbf{R_5}$ is calculated assuming $\mathbf{R_1}$ = 23.073, $\mathbf{R_2}$ = 19.284, $\mathbf{R_3}$ = 44.125, $\mathbf{R_4}$ = 25.321

$$\mathbf{23.073 + 19.284 + 44.125 + 25.321 + R_5 = 86.83 \text{ or } R_5 = \text{Negative}}$$

Thus there are five alternative criteria's, which are expressed in **table 8**, are available to explain the average IVI of species to be maintained the variance in average IVI of the species between various vegetation types to be significant as well as maintaining non significant status of variance in average IVI of the species between various threat and conservation categories.

Table 8:- Various alternative criteria's, between different vegetation types for average IVI

Vegetation type	Different criterias for average IVI					Existing average IVI in C_1
	Criteria 1	Criteria 2	Criteria 3	Criteria 4	Criteria 5	
Trees	**-ve**	23.073	23.073	23.073	23.073	23.073
Shrubs	19.284	**-ve**	19.284	19.284	19.284	19.284
Lianas	44.125	44.125	**9.085**	44.125	44.125	44.125
herbs	25.321	25.321	25.321	**-ve**	25.321	25.321
Grasses	10.067	10.067	10.067	10.067	**-ve**	10.067
Total	**86.83**	**86.83**	**86.83**	**86.83**	**86.83**	121.87

The Criteria 3 is optimal and feasible solution for the average IVI in threat and conservation category 1. The other four criteria's (criteria 1, 2, 4 and 5) show the negative value of average IVI with in various vegetation types. The average IVI of the species between threat and conservation category 1 is the critical value of 86.83. This suggests that average IVI between threat and conservation category 1 should be 23.073, 19.284, 9.085, 25.321 and 10.067 with in trees, shrubs, lianas, herbs and grasses respectively. The number of lianas species should be increased to lower the average IVI of the species to the value of 9.085 as compare to 44.125. The liana species is the critical one which should be enriched in study area so that average IVI between threat and conservation category 1 assumes the lower value 9.085.

5. CONCLUSION:

The variance of the number of species between various vegetation types of trees, shrubs, lianas, herbs and grasses are not significant at 5% level of significance. The study area is poor in number of species between trees, shrubs, lianas, herbs and grasses.

In order to maintain the variance in number of species between various vegetation types to be significant as well as maintaining non significant status of variance in number between various threat and conservation categories, the optimal numbers of species are 155 in study area. The species of 58 tree, 28 shrubs, 30 lianas, 20 herbs, 19 grasses (Total 155) are required to make the significant diversity in number. Thus the 22 number of more lianas species are required to enrich the study area for significant variance in number of species as well as non significant status between threat and conservation categories.

Thus, when the variance of average IVI between various vegetation types is taken, there is no richness of species diversity in study area. But there is a significant difference in variance of average IVI of the species between the threat and conservation categories. Hence average IVI of the species is an important parameter as IVI of particular species includes the frequency, density and dominance in itself. Thus, the study area does not show the richness in species diversity but it shows the high stress in threat category.

In order to reduce the stress and improve the richness the variance of average IVI of the species between threat and conservation categories as **non significant** as well as the variance of average IVI between various vegetation types as **significant**. In order to fulfill the above the two objectives simultaneously, the average IVI in threat and conservation category 1 is should be 86.83 which is optimum value of IVI. The average IVI between threat and conservation category 1 should be 23.073, 19.284, 9.085, 25.321 and 10.067 within trees, shrubs, lianas, herbs and grasses respectively. The number of lianas species should be increased to lower the average IVI of the species to the value of 9.085 as compared to 44.125.

The liana species is the limiting species which should be enriched in study area so that average IVI between threat and conservation category 1 assumes the lower value 9.085. The tuber is another kind of vegetation type which should be enriched in the study area.

The area is dominated by majority of tree species which are restricting the growth of shrubs, lianas, herbs and grasses. The species of *Lantana camara* and *Ocimun basilicum* are invading the study area. These species are appearing as weeds which are checking the growth of other species in the area. The various tree species are not converting into trees due to excessive invasion of *Lantana camara* as majority of species remaining in bushy form. The invasion of *Ocimun basilicum* as a weed, is limiting the growth of herbs and grass species. The forest of the study area should be protected from illicit felling, grazing and from fire. The soil moisture conservation activity should be taken on massive scale apart from ex-situ conservation.

The relevance of the study provides method of ecological modeling and procedure for designing species diversity in a forest area. In designing procedure, the various alternative strategies are developed to find the number of species between various vegetation types to make the species diversity optimum in the study area and at the same time minimizing the threat parameters. This will help in future research on the vegetation and allied conservation measures of various species with higher degree of precision and accuracy.

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