# Assessment of Richness of Diversity between Various Species of Vegetation Type and their Threat Status in Mukundpur Forest Area, Satna District, Madhya Pradesh, India

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## 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 the 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 current status of species diversity current diversity and it also designing procedure for optimal species diversity in the study area by developing various alternative strategies to assess

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the number of species and their IVI between various vegetation types with optimum species diversity and minimising the threat parameters simultaneously. The study area was the forest area of 111.55 km2 of Mukundpur range of Satna Forest division, Madhya Pradesh, India. Field work was carried out during October 2015 to January 2016.The study about the current status reveals that there was a nonsignificant richness of species diversity between various vegetation types and threat and conservation categories when the number of the species was considered as a parameter. The species diversity was in the significant state of threat and conservation categories, but same was insignificant between various vegetation types when average IVI of the species was considered as a other parameter. The optimisation technique was used to find out the number and 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 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; optimisation technique; significant and non Significant; threat and conservation categories.*

## 1. INTRODUCTION

The study and analysis have been carried out with the purpose of conservation, propagation of diversity of vegetation with an innovative methodology employing a 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. The relevance of the study provides a method of ecological modelling 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 minimising 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. In the study area the present status of species diversity in terms of number and average IVI had been assessed in the study area. After evaluating the present status of species diversity, the optimal number of species and average IVI was evaluated to optimise species diversity and minimising threat and conservation status in the study area.

There are two popular diversity indices [1, 2]. These indices do not represent the species which are responsible for threatening status in a particular ecosystem. About 42% of world forests are dry forest [3] at global level. At the 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 Jain and Rao [8]. Conservation and economic evaluation of biodiversity has been done by Nayar et al. [9]. At regional level, threat assessment of Vindhyan region of Madhya Pradesh has been made by Myres [10], Nayar and Sastry [11], Nayar and Sastry [12], Nayar and Sastry [13] and Nautiyal [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, industrialisation, 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 map of the study area is shown in Fig. 1. 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. MATERIALS AND METHODS

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.

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 Fig. 2 was done with the help of prismatic compass Anon [20]. The combined map with sample plot in the study area is presented Fig. 3.

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 analysed 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 summarised in decreasing order and analysed further to assess the conservation and protection status of species by using the NORMAL DISTRIBUTION PRINCIPLE [24] as represented in Fig. 4, normal distribution curve of IVI values. Principle is as under:

$\mu$ = mean of IVI of all species, $\sigma$= 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 $\mu - 2.58\sigma$.

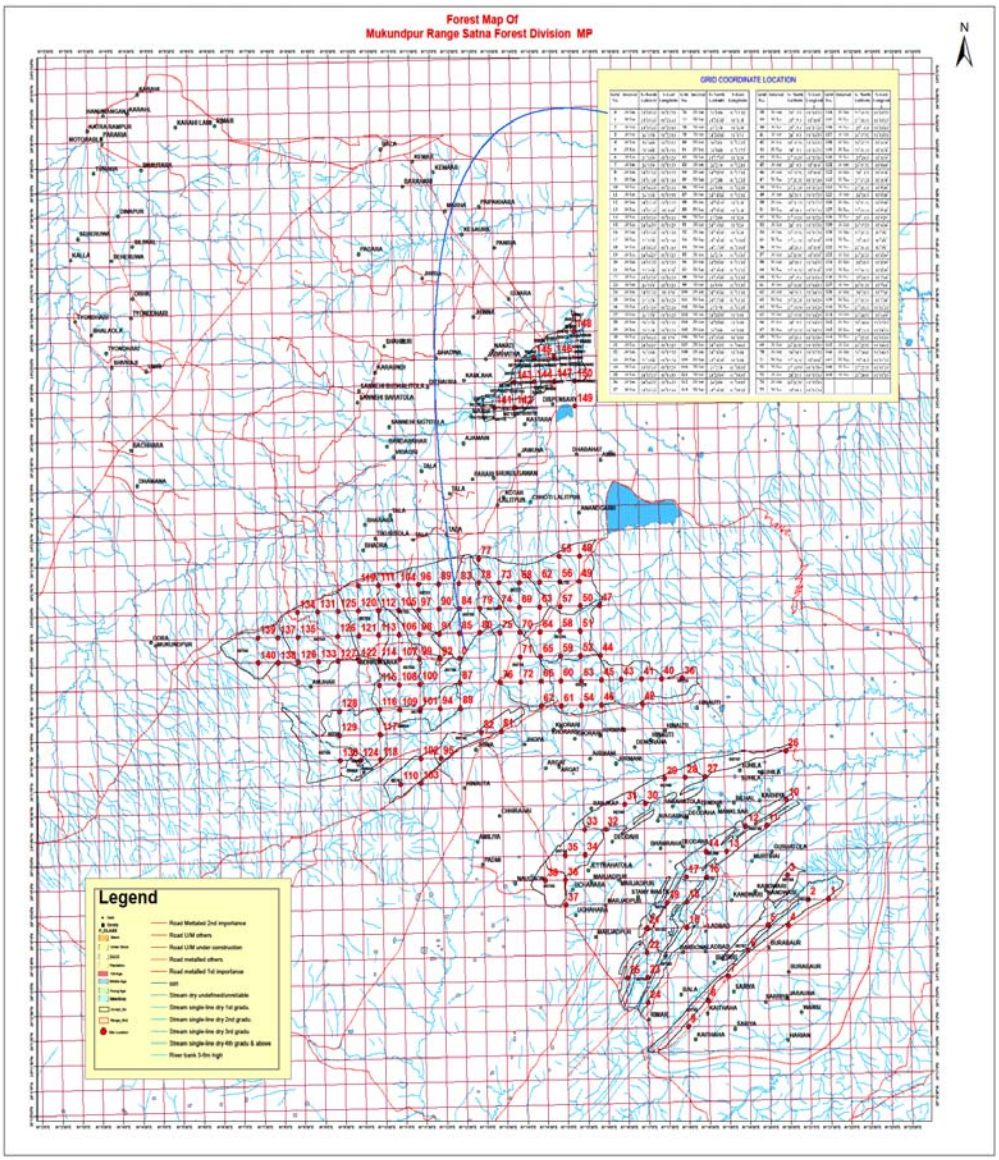
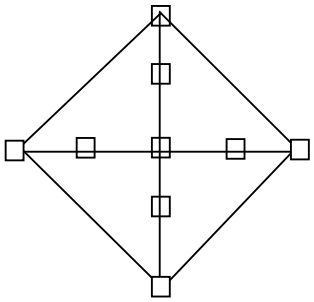



**Fig. 1. Map of the study area**



**sample plot area 0.16 or 0.1 ha**

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

**Fig. 2. Sample plot with their Quadrat**

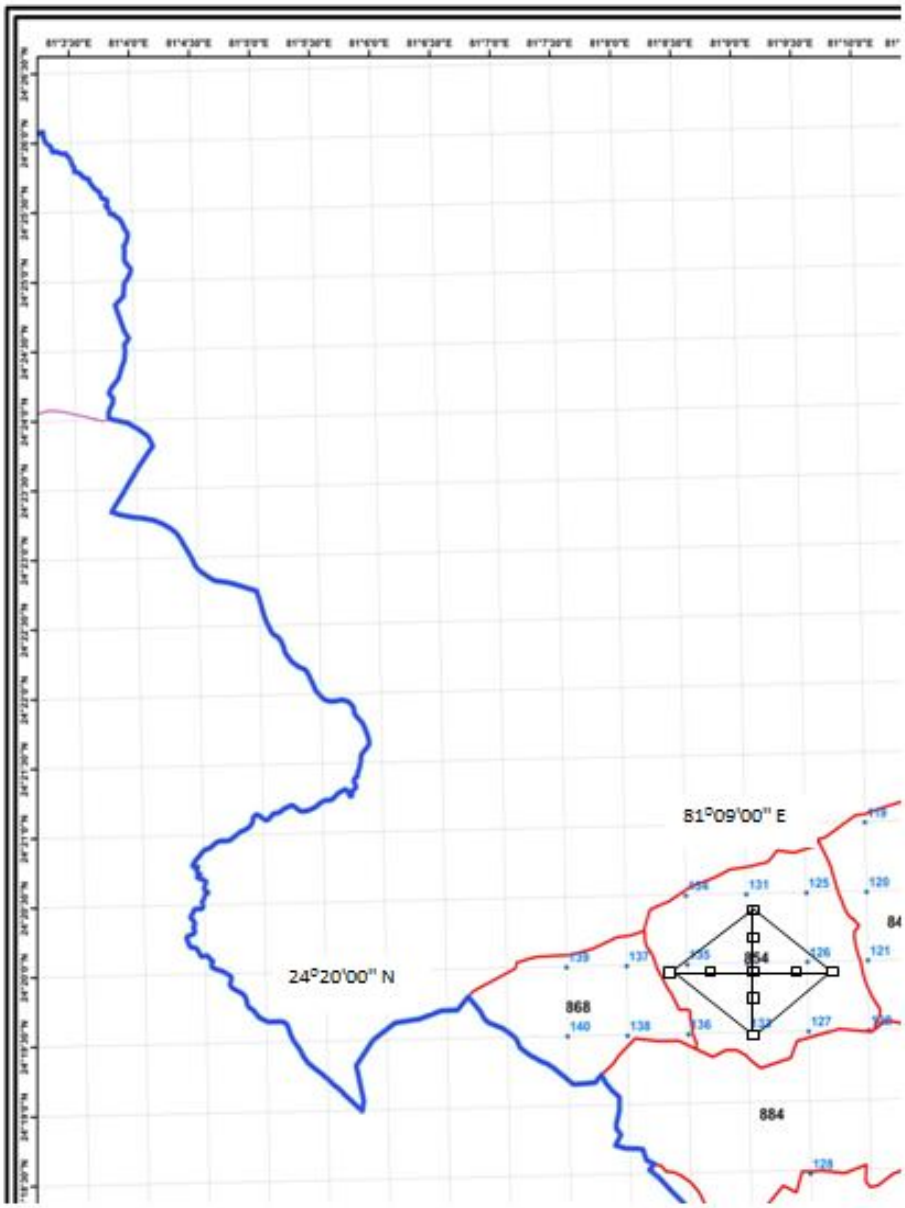



**Fig. 3. Combined map of the study area with sample plot**

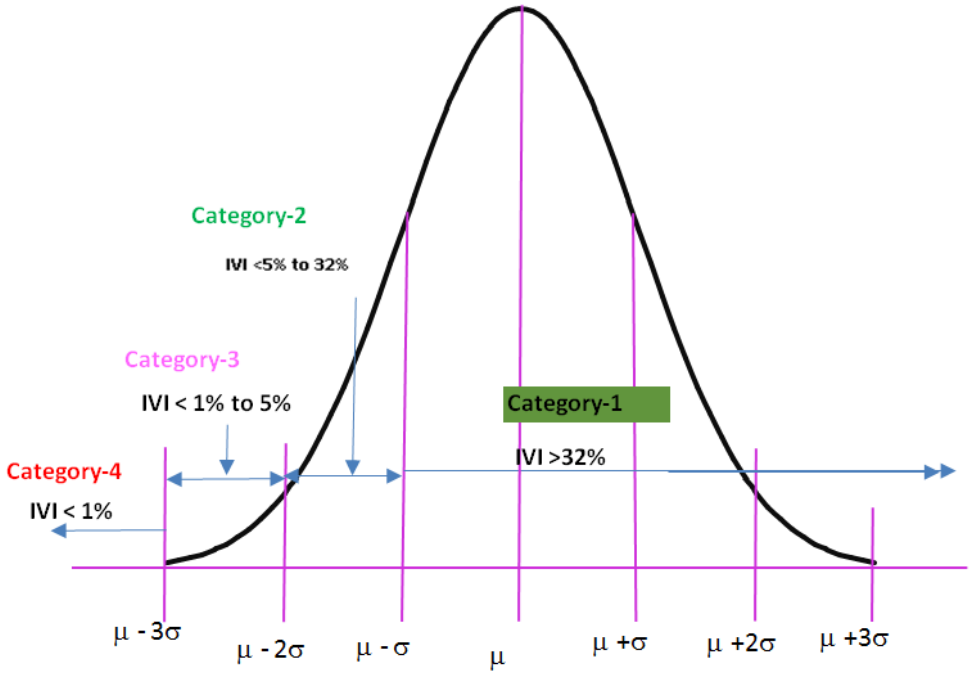



**Fig. 4. Normal distribution curve of IVI values**

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, $\mu$ 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], categorisation 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 analysing 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 optimise 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 optimisation 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 optimisation technique, Murthy [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 stricta*, *Paspalum notatum*, *Dichanthium annulatum* and *Cassia tora*.

### 4.6 Present Status of Species Diversity in Study Area in Terms of Number of Kinds of Species

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) |

**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 in Table 2.

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.

At present in the study area above results indicate that variance of the number of species between various vegetation types (trees, shrubs, lianas, herbs and grasses) and between threat and conservation categories are not significant at 5% level of significance. Regarding comparing the results from other literatures suggest that the systems requires urgent development of programmes for biodiversity assessment and monitoring [27, 28], but standard methods are missing. 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.

### 4.7 Present Status of Species Diversity in Study Area in Terms of Number of Kinds of Species

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 3.

**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 | | | |

**Table 3. 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 |

**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 in Table 4.

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.

The present status of species diversity in study area, when the variance of average IVI between various vegetation types is taken, there is no richness of species diversity. 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 the threat category. Regarding comparing these results from other literatures much information are not available but Chiarucci [29] states that no reliable method yet exists for estimating species richness in an area. Many authors have suggested diversity indices appropriate for their own studies, no one of which can be considered a priori correct for general application [30, 31, 32, 33, 34]. 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.

### 4.8 Evaluation of Optimum Species Diversity in Study Area in Terms of Number of Kinds of Species with Minimising the Threat and Conservation Status

In order to optimise the species diversity in number of kinds of species and at the same time minimising the threat and conservation status $F_{calculated} > 3.26$, say $F_{calculated} = 3.3$. 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 5.

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).

**Table 4. ANOVA for Table 3**

| 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 | | | |

**Table 5. 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 | | | |

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 $F_{calculated} = 2.68 < F_{tabulated}$ (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 $R_2 = 28$, $R_3 = 8$, $R_4 = 20$, $R_5 = 19$

$R_1^2 + 28^2 + 8^2 + 20^2 + 19^2 = 5799.4$ or $R_1 = 64$

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

$58^2 + R_2^2 + 8^2 + 20^2 + 19^2 = 5799.4$ or $R_2 = 40$

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

$58^2 + 28^2 + R_3^2 + 20^2 + 19^2 = 5799.4$ or $R_3 = 30$

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

$58^2 + 28^2 + 8^2 + R_4^2 + 19^2 = 5799.4$ or $R_4 = 35$

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

$58^2 + 28^2 + 8^2 + 20^2 + R_5^2 = 5799.4$ or $R_5 = 35$

Thus there are five alternative criteria's, which are expressed in Table 6, are available to explain the number of species to be maintained the variance in the 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.

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.

### 4.9 Evaluation of Optimum Species Diversity in Study Area in Terms of Average IVI of Species with Minimising the Threat and Conservation Status

In order to make the significant species diversity and making the threat and conservation

**Table 6. 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 |

**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 | | | |

categories for average IVI of the species, non significant the $F_{calculated} < 3.49$, say F calculated = 3.49. For making the non significant threat and conservation category in average IVI, ANOVA Table 4 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.

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 $F_{calculated}$ = 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

$C_1^2/5 + C_2^2/5 + C_3^2/5 + C_4^2/5$ & 1185.95 = 414.81

$C_1^2 + C_2^2 + C_3^2 + C_4^2 = 5*(1185.95 + 414.81)$

$C_1^2 + C_2^2 + C_3^2 + C_4^2 = 8003.6$

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:-** $C_1$ is calculated assuming $C_2$ = 10.578, $C_3$ = 18.578, $C_4$ = 2.81,

$C_1^2 + 10.578^2 + 18.578^2 + 2.81^2 = 8003.6$ or $C_1$ = 86.83

**Criteria 2:-** $C_2$ is calculated assuming $C_1$ = 121.87, $C_3$ = 18.578, $C_4$ = 2.81,

$121.87^2 + C_2^2 + 18.578^2 + 2.81^2 = 8003.6$ or $C_2$ = Imaginary

**Criteria 3:-** $C_3$ is calculated assuming $C_1$ = 121.87, $C_2$ = 10.578, $C_4$ = 2.81,

$121.87^2 + 10.578^2 + C_3^2 + 2.81^2 = 8003.6$ or $C_3$ = Imaginary

**Criteria 4:-** $C_4$ is calculated assuming $C_1$ = 121.87, $C_2$ = 10.578, $C_3$ = 18.578,

$121.87^2 + 10.578^2 + 18.578^3 + C_4^2 = 8003.6$ or $C_4$ = 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:

$R_1 + R_2 + R_3 + R_4 + R_5 = 86.83$

**Criteria 1:-** $R_1$ is calculated assuming $R_2$ = 19.284, $R_3$ = 44.125, $R_4$ = 25.321, $R_5$ = 10.067

$R_1 + 19.284 + 44.125 + 25.321 + 10.067 = 86.83$ or $R_1$ = Negative

**Criteria 2:-** $R_2$ is calculated assuming $R_1$ = 23.073, $R_3$ = 44.125, $R_4$ = 25.321, $R_5$ = 10.067

$23.073 + R_2 + 44.125 + 25.321 + 10.067 = 86.83$ or $R_2$ = Negative

**Criteria 3:-** $R_3$ is calculated assuming $R_1$ = 23.073, $R_2$ = 19.284, $R_4$ = 25.321, $R_5$ = 10.067

$23.073 + 19.284 + R_3 + 25.321 + 10.067 = 86.83$ or $R_3$ = 9.085

**Criteria 4:-** $R_4$ is calculated assuming $R_1$ = 23.073, $R_2$ = 19.284, $R_3$ = 44.125, $R_5$ = 10.067

$23.073 + 19.284 + 44.125 + R_4 + 10.067 = 86.83$ or $R_4$ = Negative

**Criteria 5:-** $R_5$ is calculated assuming $R_1$ = 23.073, $R_2$ = 19.284, $R_3$ = 44.125, $R_4$ = 25.321

$23.073 + 19.284 + 44.125 + 25.321 + R_5 = 86.83$ or $R_5$ = 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.

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

**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 |

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

Presently in the study area, there were species of 58 trees, 28 shrubs, 08 lianas, 20 herbs and 19 grasses (total 133). The species under threat and conservation category 4 were likely to be extinct in near future locally. The category 3 species could go to category 4 in near future. These species were mentioned in the study area which would be monitored local forest officer.

At present status of the richness in the study area indicated that variance of the number of species between various vegetation types (trees, shrubs, lianas, herbs and grasses) and between threat and conservation categories are not significant at 5% level of significance.

The present status of species diversity in the study area, when the variance of average IVI between various vegetation types was taken, there was no richness of species diversity. But there was a significant difference in the 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 when average IVI of species were taken as parameter.

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

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 was should be 86.83 which was the 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 was 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.

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## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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