Journal of Bioresearch 3(1): 25-37 (January - June, 2024)
Online: ISSN 2771-5868
Print: ISSN 2771-585X

## Original Research Article

# Phytodiversity of Some Selected Economically Important Tree Species of Five Different Forests in Gondia District (Maharashtra), India

Dilip M. Lanje[1], Amol M. Badole[1], Ravindra B. Zode[2], Walay Y. Tagade[2], Khushal Borkar[3] and Mahesh V. Kawale[1*]

[1] Department of Botany, Dhote Bandhu Science College, Gondia, MS India-441614

[2] C.J. Patel College, Tirora, Gondia MS India-441911

[3]M.B. Patel College, Sakoli, Dist Bhandara MS India-441802

*Corresponding Author: kawalemahesh@gmail.com

Received: January 04, 2023; revised: May 24, 2023; accepted: June 02, 2023

Available Online: July, 2023.

https://doi.org/10.56716/4/2280

**Abstract:** Trees are one of the main component of the forest ecosystem. Many trees are used for timber purpose while others are used for non-timber products. Rural and poor communities from villages are depend on such economically important trees. Anthropogenic disturbances lead to reduction in the population of some important trees in natural vegetation. However, no research had been done to know the diversity of trees in Maharashtra's Gondia district. Hence, field data was collected from 5 different forests in Gondia to understand species diversity and population structure of 6 selected tree species. Study was conducted by using centre point quadrate method. Quantitative analysis documented total 3717 Trees. *Terminalia alata* (1401) had shown overall dominance in all sites based on highest density, IVI and basal area. Similarly, *Buchanania lanzan* (1094) and *Anogeissus latifolia* (923) were also found dominant at Ghumdhawda forest. In contrary, *T. arjuna* (38) was least prevailing tree in all forests. Amongst all sites, Ghumdhawda forest was found to be the most diverse forest where all the selected trees found in number. At Khairbanda, Ghumdhawda and Pangdi forests 5 (83%) out of the 6 species encountered showed contagious distribution while 1 (17%) species had random distribution and no species with regular distribution. Whereas in Bodhalkasa and Murdoli forests, 4 (67%) species showed contagious distribution and 2 (33%) species had random distribution. From this study it can be concluded that except *T. alata* and *B. lanzan*, rest of all tree species are not abundant and have poor diversity in forests of Maharashtra's Gondia district.

**Key words:** Associated species, Combretaceae, Distribution pattern, Diversity indices, IVI

## Introduction

Forests are the precious source of nature. It provides shelter for many animals, birds, insects and microbes. Apart from these, all human beings are depends on the forest resources. Thus forests play an important role in the Biodiversity. Forest perform various ecological services like species conservation, soil erosion prevention, habitat preservation for plants and animals, sinking of carbon from atmosphere and plays a significant role as Non Timber Forest Products (NTFP) in the life of tribal population living around forests. Hence, dependency of tribal people on these forests is much greater and more extensive. In India, about 40% of the rural population, particularly the indigenous forest dwellers and the poor, depends on forest resources for energy, forest products and employment. They make their livelihood from the sale of forest products contributing 40-60% to their total income. This dependence on forest is unavoidable in India and therefore the pressure on forest by the ever-increasing population is continuously increasing (Pragasan and Parthasarthy, 2010). Moreover, expansion of agricultural lands, sustained heavy grazing, forest fires and other activities have been reducing the forest cover globally in recent time. Similar opinion was given by Mengistu *et al.*, (2005) and Chow *et al.*, (2013). Such disturbances directly cause loss of tree cover and subsequently affect other life forms, reducing overall forest species diversity (Campbell *et al.*, 2017). Thus, losing tree species in a forest, destroy the structure, function and composition of plant communities and eventually can harm the ecosystem services provided by the forest.

Understanding tree composition and structure of forest is a vital instrument in assessing the sustainability of the forest, species conservation, and management of forest ecosystems (Kacholi, 2014). Similarly, long-term biodiversity conservation depends basically on the knowledge of the structure, species richness, and the ecological characteristics of any vegetation. To know these parameters quantitative analysis of tree species is important factor and to understand the forest dynamic. Such quantitative reports also help to identify species that are in different stages of vulnerability and various factors that influence the existing vegetation in any region (Paladila *et al.*, 2004).

Forest services are renewable because they have regeneration potential (Tripathi and Khan, 2007). Regeneration is a key process for the existence of species in the community. Regeneration mechanism of a forest directly depends on their biotic and abiotic characteristics and its geographic distribution (Grubb, 1977). The successful regeneration of a tree species depends on the ability of its seedlings and saplings to survive and grow. Thus, regeneration has a significant role in the diversity of the plant species in forest. However, ecosystem functions like soil organic matter accumulation, carbon sequestration, hydrologic regulation, nutrient cycling and pollination etc or the diversity of canopy and understory species (Poorter *et al.*, 2016) predicts the future health of the forest ecosystem (Good and Good, 1972; Pala *et al.*, 2012). It leads to the changing structure, composition, and function of regenerating forests (Rozendaal and Chazdon, 2015). Tree population structure and diversity status of tropical forests from developing countries are often insufficient for extensive management (Appiah, 2013). For this purpose, the phytosociological assessment is very helpful and provides the information about the status of tree population and its future diversity. The population of the forest ecosystems and its future health depends on the tree regeneration potential, which is observed by a sufficient population of different life phases (i.e. tree, sapling and seedling) in the plants.

The tropical forests are diversified terrestrial, species-rich ecosystem on the earth (Myers *et al.*, 2000), and have high genetic resources because of variations in soil, climate and elevation (Davidar *et al.*, 2007). Tropical dry deciduous type of forest is prominently found in the central India. These dry tropical forest communities are world's most threatened systems and an urgent attention are needed to protect and restore them. Gondia district is one of the richest biodiversity centers, with high species density and diversity. This region is phytogeographically important and considered as the dispersal route for plants of northern to the southern India and vice versa. For conservation planning of this region, the primary requirement is quantitative information on composition, distribution and abundance of tree species, which is not available.

Hence, present study carried out in 5 forest areas of 3 talukas such as Bodhalkasa forest (Tirora), Gumadhawada forest (Tirora), Khairbanda forest (Gondia), Pangadi forest (Gondia) and Murdoli forest (Sadak Arjuni). This study intended to understand floristic diversity and natural regeneration status of economically important tree species like *Terminalia alata, T. chebula, T. bellirica, T. arjuna, Buchanania lanzan* and *Anogeisus latifolia*. Information generated through this study would serve as baseline information on a quantitative diversity of selected tree species in the study area.

## Materials and methods

### Study sites

Gondia is a north-eastern district of Maharashtra state and share the border of Chhattisgarh and Madhya Pradesh state. Gondia lying between Longitude 79°.50’ to 80° 41’ East and Latitude 20° 39’ to 21° 38’ North and average altitude is 300 meter above mean sea level. The average temperature ranges between 6°C-26°C during winter and 28°C-46°C during summer season. The district receives an average annual rainfall between 130 and 500 mm. Gondia is highly rich in terms of forest cover. As per India State forest Report 2011, the total geographic area of Gondia district is 5733 km$^2$ out of which 2011 km$^2$ is forest area, which is 35.08% of the total area. Two protected areas, namely Nagzira wildlife sanctuary and Navegaon Bandh National Park are in Gondia district. Forest of Gondia district comes under tropical dry deciduous type.

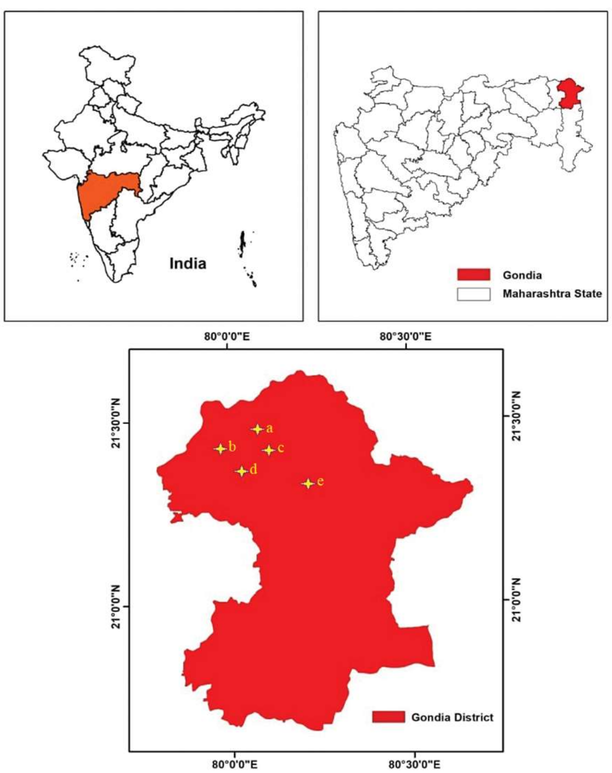


**Fig. 1.** Map showing location of Gondia district with study sites

a. Khairbanda forest 21.46632N 80.07058E

b. Ghumdhawda forest 21.43777N 79.98271E

c. Pangdi forest 21.40720N 80.10364E

d. Bodhalkasa forest 21.34269N 80.02939E

e. Murdoli forest 21.23351N 80.21282E


**Fig. 2.** Evidence of Forest sites where study carried out.

a. Khairbandha, b. Murdoli, c. Bodhalkasa, d. Pangdi and e. Ghumdhawda

Various small hills covered by dense forest are distributed throughout the district. The details of five selected forests sites are shown in Figure 1 and 2.

### Field methods

The study carried out by visiting frequently to the selected study sites during 2019-2020 and by lying quadrates. The data recorded by applying center point quadrate method given by Kent and Coker (1992). Trees (GBH $\geq$ 10 cm) (Girth at Brest Height) analyzed by 20m X 20m sized quadrates, saplings (GBH - 5 - 10 cm) by 5m X 5m sized quadrates, and seedling (GBH $\leq$ 5 cm) by 1m X 1m sized quadrates, which were randomly laid out within each 20 m X 20 m sized quadrate at each site. Diameter of each tree was measured at breast height (1.3 meter above the ground) using a diameter tape for the calculation of Total Basal Area. For trees, ten quadrates were randomly placed at 500 to 1000m interval at each study site.

All the plant specimens worked out taxonomically for identification. During the field survey, care was taken to avoid disturbance to the flora and fauna. The specimens were identified with the help of the Flora of Maharashtra (Singh and Karthikeyan, 2000).

## Data analysis

Name of selected species and number of individual species in each unit recorded and density, relative density, frequency, relative frequency, basal area and relative dominance along with Important Value Index (IVI) were calculated by using Microsoft Excel as per Misra (1968). Various diversity indices like Margalf's Index of species richness, Barger-Parker Diversity index, Simpson's diversity Index (Simpson, 1949), Shannon Weiner Diversity Index (Shannon and Wiener, 1963), Ginni-Simpson index and Pielou's measure of evenness were calculated with the help of online Biodiversity calculator software website (Young, 2023).

The distribution pattern of trees was determined using Whitford (1949), where DP = abundance/frequency (A/F Ratio). A value < 0.025 would imply a regular distribution, A value between 0.025-0.05 means a random distribution and a value > 0.05 would mean a contagious distribution (Ndah *et al.*, 2013).

From the collected data, similarity indices like Jaccard's similarity coefficient and Sorenson's similarity index were also calculated to understand the similarity percentage between studied sites. At the end, regeneration potential of selected species was calculated by comparing the Seedling, Sapling data with Trees.

## Results

A total six tree species representing 3 genera and 2 families were considered for the study. All these members are economically important trees which are mostly used as medicinal as well as Non Timber Forest Products throughout India.

Total 3717 Trees (>10 cm GBH) (Girth at Brest Height) were recorded from all sites. *Terminalia alata* was found in highest number i.e. 1401 and *Buchanania lanzan* was second highest i.e. 1094, while *T. arjuna* was found in least number i.e. 38 (Figure 3).

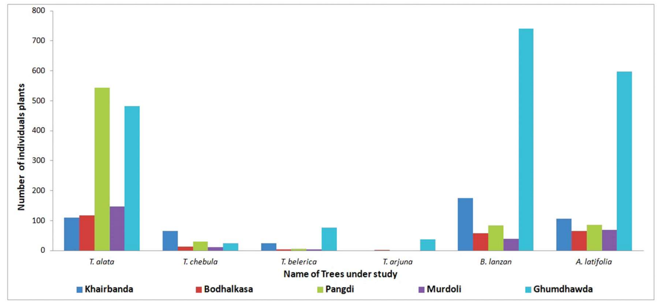


**Fig. 3.** Comparison of total number of Tree individuals observed at different forest sites

## Phytosociological Analysis

Observations of the study showed that *B. lanzan* found most dominant tree species in all the studied sites with abundance and density 74 each and 100% frequency at Ghumdhawda forest site. Followed that *T. alata* was found second most dominant tree species at Pangdi forest site with 60.3 abundance, 54.3 density and 90% frequency. Similarly, *A. latifolia* had also showed dominance at Ghumdhawda forest site with 59.7 abundance and density each and 100% frequency. *T. alata* was again found in dominant level at Ghumdhawda forest site with 48.2 abundance and density each and 100% frequency. *T. arjuna* observed as least dominant species in all the studied sites (Table 1). If frequency considered individually, *T. alata* was found most frequent tree species of the study, which observed in 90-100% frequency in all the studied sites. *B. lanzan* and *A. latifolia* were also observed with 100% frequency in 3 sites out of 5 studied sites. *T. bellirica* was observed with 100% frequency at one site only, i.e. at Ghumdhawda forest site (Table 1).

## Important Value Index (IVI)

IVI analysis of tree species at each site showed a distinct pattern. *T. alata* was found most diverse with the highest IVI (116.61) at Pangdi forest followed that Murdoli forest with 109.15 IVI. However, *T. arjuna* found least diverse with zero IVI at Khairbanda, Pangdi and Murdoli forests. Overall, *T. alata* was with highest IVI i.e. 60 to 120 in all studied sites, which signifies its dominance in all the sites. Similarly, *A. latifolia* also showed IVI that ranges between 50 to70 in all the studied sites. Similarly, *B. lanzan* was found in the range of 40 to 80 in selected 5 sites. These results showed co-dominance of *A. latifolia* and *B. lanzan* in all the studied sites. The highest IVI score of the *T. alata* deserves special mention for its frequent occurrence at all the studied sites. It covers a large area of the forest and gives a look to very dark and dense forest. (Table 1)

**Table 1.** Phytosociological parameters of selected trees at various study sites.

| Tree | Sites | Khairbanda | Bodhalkasa | Pangdi | Murdoli | Ghumdhawda |
|---|---|---|---|---|---|---|
| *T. alata* | Abundance | 11 | 11.8 | 60.3 | 14.8 | 48.2 |
| | Density (Ind/0.4H) | 11 | 11.8 | 54.3 | 14.8 | 48.2 |
| | Frequency (%) | 100 | 100 | 90 | 100 | 100 |
| | IVI | 65.68 | 84.95 | 116.61 | 109.15 | 61.04 |
| | Total Basal Area ($Cm^2$/0.4H) | 51.59 | 92.04 | 410.5 | 107.15 | 122.4 |
| *T. chebula* | Abundance | 8.25 | 2.33 | 4.28 | 2.75 | 3.57 |
| | Density (Ind/0.4H) | 6.6 | 1.4 | 3.0 | 1.1 | 2.5 |
| | Frequency (%) | 80 | 60 | 70 | 40 | 70 |
| | IVI | 50.58 | 26.87 | 35.99 | 29.87 | 23.4 |
| | Total Basal Area ($Cm^2$/0.4H) | 28.84 | 4.9 | 15.03 | 4.37 | 3.17 |
| *T. bellirica* | Abundance | 2.77 | 1.33 | 1.5 | 1.33 | 7.6 |
| | Density (Ind/0.4H) | 2.5 | 0.43 | 0.6 | 0.4 | 7.6 |
| | Frequency (%) | 90 | 30 | 40 | 30 | 100 |
| | IVI | 48.11 | 30.54 | 51.56 | 33.32 | 49.3 |
| | Total Basal Area ($Cm^2$/0.4H) | 13.12 | 4.96 | 9.50 | 2.54 | 29.64 |
| *T. arjuna* | Abundance | 0 | 1.00 | 0 | 0 | 9.25 |
| | Density (Ind/0.4H) | 0 | 0.1 | 0 | 0 | 3.7 |
| | Frequency (%) | 0 | 10 | 0 | 0 | 40 |
| | IVI | 0 | 38.28 | 0 | 0 | 37.61 |
| | Total Basal Area ($Cm^2$/0.4H) | 0 | 3.82 | 0 | 0 | 139.15 |
| *B. lanzan* | Abundance | 17.5 | 5.7 | 11.8 | 4.33 | 74 |
| | Density (Ind/0.4H) | 17.5 | 5.7 | 8.3 | 3.9 | 74 |
| | Frequency (%) | 100 | 100 | 70 | 90 | 100 |
| | IVI | 79.14 | 56.85 | 41.89 | 56.73 | 67.93 |
| | Total Basal Area ($Cm^2$/0.4H) | 82.07 | 30.38 | 37.59 | 18.29 | 117.66 |
| *A. latifolia* | Abundance | 17.8 | 6.5 | 9.4 | 6.9 | 59.7 |
| | Density (Ind/0.4H) | 10.7 | 6.5 | 8.5 | 6.9 | 59.7 |
| | Frequency (%) | 60 | 100 | 90 | 100 | 100 |
| | IVI | 56.43 | 62.44 | 53.89 | 70.87 | 60.62 |
| | Total Basal Area ($Cm^2$/0.4H) | 51.89 | 350.67 | 59.5 | 32.91 | 94.92 |

## Total Basal Area

As the basal area depends on density and GBH, *T. alata* had the highest basal cover with 410.5 $cm^2$/0.40H at Pangdi forest, followed by *A. latifolia* with 350.67 $cm^2$/0.40H at Bodhalkasa forest. *T. arjuna* which was almost absent at other sites had 139.15 $cm^2$/0.40H basal area at Ghumdhawda forest. (Table 1)

## Diversity Indices

To understand the overall status of diversity at selected sites, data analyzed by using various indices. The species richness of selected forests was ranged between 0.66 of Ghumdhawda forest to 0.90 at Bodhalkasa forest. As per Margalef's diversity index, more value of 'd' show more diversity of that site and vice versa, hence, Bodhalkasa and Murdoli forests had highest species richness, with 0.90 and 0.89 value of d respectively. Whereas, Khairbanda and Pangdi forests was found in the medium range of index values, i.e. 0.80 and 0.75, respectively. However, species richness of Ghumdhawda forest was found to be lowest, i.e. 0.66 (Table 2).

As per Barger-Parker diversity index($D_{BP}$), higher value of $D_{BP}$ indicates less species diversity and vice versa. Khairbanda and Ghumdhawda forests with $D_{BP}$ value 0.36 and 0.38 had more species diversity and Pangdi forest with 0.73 $D_{BP}$ value had less species diversity. Bodhalkasa and Murdoli

**Table 2.** Comparison of various diversity indices at different study sites.

| Sites | d | DBP | DBPC | Hs | DGS | Ds | J' |
|---|---|---|---|---|---|---|---|
| Khairbanda | 0.80 | 0.36 | 0.64 | 1.45 | 0.75 | 0.24 | 1.00 |
| Bodhalkasa | 0.90 | 0.46 | 0.54 | 1.27 | 0.68 | 0.32 | 0.95 |
| Pangdi | 0.75 | 0.73 | 0.27 | 0.88 | 0.44 | 0.55 | 0.61 |
| Murdoli | 0.89 | 0.55 | 0.45 | 1.14 | 0.62 | 0.38 | 0.78 |
| Ghumdhawda | 0.66 | 0.38 | 0.62 | 1.33 | 0.69 | 0.30 | 1.00 |

Margalef's diversity index (Species richness) = d, Barger-Parker Diversity index = DBP; Berger Parkar complement index =DBPC, Shannon-Wiener index = Hs; Ginni-Simpson index = DGS, Simpson diversity index (Dominance) =Ds; Pielou's measure of evenness = J'

forests showed a median level of diversity with $D_{BP}$ value 0.46 and 0.55, respectively.

Similar pattern of diversity richness was observed when data analyzed with $D_{BPC}$ index. According to Berger Parker complement diversity index ($D_{BPC}$), high index value represents more diverse site, and low index value represents less diversity. Khairbanda and Ghumdhawda forests showed more $D_{BPC}$ value, i.e. 0.64 and 0.62, means had higher diversity than all other sites, while Pangdi forest ($D_{BPC}$-0.27) was having less diversity. Bodhalkasa and Murdoli forests showed a median level of diversity with $D_{BPC}$ values 0.54, 0.45, respectively (Table 2).

Shannon-Wiener diversity index (Hs) had also given similar trend of diversity distribution among studied sites. In this, index values were positively correlated with diversity level of the site. Hs value of Khairbanda forest was maximum, i.e. 1.45, followed by Ghumdhawda forests with 1.33 and Bodhalkasa with 1.27. These values support earlier trends of diversity variation at different sites, i.e. Khairbanda and Ghumdhawda forests were most diverse and Pangdi forest was least diverse amongst the studied sites. Similarly, Ginni-Simpson index ($D_{GS}$) values showed a positive correlation with diversity and gave very much same results as Shannon-Wiener diversity index had given (Table 2).

Simpson diversity index ($D_S$) values were inversely proportionate to the level of diversity. Values of Simpson's diversity index range from 0.24 to 0.55. Khairbanda forest had lowest Ds value (0.24) which also supports results of earlier indices. Ghumdhawda and Bodhalkasa forests had given relatively similar Ds values, 0.30 and 0.32, respectively. It showed both these sites were equally diverse. Pangdi forest had highest Ds value, i.e. 0.55 indicates least diversity of site (Table 2).

Moreover, Pielou's measure of evenness (J') value appeared 1.00 for Khairbanda and Ghumdhawda forests, which indicates that there was more or less balanced distribution of individuals of studied trees. Low evenness value for Pangdi and Murdoli forests showed that there was an unbalanced representation of individuals of different trees. The reason for low evenness could be attributed to excessive disturbance, variable conditions for regeneration and exploitation of some species (Wassie *et al.,* 2005). The diversity and evenness indices imply the need to conserve the forests from both floristic diversity and human disturbance perspectives. However, The pielou's measure of evenness showed that all five studied sites had low evenness or high single-species dominance as the values were closer to zero (0) than to one (1) (Table 2).

**Correlation analysis**

Correlation analysis carried out between different phytosociological parameters and is given in Figure 4 (a-f). Density (hac-1) found positively correlated with the Shannon diversity index with (r = 0.139) while negatively correlated with species richness (r = -0.920). The Shannon diversity index found positively correlated with evenness (r= 0.970) whereas negatively correlated with species richness (r= -0.0068). The species richness was found negatively correlated with the concentration of dominance (r= -0.069) and with Evenness (r= -0.077).

**Similarity Indices**

As per the Jaccard's similarity coefficient and Sorenson's similarity index, Pangdi and Khairbandha, Murdoli and Khairbandha, Ghumdhawda and Bodhalkasa, Murdoli and Pangdi forest pairs had maximum similarity i.e. 1% in diversity level. While, forest pairs like Bodhalkasa and Khairbandha, Ghumdhawda and Khairbandha, Pangdi and Bodhalkasa, Murdoli and Bodhalkasa, Ghumdhawda and Pangdi, Ghumdhawda and Murdoli also had equal similarity i.e. 0.83% and 0.91% as per the Jaccard's similarity coefficient and

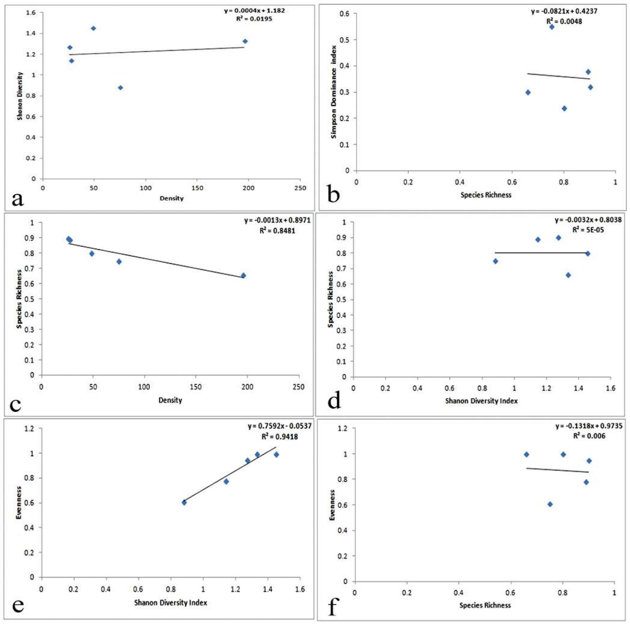


**Fig. 4.** Correlations between various phytosociological attributes

a. Shanon diversity with density, b. Simpson dominance with Sp. Richness,
c. Species richness with density, d. Sp. richness with shanon diversity
e. Evenness with Shanon diversity f. Evenness with species richness

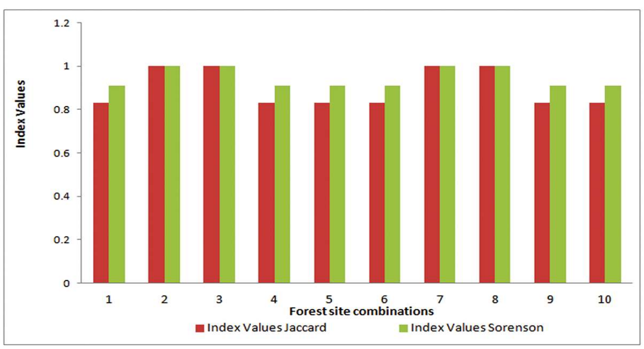


**Fig. 5.** Similarity level between studied sites analyzed by Jaccards's & Sorenson's index.

1. Bodhalkasa & Khairbanda
2. Pangdi & Khairbanda
3. Murdoli & Khairbanda
4. Ghumdhawda & Khairbanda
5. Pangdi & Bodhalkasa
6. Murdoli & Bodhalkasa
7. Ghumdhawda & Bodhalkasa
8. Murdoli & Pangdi
9. Ghumdhawda & Pangdi
10. Ghumdhawda & Murdoli

Sorenson's similarity index respectively in their diversity level (Figure 5).

## Distribution Pattern

Several tree species found in all selected sites showed varying patterns of distribution. Overall, it had been observed that *T. alata* found mostly in contiguous distribution in all sites. *T. chebula* recorded in random distribution at Bodhalkasa and Ghumdhawda forests, while found in contiguous distribution at Khairbanda, Pangdi and Murdoli forests. *T. bellirica* found randomly distributed at almost all sites, except Ghumdhawda forest. *T. arjuna* observed only at two sites i.e. Bodhalkasa and Ghumdhawda forests where it was in contiguous distribution. *B. lanzan* found in contiguous distribution at Khairbanda, Bodhalkasa, Pangdi and Ghumdhawda forests while random distribution at Murdoli forest. *A. latifolia* observed in contiguous distribution in all sites (Table 3)

## Regeneration Analysis

In this study, regeneration status of trees had analyzed on the basis of number of seedlings, saplings and trees recorded at particular forest site. Regeneration status of selected trees ranged from poor to no regeneration, i.e. number of saplings and seedlings found less compared to fully grown trees. While, in some forest sites, regeneration observed, but it was very less, like *T. alata* at Bodhalkasa and Pangdi forests, where number of sapling were more than the number of trees, similarly *T. chebula* at same Bodhalkasa and Pangdi forests, number of seedlings were more than a number of trees (Table 4). There could be various reasons behind this low regeneration percentage.

As per tree wise analysis, at Khairbanda forest, fully grown *A. latifolia* trees and seedlings numbers were found equal i.e. 107, while saplings number was less i.e. 50. At Ghumdhawda forest, numbers of fully grown trees were 597, whereas the numbers of saplings were 118 and only 5 seedlings were reported. Saplings, seedlings and fully grown trees of *T. arjuna* were altogether absent in all the sites except Ghumdhawda forest, where it was observed in good number. *T. bellirica* also observed in very less density. Only at Khairbanda and Ghumdhawda forests, numbers of fully grown trees were in two digits i.e. 25 and 76 respectively with some amount of saplings and seedlings. As *T. chebula* is concerned, seedlings numbers found more than trees at Bodhalkasa, and Pangdi, which shows good regeneration, while at Khairbanda, regeneration found equal with proportionately similar number

**Table 3.** Distribution analysis (A / F) of Trees in selected forest sites

| Plant Species | Khairbanda | Bodhalkasa | Pangdi | Murdoli | Ghumdhawda |
|---|---|---|---|---|---|
| *Terminalia alata* | 0.11(C) | 0.12(C) | 0.67(C) | 0.15(C) | 0.48(C) |
| *Terminalia chebula* | 0.10(C) | 0.04(Ra) | 0.06(C) | 0.07(C) | 0.05(Ra) |
| *Terminalia bellirica* | 0.03 (Ra) | 0.04(Ra) | 0.04(Ra) | 0.04(Ra) | 0.08(C) |
| *Terminalia arjuna* | - | 0.10(C) | - | - | 0.23(C) |
| *Buchanania lanzan* | 0.17(C) | 0.06(C) | 0.17(C) | 0.05(Ra) | 0.74(C) |
| *Anogeissus latifolia* | 0.29(C) | 0.07(C) | 0.10(C) | 0.07(C) | 0.60(C) |

Re- Regular <0.025, Ra-Random- 0.025-0.05, C- Contiguous >0.05

**Table 4.** Number of selected plants at different stages of growth at selected sites.

| | *T. alata* | | | | *T. chebula* | | | | *T. bellirica* | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| sites | Tree | Sap | Seed | Status | Tree | Sap | Seed | Status | Tree | Sap | Seed | Status |
| Khairbanda | 110 | 22 | 15 | PR | 66 | 50 | 61 | PR | 25 | 4 | 11 | PR |
| Bodhalkasa | 118 | 1057 | 45 | GR | 14 | 10 | 17 | PR | 4 | 0 | 0 | NR |
| Pangdi | 543 | 906 | 524 | GR | 30 | 29 | 67 | PR | 6 | 2 | 0 | NR |
| Murdoli | 148 | 9 | 22 | PR | 11 | 6 | 5 | PR | 4 | 0 | 0 | NR |
| Ghumdhawda | 482 | 80 | 44 | PR | 25 | 7 | 0 | NR | 76 | 21 | 1 | PR |
| | *T. arjuna* | | | | *B. lanzan* | | | | *A. latifolia* | | | |
| sites | Tree | Sap | Seed | Status | Tree | Sap | Seed | Status | Tree | Sap | Seed | Status |
| Khairbanda | 0 | 0 | 0 | NR | 175 | 114 | 104 | PR | 107 | 50 | 107 | PR |
| Bodhalkasa | 1 | 0 | 0 | NR | 57 | 29 | 4 | PR | 65 | 8 | 1 | PR |
| Pangdi | 0 | 0 | 0 | NR | 83 | 36 | 18 | PR | 85 | 34 | 24 | PR |
| Murdoli | 0 | 0 | 0 | NR | 39 | 14 | 7 | PR | 69 | 4 | 7 | PR |
| Ghumdhawda | 37 | 12 | 41 | PR | 740 | 263 | 54 | PR | 597 | 118 | 5 | PR |

GR- Good Regeneration, NR- No Regeneration, PR- Poor Regeneration

of trees, saplings and seedlings observed. In *T. alata*, regeneration declined at Khairbanda, Murdoli and Ghumdhawda with very less number of saplings and seedlings compared to fully grown trees, while at Bodhalkasa, and Pangdi forests, sapling number was more than compared to trees, which indicates good regeneration, however seedling number again decreased (Table 4).

## Associated Species

Plants which found in association with the targeted trees were also plays an important role as they form the distinct community and have a separate phyto-social association between them. In selected forests, few plants were recorded, which were mostly observed in association with our targeted species. The details of these plants are given in Table 5.

## Discussion

In this study, *T. alata* found most dominant tree in almost all studied sites on the basis IVI and basal area. However, if

**Table 5.** Associated species of selected trees at different sites.

| Sites | Associated species | |
|---|---|---|
| Khairbanda | •*Holarrhena antidysenterica* | •*Phyllanthus emblica* |
| | •*Cleistanthus collinus* | •*Tectona grandis* |
| | •*Diospyros melanoxylon* | •*Gardenia resinifera* |
| Bodhalkasa | •*Holarrhena antidysenterica* | • *Cassia fistula* |
| | •*Cleistanthus collinus* | •*Nyctanthes arbor-tristis* |
| | •*Diospyros melanoxylon* | •*Madhuca indica* |
| | •*Tectona grandis* | •*Eucalyptus sp.* |
| | •*Gardenia resinifera* | |
| Pangdi | •*Holarrhena antidysenterica* | •*Tectona grandis* |
| | •*Cleistanthus collinus* | • *Madhuca indica* |
| | •*Diospyros melanoxylon* | •*Cassia fistula* |
| | •*Gardenia resinifera* | • *Aegle marmelos* |
| | •*Asparagus racemosa* | •*Chloroxylon swietenia* |
| Murdoli | •*Holarrhena antidysenterica* | •*Gardenia resinifera* |
| | •*Cleistanthus collinus* | •*Phyllunthus emblica* |
| | •*Diospyros melanoxylon* | •*Nyctanthes arbor-tristis* |
| | •*Tectona grandis* | • *Dendrocalamus strictus* |
| Ghumdhawda | •*Maytenus emarginata* | •*Syzygium cumini* |
| | •*Azadirachta indica* | •*Butea monosperma* |
| | • *Madhuca indica* | •*Soymida febrifuga* |

sites analyzed at individual level, then *B. lanzan* had showed highest density and *A. latifolia* second highest density at Ghumdhawda forest. These trees had comparatively less IVI and basal area, while their density and abundance were very high. Reason behind this could be the IVI, which is a sum of relative density, relative frequency and relative dominance (Kacholi, 2014). Relative dominance is depends on GBH (Girth at Brest Height). Less GBH leads to less IVI and basal area. IVI is a measure of how dominant a species is in any forest area. It is used for prioritizing species conservation, whereby species with low IVI value need top conservation priority compared to the ones with high IVI (Zegeye, 2006). The high IVI exhibited by *T. alata* was because of its higher relative frequency, density, and dominance compared to other species. In this study, *T. arjuna* showed least IVI value indicated the less availability of species in the forest sites. This finding was also supported by the various diversity indices applied here. IVI values not only provide the identity of dominant tree species in the forests, but they also reflect the ecological characteristics of forest ecosystems (Turkis and Elmas, 2018). The reason behind less availability of *T. arjuna* in all the study sites could be its habitat. Present study was carried out in core zones of forests, while *T. arjuna* is reported to be found dominant in riparian habitat (Sunil *et al.,* 2019). The species is in 'near threatened' IUCN category (Ved *et al.,* 2016) and occurs naturally along banks of streams and rivers at low elevations (Sunil *et al.,* 2019). As for as low diversity of *T. bellirica* is concerned, flowering is not annual in it, mostly occurs in 3-4 years, hence fruits and seed setting could be less (Sinu, 2012). Moreover, the fruits of *T. bellirica* and *T. chebula* are medicinally important. An Ayurvedic medicine 'Trifala churna' is made up of the fruits of *T. bellirica, T. chebula* and *Phyllanthus emblica*. Hence, local forest dwellers collect the fruits of these plants from forest. This could be the reason behind a low diversity of *T. bellirica* and *T. chebula* at the study sites. It has been observed that tree density significantly differed at different sites; it may be due to factors related to seed dispersal, survival, and establishment and also on resources extraction.

In this study, values of indices indicate the level of tree diversity in selected sites. In Berger-Parker index, species richness decreases with the increase in index value, while in Berger Parker complement diversity index, species richness increases with the increase in index value. Some sites showed closeness of the indices values, which revealed that communities are similar in diversity and this is strengthened by the similarity index values. These findings could be because of the existence of highly similar environmental conditions in selected sites as per Singh and Singh (2010).

The values of species diversity (H') reported in the present study are higher in some sites, this may be due to the less anthropogenic disturbances prevailing in those sites, which can increase species diversity by lowering the dominance of a few species, a basis for specialization and resource partitioning (Grubb, 1977, Denslow, 1980). In tropical forests, the value of species diversity (H') are generally high (between 5.06 and 5.40) (Knight, 1975) as compared to Indian forests,(between 0.00 and 4.21) (Agni *et al.,* 2000). The value of H' reported in the present study are well within these limits i.e. 0.88 – 1.45.

Simpson's Index (D) was computed for tree (range=0.24-0.55) and Shannon-Wiener index (H) (range=0.88-1.48) reported in the study was comparable to central Himalayan forest (range= 0.33-2.95) reported by earlier workers (Saxena and Singh, 1982, Ralhan *et al.,* 1982, Tripathi *et al.,* 1987, Rikhari, 1990, Bargali, *et al.*, 1997). Higher species diversity is generally thought to indicate a more complex and healthier community because a greater variety of species allows more species interactions, hence greater system stability, and indicates good environmental conditions (Prescott 2002, Giri *et al.,* 2006). A rich ecosystem has a large Shannon-Wiener index (H') value, while an ecosystem with a low value has low species diversity (Sobuj and Rahman, 2011; Deka *et al.*, 2012).

The dispersal limitation is an important link connecting between biotic and abiotic ecological factors to control species distribution pattern (Hubbell *et al.,* 1999). In this study, distribution of most of the trees was contiguous and *T. alata* recorded the maximum contiguous distribution pattern in all studied sites. The analysis of distribution pattern level in study showed that A/F ratio of tree species was in the range from 0.00 for *T. arjuna* to 0.67 for *T. alata*. *T. bellirica* was found in Random distribution in almost all the studied sites except Ghumdhawda forest. The pattern of distribution depends on both physico-chemical natures of the environment as well as on the biological peculiarities of the organisms themselves. Odum (1971) stated that contiguous distribution is common in nature and formed due to small but significant variation in the ambient environmental conditions, while random distribution is found only in uniform environments. Contiguous distribution of varying degree has been observed in many studies of tropical forests of India (Shanmughavel, 1994). Similar findings have also been reported by Kumar *et al.,* (2004) for tropical forest of Garhwal Himalaya. However, Reddy and Ugle (2008) observed regular type of distribution pattern of all *Terminalia* species in tropical forests of Indian Eastern Ghats. The species aggregation relationship predicts that spatial aggregation of individuals within species results in lower species richness (Sagar, *et al*., 2003). Variation in distribution pattern among sites and vegetation composition are associated with micro-environmental and biotic factors (Singhal and Soni, 1989). The current study also suggests that clumped distribution often occurs due to an uneven distribution of nutrients or other resources in the environment.

In regeneration analysis, it has been observed that except *T. alata, B. lanzan* and *A. latifolia* at few sites, all of the trees showed either poor or no regeneration. It is found that tree canopy cover, site characteristics, availability of sunlight on the ground surface and important associated species impacted the regeneration of trees species in the forest (Raj, 2018). The reason behind no regeneration of *T. arjuna* could be the sites where study was carried out are not its natural habitat and hence fully grown seedlings were not found and regeneration was also not observed. As for as *T. chebula* and *T. bellirica* is concerned, as discussed earlier, fruits of both these trees are used Ayurvedic medicine and hence get harvested from the forest before releasing seeds on the ground. Another reason could be due to thick litter accumulation which reduced seed germination of most canopy species (Janzen 1970, Singh & Singh 1992). The forest stands characterized by the abundance of only adults of the species or absence or very low population of seedlings and saplings are expected to face local extinction (Dalling *et al.,* 1998). There could be various reasons behind low regeneration of trees like edapho-climatic factors and biotic interference influence the regeneration of different species in the vegetation. Higher seedling density values get reduced to sapling due to soil characteristics, competition for space and nutrients and biotic disturbance (Raj, 2018). Our results are not in harmony with observations made in other forest of central India.

Based on the above results, it could be concluded that except *T. alata* and *B. lanzan*, rest of all the tree species were not abundant and poor in density. Moreover, study found that selected trees were non-regenerating species in almost all of the studied sites. The species composition of the forest would be affected in future with such non-regenerating species. If the situation continues, selected forests may lose those non-regenerating species forever. Thus, in these forests, management strategies should be planned to promote the regeneration of these identified non-regenerating species. Trees like *T. arjuna* and *T. bellirica* were found very less in diversity. This study will serve as a primary input towards the diversity of selected plants and also would help in designing the conservation policies. All these selected trees have medicinal value and socioeconomic importance. Therefore, there is a need for necessary action towards sustainability of forest and conservation of species at large. The most important conservation measure is environment education, explaining the importance of forest ecosystem to the villagers. The implementation of the conservation activities will lead to a natural regeneration, climate change mitigation and to protect the biodiversity for future generations.

## Acknowledgment

The authors are thankful to Forest Department of Gondia, Government of Maharashtra for providing necessary permission to carry out the studies at different forest sites in Gondia district.

## References

**Agni T, Pandit A, Pant K and Tewari A. 2000.** Analysis of Tree Vegetation in the Tarai-Bhabhar Tract of Kumaun Central Himalaya. Indian Journal of Forestry. 23(2): 252-261.

**Appiah M. 2013.** Tree population inventory, diversity and degradation analysis of a tropical dry deciduous forest in Afram Plains, Ghana. Forest Ecology Management. 295: 145-154.

**Bargali SS and Singh RP. 1997.** *Pinus patula* plantations in Kumaun Himalaya. I. Dry matter dynamics. Journal of Tropical Forest Science. 9(4): 526-535.

**Campbell MJ, Edwards W, Magrach A, Laurance SG, Alamgir M, Porolak G and Laurance WF. 2017.** Forest edge disturbance increases rattan abundance in tropical rain forest fragments. Scientific Reporter. 7(1): 6071.

**Chow J, Doria G, Kramer R, Schneider T and Stoike J. 2013.** Tropical forests under a changing climate and innovations in tropical forest management. Trop. Conserv. Sci. 6(3): 315 324.

**Dalling JW, Hubbell SP and Silvera K. 1998.** Seed dispersal, seedling establishment and gap partitioning among tropical pioneer trees. Journal of Ecology. 86: 674-689.

**Davidar P, Rajagopal B, Mohandass D, Puyravaud JP, Condit R, Wright SJ and Leigh EG. 2007.** The effect of climatic gradients, topographic variation and species traits on the beta diversity of rain forest trees. Global Ecology and Biogeography. 16(4): 510-518.

**Deka J, Tripathi OP and Khan ML 2012.** High Dominance of *Shorea robusta* Gaertn. in Alluvial Plain Kamrup Sal Forest of Assam, N. E. India. International Journal of Ecosystem. 2(4): 67-73.

**Denslow JS. 1980.** Gap partitioning among Tropical Rain Forest trees. Biotropica. 12 (Suppl.): 47-55.

**Giri D, Tewari A and Rawat YS. 2006.** Vegetation Analysis in mixed Banj (*Q. leucotricophora*, A. Camus) Tilonj Oak (*Q. floribunda*, Lindl.) forests in Nainital catchment. Indian Journal of Forestry. 31(2): 167-174.

**Good NF and Good RE. 1972.** Population dynamics of tree seedlings and saplings in mature Eastern hardwood forest. Bull Torrey Bot. Club. 99.

**Grubb PJ. 1977.** The maintenance of species richness in plant communities: The importance of the regeneration niche. Biological Review. 52: 107-145.

**Hubbell SP, Foster RB, O'Brien ST, Harms KE, Condit R, Wechsler B, Wright SJ and De Lao SL. 1999.** Light-gap disturbances, recruitment limitation, tree diversity in a neotropical forest. Science. 283(5401): 554-557.

**Janzen DH. 1970.** Herbivores and the number of tree species in tropical forest. American Naturalist. 104: 501-528.

**Kacholi DS. 2014.** Analysis of Structure and Diversity of the Kilengwe Forest in the Morogoro Region, Tanzania. International Journal of Biodiversity. 516840: 8.

**Kent M and Coker P. 1992.** Vegetation description and analysis. London, UK: Balhaven Press.

**Knight DH. 1975.** A phytosociological analysis of species-rich tropical forest on Barro Colorado Island, Panama. Ecological Monographs. 45(3): 259-284.

**Kumar M, Sharma CM and Rajwar GS. 2004.** A study on the community structure and diversity of a sub-tropical forest of Garhwal Himalayas. Indian Forester. 130(2): 207-214.

**Mengistu T, Teketay D, Hulten H and Yemshaw Y. 2005.** The role of enclosures in the recovery of woody vegetation in degraded dryland hillsides of central and northern Ethiopia. Journal of arid environments. 60(2): 259-281.

**Misra R. 1968.** Ecology work book. Oxford and IBH Publishing Company, New Delhi.

**Myers N, Mittermeier RA, Mittermeier CG, Da Fonseca GA and Kent J. 2000.** Biodiversity hotspots for conservation priorities. Nature. 403(6772): 853.

**Ndah NJ, Andrew EE and Bechem E. 2013.** Species composition, diversity and distribution in a disturbed Takamanda Rainforest, South West, Cameroon. African Journal of Plant Science. 7(12): 577-585.

**Odum EP. 1971.** Fundamentals of Ecology. III ed. W.B. Saunders Co., Philadelphia. USA.

**Padalia H, Chauhan N, Porwal MC and Roy PS. 2004.** Phytosociological observations on tree species density of Andaman Islands, India. Current Science. 87(6): 799-806.

**Pala NA, Negi AK, Gokhale Y, Bhat JA and Tadoria NP. 2012.** Diversity and regeneration status of sarkot Van Panchayat in Gharwal Himalaya, India. Journal of Forest Research. 23: 399 404.

**Poorter L, Bongers F, Aide TM, Zambrano AMA, Balvanera P, Becknell JM and Chazdon RL. 2016.** Biomass resilience of Neotropical secondary forests. Nature. 530: 211-214.

**Pragasan LA and Parthasarathy N. 2010.** Landscape-level tree diversity assessment in tropical forests of southern Eastern Ghats, India. Flora - Morphology, Distribution, Functional Ecology of Plants. 205: 728-737.

**Prescott CE. 2002.** The influence of the forest canopy on nutrient cycling. Tree Physiology. 22: 1193-1200.

**Raj A. 2018.** Population structure and regeneration potential of Sal dominated tropical dry deciduous forest in Chhattisgarh, India. Tropical Plant Research. 5(3): 267-274.

**Ralhan PK, Saxena AK and Singh JS. 1982.** Analysis of forest vegetation at and around Naini Tal in Kumaun Himalaya. Proceedings of Indian National Science Academy. 48: 121-137.

**Reddy SC and Ugle P. 2008.** Tree Species Diversity and Distribution Patterns in Tropical Forest of Eastern Ghats, India: A case study. Journal of Life Science. 5(4):87-93.

**Rikhari HC. 1990.** Biomass input and Habitat role of course woody debris in a mixed Oak forest in Kumaun Himalaya. Ph.D. Thesis, Kumaun University, Nainital.

**Rozendaal DMA and Chazdon RL. 2015.** Demographic drivers of tree biomass change during secondary succession in northeastern Costa Rica. Ecological Applications. 25(2): 506-516.

**Sagar R, Raghubanshi AS and Singh JS. 2003.** Tree species composition, dispersion and diversity along a disturbance gradient in dry tropical forest region of India. Forest Ecology & Management. 186: 61-71.

**Saxena AK and Singh JS. 1982.** A phytosociological analysis of woody species in forest communities of a part of Kumaon Himalaya. Vegetation. 50: 3-22.

**Shanmughavel P. 1994.** Phyto-sociological studies of Dimbam Hill, Sathyamangalam Forest Division, Tamil Nadu. Van Vighyan. 32(4): 80-85.

**Shannon CE and Wienner W. 1963.** The Mathematical Theory of Communication, University of IIIinois, Urana.

**Simpson EH. 1949.** Measurement of Diversity. Nature. 163: 688.

**Singh E and Singh MP. 2010.** Biodiversity and Phytosociological Analysis of Plants around the Municipal Drains in Jaunpur. International Journal of Biological, Biomolecular, Agricultural, Food and Biotechnological Engineering. 4(1): 84-89.

**Singh JS and Singh SP 1992.** Forest of Himalaya: Structure and Functioning & Impact of Man. Gyanodya Prakashan, Nainital.

**Singh NP and Karthikeyan S. 2000.** Flora of Maharashtra state: Dicotyledons, Vol I, Botanical Survey of India, Howrah, Calcutta, India.

**Singhal RM and Soni S. 1989.** Quantitative ecological analysis of some woody species of Mussoorie Himalayas (UP). Indian Forester. 115(5): 327- 336.

**Sinu PA. 2012.** Seed predators of an old-world tropical deciduous tree (*Terminalia bellirica*: Combretaceae) in wet habitats of the Western Ghats, India. Current Science. 103(3): 309-315.

**Sobuj NA and Rahman M. 2011.** Comparison of Plant Diversity of Natural Forest and Plantations of Rema-Kalenga Wildlife Sanctuary of Bangladesh. Journal of Forest Science. 27(3): 127-134.

**Sunil C, Somashekar RK and Nagaraja BC. 2019.** Influence of *Terminalia arjuna* on the riparian landscapes of the River Cauvery of South India. Landscape Research. 44(8): 982-996.

**Tripathi BS, Rikhari HC and Singh RP. 1987.** Dominance and diversity distribution in certain forest of Kumaun Himalayas. IX International Symposium on Tropical Ecology. Pp:235.

**Tripathi RS and Khan ML 2007.** Regeneration dynamics of natural forest- A review. In Proceeding of Indian National Science Academy. 73: 167-195.

**Turkis S and Elmas E. 2018.** Tree species diversity and Importance value of different forest communities in Yenice forests. Fresenius Environmental Bulletin. 27(6): 4440-4447.

**Ved DK, Sureshchandra ST, Barve V, Srinivas V, Sangeetha S, Ravikumar K and Desale N. 2016.** FRLHT's ENVIS Centre on medicinal plants, Bengaluru. Copyright: FRLHT, Bengaluru and MoEFCC, GOI. (envis.frlht.org/frlhtenvis.nic. in). Retrieved from http:// envis.frlht.org.

**Wassie A, Teketay D and Powell N. 2005.** Church forests in north Gonder administrative zone, northern Ethiopia. Forests, trees and livelihoods. 15(4): 349-373.

**Whitford PB. 1949.** Distribution of woodland plants in relation to succession and clonal growth. Ecology. 30: 199-208.

**Young Tanner M. 2023.** Online Biodiversity calculator. https://www.alyoung.com/labs/biodiversity_calculator.html.

**Zegeye H, Teketay D and Kelbessa E. 2006.** Diversity, regeneration status and socio-economic importance of the vegetation in the islands of Lake Ziway, South-Central Ethiopia. Flora. 201(6): 483-49.