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Measurement of Diversity in the Floristic Angiospermic Taxa of Nawada, Bihar (India)

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Abstract: *The floristic composition and biodiversity in the fourteen blocks of Nawada District were studied. A total of 105 plant species belonging to 34 families, 75 genera and 5 life forms were recorded. Fabaceae, Moraceae, Meliaceae and Apocyanaceae were the overall diverse families (in terms of species richness) of the adult species, contributing 44.5% of all the species in the study. Trees were the most dominant life form (48.5%) followed by lianas (16.8%), herbs (10.9%), epiphytes (8.9%), shrubs (3.9 %) and the others (4.7%). Species richness among all life forms was highest in the Nda (90.5%) followed by Ap (87.6%), Pb (77%), Sda (73%), Ha (70.25%) and Gp (68.95%). Fabaceae, Moraceae and Meliaceae and Apocyanaceae were the most diverse families distributed in all the fourteen blocks of Nawada.*

The trees in all the forest types studied were generally tall. The difference in height of tree species could be partly explained by degradation in the form of logging of tall and big trees which has undoubtedly affected the vertical structure. Even though tree size (dbh) correlated with tree height in all the forest types, the relationship was stronger (r = 0.741 to 0.368; p = 0.000- 0.002). Thus, dbh of trees could be a better predictor of tree height.

There were a total of 4167 individuals of woody species (excluding epiphytes) identified in the forest areas of fourteen blocks. Trees were more abundant (2916 individuals/ha) followed by lianas (1603 individuals/ha) and shrubs (248 individuals/ha). Tree density was greatest in the Kac (290/ha) followed by Gp (287/ha), Mkr (285/ha),Ha (280/ha), Sda (250/ha), Rh (215/ha) and Rjl (214/hac). Density of Liana was maximum in Pb(126/ha) followed by Sda (124/ha), Nda (121/ha), and Wg and Nht (108/ha each) . Other areas have low density of Liana. Similarly density of shrubs was maximum in Ab(19/ha) followed by Kal and Kac(17/ha), Rjl (18/ha), Rh (16/ha) and Sda (15/ha). Others have low density of shrubs. Shannon-Wiener index was greater in the Ap (H´ = 3.80) compared to Mkr (H´= 3.70) and Rjl, Gp, Pb and Kal (H´ =23.50 to 3.60). Others have H´ value of less than 3.0. Density of plant species differed significantly between the forest types (F=8.96: df = 2; p = 0.000). In all, C. mildbraedii was by far the most abundant species accounting for an average 10% of stems in all the habitats whereas T. scleroxylon was the most dominant species in terms of basal area representing 25% on the average. The overall dominant species in terms of the species importance value (average) were T. scleroxylon (28.2) and C. mildbraedii (23.7). The commonest species were C. mildbraedii and Alafia barteri with the average occurrence of 6.8 and 5.2 % respecttively. On forest type basis C. mildbraedii, C. zenkeri, L. welwitschii, Ansiona altissima, N. papaverifera and T. scleroxylon were the dominant species in all the forest areas of eighteen blocks (Table 3). B. papyrifera, C. mildbraedii, N. papaverifera, P. africanum and S. oblonga were the donant species in terms of basal area representing 25% on the average. The overall dominant species in terms of the species importance value (average) were T. scleroxylon (28.2) and C. mildbraedii (23.7). The commonest species were C. mildbraedii and Lafia barteri with the average occurrence of 6.8 and 5.2 % respectively.

The forest reserve of Nawada looks floristically rich and structurally complex in the face of logging, farming activities and invasion in some parts of the forest. Thus, there is the need to curb the anthropogenic activities and plant invasion so as to protect the integrity of the forest including medicinal plants.

Key Words: Floristic composition, Diversity measurement, Forest area, Rajouli, Kawakol

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I. Introduction

Nawada district is one of the thirty-seven districts of Bihar state, India, and Nawada town is the administrative headquarters of this district. Nawada district occupies an area of 2492 km² and is located at 24.88N 85.53E with an average elevation of 80 meters (262 feets). This district lies on both sides of the river Khuri in $24^0$53'N and 85^0 33'E, and includes two sub divisions viz. **Nawada** and **Rajauli** and fourteen blocks viz. **Kawakol,Varsaliganj,**

Nawadah, Rajouli, Akbarpur, Hisua, Narhat, Govindpur, Pakribarawan, Sirdalla, Kasichak, Roh, Nardiganj and Meskaur. Paddy is the main agricultural crop grown in this area. The climatic conditions of Nawada are somewhat dry and healthy. The winter, summer and rainy seasons are well marked. The overall rainfall is 1142.3mm with maximum i.e. around 92% of rainfall being received during monsoon months.

Google Map of Nawada

Map of Fourteen Blocks of Nawada District

Angiosperms are seed-bearing vascular plants. Their reproductive structures are flowers in which the ovules are enclosed in an ovary. Angiosperms are found in almost every habitat from forests and grasslands to sea margins and deserts. Angiosperms display a huge variety of life forms including trees, herbs, submerged aquatics, bulbs and epiphytes. The largest plant families are Orchidaceae, Compositae and Leguminosae. There are an estimated 352,000 species of flowering plants or angiosperms. The angiosperms provide valuable pharmaceuticals. With the exception of antibiotics, almost all medicinal either are derived directly from compounds produced by angiosperms or, if synthesized, were originally discovered in angiosperms. This includes some vitamins (e.g., vitamin C, originally extracted from fruits); aspirin, originally from the bark of willows (*Salix;* Salicaceae); narcotics (e.g., opium and its derivatives from the opium poppy, *Papaver somniferum;* Papaveraceae); and quinine from *Cinchona (*Rubiaceae) bark. The contribution of the angiosperms to biodiversity and habitat is so extremely important that human life is totally dependent on it. A significant loss of angiosperms would reduce the variety of food sources and oxygen supply in a habitat and drastically alter the amount and distribution of the world's precipitation. Many sources of food and medicine doubtless remain to be discovered in this group of vascular plants (Purseglove, 1968) [1].

The importance of documenting the plants of Nawada District is undeniable considering its status as a forest divisiobn with biological megadiversity on one hand and the accelerated destruction of its ecosystems on the other. However, a flora of Nawada District is unavailable, and we do not even have a reliable published list of species.

Water logging is an important determinant of species distribution and ranks alongside water shortage, salinity, and extreme temperatures as major abiotic stresses (Visser *et al* ., 2003) [2]. The consequences of water logging to terrestrial plants can be fatal, because, as aerobic respiration ceases, levels of energy-rich adenylates drop rapidly, causing a dramatic decline in ion uptake and transport (Huang *et al.*, 2003; Vartapetian *et al.*,

2003) [3, 4]. Even if a short period of water logging does not kill vegetation, it has considerable long-term effects on plant growth (Malik *et al.,* 2002) [5], reducing the competitive abilities of species. Wherever water logging causes local extinctions of intolerant species, it may shape the composition of the local assemblages (Nicol *et al.,* 2003; Visser *et al.,* 2003) [6, 2].

The current composition of an assemblage is thought to be the result of different historical sequences of species entering the locality and ecological constraints acting as environmental filters (Chase, 2003) [7]. Their relative influence on assemblage composition has been the subject of much debate (Gentry, 1988; Kinzig *et al.,* 1999; Chase, 2003) [8, 9, 7]. However, since theoretical models (e.g. Law & Morton, 1996) [10] and controlled experiments (e.g. Tilman *et al* ., 1986; Sommer, 1991) [11, 12] often find little or no effect of history, even when the history in which species invade a community is highly variable, environmental constraints should play the major role in determination of communities. The most practical way for summarizing the processes that structure the community is through a measure of diversity (Magurran, 2004; Hooper *et al.,* 2005) [13, 14]. Nevertheless, it has become clear that simple estimation of species diversity is a very crude estimation of community structure (Ricotta, 2005) [15]. Consequently, responses of assemblages to environmental constraints are better understood, when the entire taxonomic hierarchy is considered (Warwick & Clarke, 1995; Rogers *et al.,* 1999; Ricotta *et al.,* 2005) [16, 17, 15]. For example, if an environmental filter acts replacing a community in which most species belong to the same genus by others with similar abundances but from different genera, small-scale analyses of specific diversity or abundance will not reveal the constraint effects of environment on community (Ricotta *et al.,* 2005) [15]. Also, specific diversity or richness is difficult to relate to community disturbance, because the diversity–productivity relationship remains controversial (Grace, 1999; Mackey & Currie, 2001; Hooper *et al.,* 2005) [18, 19, 14]. Thus, contemporary ecological processes that structure community composition may be better understood, when a measure of phylogenetic distance of the species (phylogenetic relatedness) within the community is used (Webb, 2000; Webb *et al.,* 2002) [20, 21].

Clarke and Warwick (1998) [22] proposed a method to measure the taxonomic distinctness and taxonomic diversity of a community that was shown to be very sensitive to perturbation, robust with respect to differences in sampling methods, and appropriate to assess differences among communities (Warwick & Clarke, 1995; Rogers *et al.,* 1999; Magurran, 2004) [16, 17, 13]. Whereas taxonomic distinctness is purely a measure of phylogenetic relatedness of species, taxonomic diversity mixes phylogenetic relatedness with the evenness properties of abundance distribution (Clarke & Warwick, 1998) [22]. Another diversity measure that seems very adequate to capture the changes in community structure is the 'expected taxonomic distinctness', which combines species relative abundances with their taxonomic distinctiveness and allows one to set the index sensitivity to differences in the domain of rare species (Ricotta, 2004; Ricotta *et al.,* 2005) [23, 15]. The taxonomic distinctiveness refers to the distinctiveness of a particular species in relation to the rest of the community and differs from taxonomic distinctness, which is a property of the community as a whole (Warwick & Clarke, 2001) [24]. Species are usually treated as equivalent units, with independent functional traits (Petchey and Gaston, 2002; Hooper *et al.,* 2005) [25, 14]. Nevertheless, because of the conservatism of many species traits in the evolution of a lineage, there is, in general, a positive relationship between a measure of the phylogenetic relatedness of two species and a measure of their overall life history and ecological similarity (Harvey and Pagel, 1991; Silvertown *et al.,* 1997) [26, 27]. Congeners generally occupy similar ecological niches, and the competition by the same resources may lead to a local extinction of species in a genus (Webb, 2000) [20]. For these reasons, analyses involving phylogenetic relationships of species (phylogenetic structure) within communities also provide insight into their ecological similarity (Webb, 2000; Webb *et al*., 2002) [20, 21].

In the present investigation two forest divisions of Nawada viz. Rajauli and Kawakol covering fourteen blocks viz. Nawada (Nda), Akbarpur (Ap), Warisaliganj (Wg), Pakribarawan (Pb), Sirdala (Sda), Rajauli (Rjl), Roh (Rh), Kawakol (Kal), Hisua (Ha), Nardiganj (Ndg), Narhat (Nht), Gobindpur (GP), Meskaur (Mkr) and Kashichak (Kac) were selected for biodiversity measurement. Both divisions are physiognomically similar: grasslands, with few scattered shrubs and dwarf trees and trees.

II. Materials and Methods

The flowering plants were collected from May 2015 to April 2016 and identified and their dbh (diameter at breast height) measured with a diameter tape. The height of all plants was determined with clinometers. In each quadrate all trees (dbh ≥ 10 cm) were examined for the presence of climbers (lianas with dbh ≥ 2 cm and vines). Trees were also surveyed for epiphytes according to the method described by Addo-Fordjour et al. (in press). Trees (dbh ≥ 10 cm) were classified into four groups based on their height; understorey (< 20 m), lowe canopy (20-30 m), upper canopy (30-40 m) and emergent (> 40 m) species. The percentage canopy cover of each plot was determined by a spherical densitometer. At each plot four readings from the four cardinal directions were taken at four different points. The average of all readings for plots in each block (14 readings) was calculated and used as the percentage canopy cover of that forest type (Anning *et al*., 2008) [28].

The diameter of lianas was determined at 1.3 m from the rooting base (Addo-Fordjour *et al*., 2009) [29]. Each quadrate of 25 m x 25 m was subdivided into twenty-five 5 m x 5 m small quadrates and fifteen of these (accounting for 60% of the plot area) were randomly sampled for herbs and regeneration of the tree species. All herbs with (≤ 2 m high with dbh < 10 cm) were identified and counted. Identification was performed by a plant taxonomist aided by manuals and Floras (Hawthorne, 1990; Arbon- nier, 2004; Poorter *et al*., 2004; Hawthorne and Jongkind, 2006) [30, 31, 32, 33]. Identification of the species was confirmed at the KNUST, Kumasi and the Forestry Commission, Kumasi herbaria.

Data Analysis: For calculating the species composition, abundance, and diversity indices at the transect level, the following common variables were used: basal area, relative dominance, and relative frequency following Phillips et al., (1994) [34].

$$\textbf{Frequency} = \frac{\textbf{Number of sampling units (quadrates) in which a species occurs}}{\textbf{Total number of sampled units studied}} \times 100$$

$$\textbf{Density} = \frac{\textbf{Total number of individuals in all sampling units}}{\textbf{Total number of sampled units studied}} \times 100$$

$$\textbf{Abundance} = \frac{\textbf{Total number of individuals in all sampling units}}{\textbf{Total number of sampling units of occurrence}} \times 100$$

The basal area was calculated using the following formula:

Basal area of a single tree = $\pi_X r^2$
r = radius, $\pi = 3.14$
Basal cover (m2/ha) for shrub and tree species obtained by adding value of all species together and presented as follows:

$$BC = \frac{\sum_{i=I}^{sh} BASh}{PA}, \quad \frac{\sum_{k=I}^{m} BAT}{PA}$$

where BC = basal cover or basal area, Sh = shrubs, and m = tree and BASh and BAT are basal area for shrub, tree species respectively, and PA = plot area or quadrat. The total basal cover calculated by the multiplying mean basal cover and density of the species.

Diversity Indices: Diversity is a combination of two factors; the number of species present, species richness, and the distribution of individuals among the species are referred to as evenness or equitability. Whittaker distinguishes three types of diversity.

1. alpha diversity—diversity within a particular area or ecosystem,
2. beta-diversity—the change in diversity between ecosystems, and
3. gamma diversity—the overall diversity of a landscape comprising of several ecosystems.

The two most widely used species diversity indices are Shannon and Simpson indices. They are adopted by ecologists to describe the average degree of uncertainty in predicting the species of an individual picked at random from a given community. As the number of species increases, the uncertainty of occurrence also increases along with distribution of individuals, more evenly among the species already present.

The Shannon–Wiener Index or species diversity (Whitt, when properly manipulated, always results in a diversity value (H′) ranging between 0, indicating a low community complexity and 4 and above indicating high community complexity. Species diversity (H′) was computed following the Shannon and Weiner (1963) [35] information index as follows:

$$H' = \sum \frac{ni}{N} log \frac{ni}{N}$$

where ni is the total density value for species, i, and N is the sum of the density values of all the species in that site.

Beta-diversity (β) among all the studied forests was calculated following the method given by Whittaker (1975) [36].

$$\beta = \sum \frac{Sc}{S}$$

where N = total number of species and n = number of species in a given community.

Richness: The number of species per sample is a measure of richness. The more species present in a sample, the "richer" the sample.

Evenness: Evenness is a measure of the relative abundance of different species making up the richness of an area. A community dominated by one or two species is considered less diverse than the one in which several different species a similar abundance.

Species richness and evenness increase, so does diversity. Simpson diversity index is a measure of diversity which takes into accounts both richness and evenness. The term "Simpson's Diversity Index" can actually refer to any one of 3 closely related indices. Simpson's Index (D) measures the probability of two individuals randomly selected from a sample belonging to the same species (or some category other than species).

$$\text{Simpson index (D)} = \frac{\sum n\,(n-1)}{\sum N\,(N-1)}$$

where N = total number of species and n = number of species in a given community.

The angiospermic flora of two forest divisions viz. Rajauli and Kawakol were sampled in all seasons: at mid-rainy season, when the both the forest divisions were waterlogged; at late rainy season; at dry season; at early rainy season; and again at mid rainy season. In each survey, ten $1m^2$ quadrats were placed randomly, in which all the vascular planta were sampled. The total sampling effort, thus, was 50 quadrats in each vegetation form. We counted the number of individuals belonging to each species was counted. In the case of cespitose grasses and sedges, we considered as an individual the whole tuft. The species was identified following standard monograph by comparing the collected material, and stored in the form of herbarium.

The data from all surveys were used to construct the phylogenetic tree and compute the taxonomic distinctness (Δ*), the taxonomic diversity (Δ), and the expected taxonomic distinctness (*T* (*m*)) of both forest divisions.
The *T (m*) value was computed following the procedure described by Ricotta (2004) [23] and Ricotta *et al.*,(2005) [15]. The values of *N (m*) was calculated by the equation:

$$N\,(m) = \sum_{i=1}^{N}(1-(1-pi)^{m}$$

Where *pi* is the proportion of individuals belonging to the *I* th species and *m* is the sensitivity to rare species. By increasing the value of the parameter *m* , one can enhance the sensitivity of this index to the least abundant species, and the expected species diversity will be more and more sensitive to the abundances of awider range of species and not only the most abundant ones
(Ricotta *et al.*, 2005) [15]. Then, we computed the pairwise species distances (d *ij)* based on the topological distance (i.e. the number of edges) between the *I* th and the *j* th species in the taxonomic tree of each vegetation form, obtaining a species distance matrix. After that, we computed the taxonomic distinctiveness *wi* of each species, adding all *d ij* elements along row *I* of this matrix and dividing the result by the number of non-zero distances K − 1. Finally, we determined the expected taxonomic distinctness, by increasing values of the parameter *m* through the equation:

$$T\,(m) = \frac{\sum_{i=1}^{N} wi\,(1-pi)^{m}}{N(m)}$$

The *m* values were selected arbitrarily that were equally spaced on a log 2 scale ranging from *m* = 1 (log 2 *m* = 0) to *m* = 32,768 (log 2 *m* = 15), as suggested by Ricotta *et al*., (2005) [15]. To check whether the *T* (*m*) from the two forest divisions were different, their *N* (*m*) against log 2 *m* profiles were compared. The species, genus, and family similarities between the two forest divisions were also calculated with the abundance-based Chao estimator for Sørensen index (Chao– Sørensen), which reduces under sampling bias by estimating and compensating for the effects of unseen, shared species (Chao *et al.*, 2005) [37]. We calculated the Chao–Sørensen index and its standard deviation (SD) using the Estimate S 7.5 software (Colwell, 2005) [38]. Confidence intervals (CI) of each Chao–Sørensen index was obtained by multiplying the standard deviation value by the upper 2.5% limit of the *t* -distribution with *n* – 1 degrees of freedom (Manly, 1997) [39].

The number of species of angiospermic flora (Dicotyledonous and Monocotyledonous species) and their percentage occurrence in forest divisions of Nawada have been estimated using geometric mean (G) and logarithmic version as follows:

$$G = \sqrt[n]{x1\,.x2\ \ldots\ x_n} = \sqrt[n]{\prod_{i=1}^{n} xi}$$

$$\log G = \frac{\sum_{i=1}^{n} \log\,(xi)}{n}$$

III. Results

The angiospermic flora collected from two forest divisions of Nawada, their family and habit has been presented in Table-1. The abundance and dominance of Angiospermic flora have been presented in Table-2. The characteristics of the Floristic composition and structure of the Angiospermic flora in fourteen blocks of Nawada are illustrated in Table-3.

Table-1: Important Angiospermic flora of Nawada

Species	Family	Habit
Acacia kamerunensis Gand.	Fabaceae	Liana
Acanthaceae sp	Acanthaceae	Herb
Acacia pentagona (Schum. & Thonn.) Hooker f	Fabaceae	Liana

Afromomum sp	Zingiberaceae	Herb
Afzelia bella Harms	Fabaceae	Herb
Aidia genipiflora (DC.) Dandy	Rubiaceae	Tree
Alafia barteri Oliv	Apocynaceae	Liana
Albizia adianthifolia (Schum.) W.F. Wight	Fabaceae	Tree
Albizia glaberrima (Schum. & Thonn.) Benth	Fabaceae	Tree
Albizia zygia (DC.) J.F. Macbr	Fabaceae	Tree
Alstonia boonei De Wild	Apocynaceae	Tree
Amphimas pterocarpoides Harms	Fabaceae	Tree
Anchomanes difformis (Blume) Engl.	Araceae	Herb
Antiaris toxicaria (Rumph ex Pers.) Leschen	Moraceae	Tree
Antrocaryon micraster A. Chev. & Guillaum	Anacardiaceae	Tree
Baphia nitida Lodd.	Fabaceae	Tree
Baphia pubescens Hook.f.	Fabaceae	Tree
Blighia sapida Kon.	Sapindaceae	Tree
Blighia welwitschii (Hiern) Radlk	Sapindaceae	Tree
Bombax buonopozense P.Beauv.	Bombacaceae	Tree
Bridelia atroviridis Müll.Arg.	Euphorbiaceae	Tree
Bridelia grandis Pierre ex Hutch.	Euphorbiaceae	Tree
Broussonetia papyrifera Vent.	Moraceae	Tree
Bussea occidentalis Hutch.	Fabaceae	Tree
Calpocalyx brevibracteatus Harms	Fabaceae	Tree
Calycobolus africanus (G.Don) Heine	Convolvulaceae	Tree
Calyptrochilum emarginatum Schltr.	Orchidaceae	Epiphyte
Ceiba pentandra (L.) Gaertn.	Bombacaceae	Tree
Centrocema pubescens Benth.	Fabaceae	Herb
Chromolaena odorata (L.) King & Robinson	Asteraceae	Herb
Chrysophyllum perpulchrum Mildbr. Ex Hutch. & Dalziel	Sapotaceae	Tree
Chrysophyllum sp.	Sapotaceae	Tree
Cissus sp.	Vitaceae	Liana
Combretum bipindense Engl. & Diels	Combretaceae	Liana
Combretum smeathmannii G.Don	Combretaceae	Liana
Combretum sp.	Combretaceae	Liana
Cordia millenii Baker	Boraginaceae	Tree
Cordia senegalensis Juss.	Boraginaceae	Tree
Corynanthe pachyceras K.Schum.	Rubiaceae	Tree
Rhaphidophora 51uperb51e N.E.Br.	Araceae	Vine
Dalbergia 51uperb51e Benth.	Fabaceae	Liana
Diospyros viridicans Hiern	Ebenaceae	Tree
Entandrophragma angolense (Welw.) DC.	Meliaceae	Tree
Ficus asperifolia Miq.	Moraceae	Shrub
Ficus 51uperb51e5151 Vahl	Moraceae	Shrub
Ficus sur Forssk.	Moraceae	Tree
*Ficus tessellata*Warb.	Moraceae	Epiphyte
Ficus thonningii Blume	Moraceae	Epiphyte
Ficus trichopoda Baker	Moraceae	Epiphyte
Ficus 51uperb51e51 Vahl	Moraceae	Epiphyte
Ficus vogelii Miq.	Moraceae	Epiphyte
Funtumia 51uperb51 (Preuss) Stapf	Apocynaceae	Tree
Griffonia simplicifolia (Vahl ex DC.) Baill.	Fabaceae	Liana
Guarea cedrata (A.Chev.) Pellegr.	Meliaceae	Tree
Hippocratea sp.	Celastraceae	Liana

Hymenostegia afzelii (Oliv.) Harms	Fabaceae	Tree
Khaya anthotheca (Welw.) C.DC.	Meliaceae	Tree
Khaya grandifolia C.DC.	Meliaceae	Tree
Khaya ivorensis A.Chev.	Meliaceae	Tree
Lannea welwitschii (Hiern) Engl.	Anacardiaceae	Tree
Lecaniodiscus cupanioides Planch. Ex Benth.	Sapindaceae	Tree
Leptoderris sp.	Fabaceae	Liana
Lovoa trichilioides Harms	Meliaceae	Tree
Macaranga heudelotii Baill.	Euphorbiaceae	**Tree**
Mansonia altissima (A.Chev.) A.Chev.	Sterculiaceae	Tree
Marantocloa leucantha (K.Schum.) MilneRedh	Marantaceae	Herb
Microdesmis puberula Hook.f.	Pandaceae	Tree
Microsorum punctatum (L.) Copel.	Polypodiaceae	Epiphyte
Microsorum scolopendria Copel	Polypodiaceae	Epiphyte
Milicia 52uperb (Welw.) C.C.Berg.	Moraceae	Tree
Millettia chrysophylla Dunn	Fabaceae	Liana
Morinda lucida Benth.	Rubiaceae	Tree
Morus mesozygia Stapf	Moraceae	Tree
Motandra guineensis (Thonn.) A.DC.	Apocynaceae	Liana
Myrianthus arboreus P.Beauv.	Cecropiaceae	Tree
Olyra latifolia L.	Poaceae	Herb
Panicum maximum Jacq.	Poaceae	Grass
Parquetina nigrescens (Afzelius) Bullock	Asclepiadaceae	Liana
Pennisetum purpureum K.Schum.	Poaceae	Grass
Piptadeniastrum africanum (Hook.f.) Brenan	Fabaceae	Tree
Pisonia 52uperb52e L.	Nyctaginaceae	Liana
Pteris sp.	Pteridaceae	Fern
Pycnanthus angolensis (Welw.) Warb.	Myristicaceae	Tree
Ricinodendron heudelotii (Baill.) Pierre ex Pax	Euphorbiaceae	Tree
Atropa belladonna L.	Solanaceae	Herb
Digitalis spp. Linn.	Scrophulariaceae	Herb
Rauwolfia serpentine Benth. Ex Kurtz.	Apocyanaceae	Undershrub
Catheranthus roseus	Apocyanaceae	Herb
Rinorea oblongifolia (C.H. Wright) Marquand ex Chipp	Violaceae	Tree
Salacia elegans Welw. Ex Oliv.	Celastraceae	Liana
Salacia owabiensis Hoyle	Celastraceae	Liana
Salacia sp.	Celastraceae	Liana
Smilax kraussiana Meisn.	Smilacaceae	Liana
Sterculia oblonga Mast.	Sterculiaceae	Tree
Sterculia rhinopetala K.Schum.	Sterculiaceae	Tree
Sterculia tragacantha Lindl.	Sterculiaceae	Tree
Terminalia 52uperb Engl. & Diels	Combretaceae	Tree
Trichilia monadelpha (Thonn.) J.J.de Wild	Meliaceae	Tree
Trichilia prieureana A.Juss.	Meliaceae	Tree
Trilepisium madagascariense DC	Meliaceae	Tree
Capsicum sp	Solanaceae	Herb
Abutilon indicum	Malvaceae	Shrub
Adhatoda vasica	Acanthaceae	Shrub
Caesalpinia bonducela	Caesulpinaceae	Tree
Cryptostegia grandiflora	Asclepiadaceae	Shrub

Table-2: Abundance and dominance of woody angiospermic flora in all the fourteen blocks of Nawada District

Species	Nda	Ap	Wg	Pb	Sda	Rjl	Rh	Kal	Ha	Ndg	Nht	GP	Mkr	Kac
Acacia kamerunensis	-	-	0.25	0.55	0.57	0.25	0.75	1.25	-	-	-	-	0.65	-
Acacia pentagona	-	-	0.35	0.35	0.65	0.26	0.55	0.15	0.25	0.65	-	-	0.35	-
Acanthaceae sp	0.67	0.75	-	-	-	-	-	-	0.55	-	-	-	0.65	-
Afromomum sp	-	-	-	-	-	-	-	-	-	-	0.55	0.65	0.35	-
Afzelia bella	-	-	-	-	-	0.57	-	-	-	-	-	-	0.65	-
Aidia genipiflora	-	-	-	-	-	0.58	-	-	-	-	-	-	0.45	-
Alafia barteri	-	-	-	-		0.55	-	-	-	-	-	-	0.65	-
Albizia adianthifolia	2.55	3.5	5.6	6.5	7.5	7.5	4.5	4.5	6.5	7.5	3.4	7.5	6.5	-
Albizia zygia	3.5	2.6	-	-	-	1.5	-	-	-	-	-	0.75	6.0	-
Alstonia boonei	-	-	-	-	-	5.5	-	-	-	-	-	-	-	-
Amphimas pterocarpoides	-	-	-	7.5	-	-	-	-	-	5.5	-	-	-	6.5
Anchomanes difformis	-	-	-	-	-	-	-	-	-	-	8.5	-	-	-
Antiaris toxicaria	2.5	-	-	-	-	-	4.6	-	-	-	-	-	-	-
Antrocaryon micraster	-	-	0.5	-	-	-	1.5	-	3.5	-	-	-	-	-
Baphia nitida	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Baphia pubescens	0.55	-	-	-	-	-	-	-	-	0.25	-	-	-	-
Blighia sapida	5.5	-	4.5	-	-	-	6.4	-	-	-	5.5	-	-	-
Blighia welwitschii	-	-	-	3.6	-	-	-	-	4.5	-	-	-	-	2.5
Bombax buonopozense	7.5	-	-	-	8.5	9.4	-	-	-	-	-	-	6.5	-
Bridelia atroviridis	-	-	-	-	-	-	-	-	-	-	-	-	5.5	-
Bridelia grandis	-	-	-	-	-	-	-	-	-	-	-	-	6.0	-
Broussonetia papyrifera	-	2.5	-	-	-	-	-	3.5	-	-	-	2.6	-	-
Bussea occidentalis	-	5.0	-	-	-	-	-	3.0	-	-	-	2.5	-	-
Calpocalyx brevibracteatus	-	-	-	4.5	-	-	-	-	3.5	-	-	-	-	2.7
Calycobolus africanus	-	-	-	-	-	-	-	-	4.6	-	-	-	-	-
Calyptrochilum emarginatum	-	-	-	-	-	-	-	-	2.5	-	-	-	-	-
Capsicum sp.	5.5	2.4	3.5	4.7	1.5	1.5	1.5	2.7	2.5	2.6	2.0	3.5	5.5	4.5
Ceiba pentandra	7.6	7.0	-	-	-	-	7.0	-	-	5.0	6.5	-	4.5	3.6
Centrocema pubescens	-	-	-	-	-	-	-	-	5.0	-	-	-	6.5	-
Chromolaena odorata	4.5	4.0	3.5	2.7	3.5	-	-	-	5.0	-	-	-	6.5	-
Chrysophyllum perpulchrum	6.5	6.0	4.0	3.5	1.2	0.5	-	0.6	-	0.4	-	-	-	0.7
Chrysophyllum sp.	-	0.5	-	0.7	-	-	-	1.5	-	-	2.0	-	-	-
Cissus sp.	-	-	-	-	-	-	2.6	-	-	-	-	5.0	-	-
Combretum bipindense	4.0	-	-	4.7	6.5	-	-	-	-	3.8	-	-	-	2.7

Combretum smeathmannii	3.5	-	-	3.4	4.5	-	3.0	-	-	4.0	-	-	-	3.0
Combretum sp	-	-	-	3.0	-	-	-	-	-	-	-	-	-	2.5
Cordia millenii	-	-	-	-	-	-	-	-	-	-	4.5	-	-	-
Cordia senegalensis	-	-	-	-	-	-	-	-	-	-	5.0	-	-	-
Corynanthe pachyceras	-	0.57	-	-	-	-	-	-	-	-	0.55	-	-	-
Rhaphidophora africana	-	0.7	-	-	-	-	-	-	-	-	0.5	-	-	-
Dalbergia hostilis	7.5	6.5	5.0	4.7	4.6	3.5	2.8	3.6	6.5	6.5	4.5	4.5	1.0	0.5
Diospyros viridicans	-	-	-	1.5	-	-	-	-	-	-	-	-	1.7	-
Entandrophragma angolense	0.5	-	-	-	-	-	-	-	-	0.7	-	-	-	-
Ficus asperifolia	2.5	-	-	-	-	3.6	-	-	-	-	-	-	5.5	-
Ficus exasperata	1.5	-	-	-	-	2.4	-	-	-	-	-	-	2.0	-
Ficus sur	2.5	-	-	4.5	-	-	6.5	-	-	-	-	1.5	-	-
Ficus tessellata	2.5	-	-	3.5	-	-	5.0	-	-	-	-	1.7	-	-
Ficus thonningii	0.5	0.7	-	0.5	-	0.6	-	-	-	-	-	-	0.5	-
Ficus trichopoda	0.7	0.4	-	-	-	0.5	-	-	-	-	-	0.5	-	0.7
Ficus umbellata	2.5	-	-	-	-	3.5	-	-	-	4.5	-	-	-	-
Ficus vogelii	-	-	-	-	-	-	-	-	0.7	-	-	-	-	-
Funtumia elastica	-	-	-	-	1.5	-	-	-	-	-	-	-	2.6	-
Griffonia simplicifolia	-	3.5	-	-	-	-	-	0.5	-	-	-	-	-	0.4
Guarea cedrata	-	-	5.0	-	-	-	-	-	-	-	4.5	-	-	-
Hippocratea sp.	-	-	-	0.3	-	-		-	-	-	-	-	-	-
Hymenostegia afzelii	-	-	-	-	-	-	-	-	-	-	-	-	-	0.5
Khaya anthotheca	-	-	-	-	-	-	-	-	-	-	-	-	-	0.4
Khaya grandifolia	-	-	-	-	-	-	-	-	-	-	-	-	-	0.5
Khaya ivorensis	-	-	-	-	-	-	-	-	-	-	-	-	-	0.3
Lannea welwitschii	-	0.6	-	-	-	-	-	-	-	0.5	-	-	-	-
Lecaniodiscus cupanioides	-	0.5	-	-	-	-	5.5	-	-	-	-	-	-	-
Leptoderris sp.	2.5	-	-	-	3.0	-	-	-	-	-	3.5	-	-	-
Lovoa trichilioides	-	-	0.7	0.5	-	0.6	-	1.0	-	-	-	-	0.5	-
Macaranga heudelotii	2.5	-	-	-	-	-	3.0	-	-	-	-	-	-	-
Mansonia altissima	-	0.6	-	-	-	-	-	-	0.7	-	-		-	-
Marantocloa leucantha	-	-	4.0	-	-	-	-	5.2	-	-	-	3.6	-	-
Microdesmis puberula	-	-	-	0.7	-	-	-	-	-	0.5	-	-	-	0.4
Microsorum punctatum	-	-	-	0.3	-	-	-	-	-	0.5	-	-	-	0.5
Microsorum scolopendria	-	-	-	0.5	-	-	-	-	-	0.5	-	-	-	0.6
Milicia	-	-	-	0.7	-	-	-	-	-	0.5	-	-	-	0.7

excelsa														
Millettia chrysophylla	-	0.5	-	-	-	-	-	-	0.7	-	-	-	-	-
Morinda lucida	-	-	-	-	2.5	-	-	-	-	-	-	2.7	-	-
Morus mesozygia	-	-	2.5	-	-	-	-	2.0	-	-	-	-	-	-
Motandra guineensis	-	-	2.0	-	2.4	-	-	1.5	-	-	-	1.7	-	-
Myrianthus arboreus	-	-	2.6	-	2.5	-	-	2.0	-	-	-	2.5	-	-
Olyra latifolia	-	-	3.5	-	-	-	-	-	-	-	-	-	-	-
Panicum maximum	-	2.7	-	-	4.0	-	-	-	-	1.8	-	-	-	-
Parquetina nigrescens	-	-	-	-	-	0.8	-	-	-	-	-	-	0.6	-
Pennisetum purpureum	-	-	-	-	-	0.7	-	-	-	-	-	-	0.5	-
Piptadeniastrum africanum	-	-	-	-	-	0.7	-	-	-	-	-	-	0.5	-
Pisonia aculeata	1.5	-	-	-	-	-	-	1.7	-	-	-	-	-	-
Pteris sp.	6.5	5.0	6.5	6.0	4.0	2.5	4.0	2.5	3.5	3.0	2.7	2.0	3.5	1.5
Pycnanthus angolensis	3.5	-	-	-	5.0	-	-	-	-	-	-	2.5	-	-
Ricinodendron heudelotii	1.5	-	-	0.7	-	-	-	-	0.5	-	-	-	0.5	-
Atropa belladonna	3.2	-	-	3.5	-	-	4.0	-	-	-	-	3.5	-	-
Digitalis spp	-	4.0	3.5	-	-	7.0	-	-	6.0	-	-	-	5.0	-
Rauwolfia serpentine	-		-	-	5.5	-	-	-	-	-	6.5	-	-	6.0
Catheranthus roseus	2.5	2.0	1.0	1.5	2.7	3.5	3.7	4.5	3.7	3.5	3.0	2.5	2.0	3.6
Rinorea oblongifolia	0.5	-	-	-	0.6	-	-	-	0.5	-	-	0.4	-	-
Salacia elegans	1.4	-	-	1.5	-	-	-	-	-	-	1.4	-	-	-
Salacia owabiensis	1.6	-	-	1.7	-	-	2.5	-	-	-	2.0	-	-	-
Salacia sp.	1.5	-	-	2.0	-	-	3.0	-	-	-	1.7	-	-	-
Smilax kraussiana	1.7	-	-	2.5	-	-	3.0	-	-	-	4.7	-	-	-
Sterculia oblonga	3.6	-	3.5	-	2.7	-	-	2.5	-	3.0	-	-	-	4.0
Sterculia rhinopetala	2.3	-	3.6	-	2.5	-	-	-	-	-	-	-	-	-
Sterculia tragacantha	-	-	-	-	4.5	-	-	-	-	-	-	-	-	2.7
Terminalia superba	1.5	3.5	-	5.0	-	-	-	-	-	-	-	1.4	-	-
Trichilia monadelpha	-	-	-	-	-	0.5	-	-	-	-	0.7	-	-	-
Trichilia prieureana	-	-	-	-	-	1.5	-	-	-	-	2.0	-	-	-
Trilepisium madagascariense	-	-	-	-	-	2.0	-	-	-	-	1.7	-	-	-
Abutilon indicum		1.3					0.5					1.5	0.5	
Adhatoda vasica		1.5					1.6					1.8	1.6	
Caesalpinia bonducela	1.7		2.5		2.6		1.4	1.6		1.5	0.5		0.5	
Cryptostegia grandiflora				2.0		2.5					1.7	1.6	2.0	1.4

Table-3: Summary characteristics of the Floristic composition and structure of the Angiospermic flora in fourteen blocks of Nawada

Characteristics	Nda	Ap	Wg	Pb	Sda	Rjl	Rh	Kal	Ha	Ndg	Nht	Gp	Mkr	Kac
Number of tree individuals (density/ha)	85	95	107	154	250	214	215	150	280	230	107	114	217	285
Number of individual shrubs (density/ha)	8	12	10	13	15	18	16	17	10	14	17	13	9	11
Density of Liana/ha	121	105	108	126	124	60	58	69	52	104	85	108	75	85
Shannon-Wienner Index	2.5	2.6	2.9	3.5	3.4	3.6	2.8	3.5	3.7	2.8	2.9	3.1	3.6	3.4
Shannon-Wienner Index for sampling	1.30	1.34	1.35	2.70	2.50	1.45	2.50	1.36	1.35	1.34	2.68	2.36	1.85	1.80
Mean canopy height (m)	35.5±3.5	36.6±3.2	29.8±3.4	32.5±2.5.	34.40±2.6	28.30±1.58	27.50±1.75	26.35±2.50	27.25±3.12	32.15±1.78	30.26±2.15	29.10±2.16	27.35±1.85	35.15±1.26
Mean canopy cover (%)	54.3±4.5	60.5±2.5	61.5±2.6	64.5±2.4	71.2±4.2	81.3±4.3	78.5±3.5	76.6±3.5	72.5±1.5	68.5±5.0	56.2±2.6	58.5±3.6	59.5±4.5	80.5±3.4
Mean basal area (m^2/ha)	52.5±3.2	35.5±0.8	32.6±0.8	45.2±1.2	43.5±3.2	55.6±3.5	60.4±2.6	58.5±0.8	53.5±2.5	54.5±4.5	38.6±3.2	37.5±0.9	63.5±2.5	64.7±2.6

Table- 4: Number and Percentage of species angiosperms recorded from Rajauli and Kawakol forest division of Nawada

Forest division	Area in Sq. Km	Number of species	Percentage
Nawada	583.65	223	
Rajauli	About 146	102	45.73
Kawakol	About 205	121	54.26

The expected taxonomic distinctness ($T(m)$) vs. log2 m profiles of the Rajauli and Kawakol forest division have been presented in Fig-1a and b.

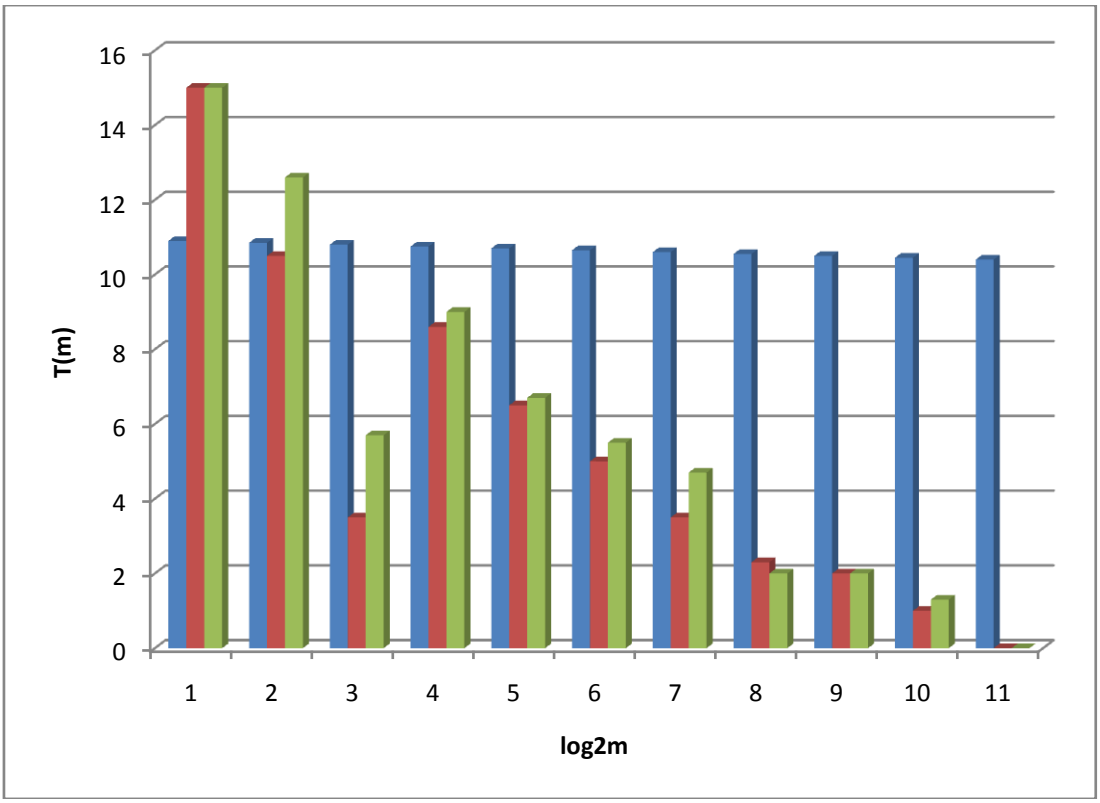

Figure-1a: Expected taxonomic distinctness ($T(m)$) vs. log2 m profiles of the Rajauli and Kawakol forest division: red bar= Rajauli, green bar= Kawakol

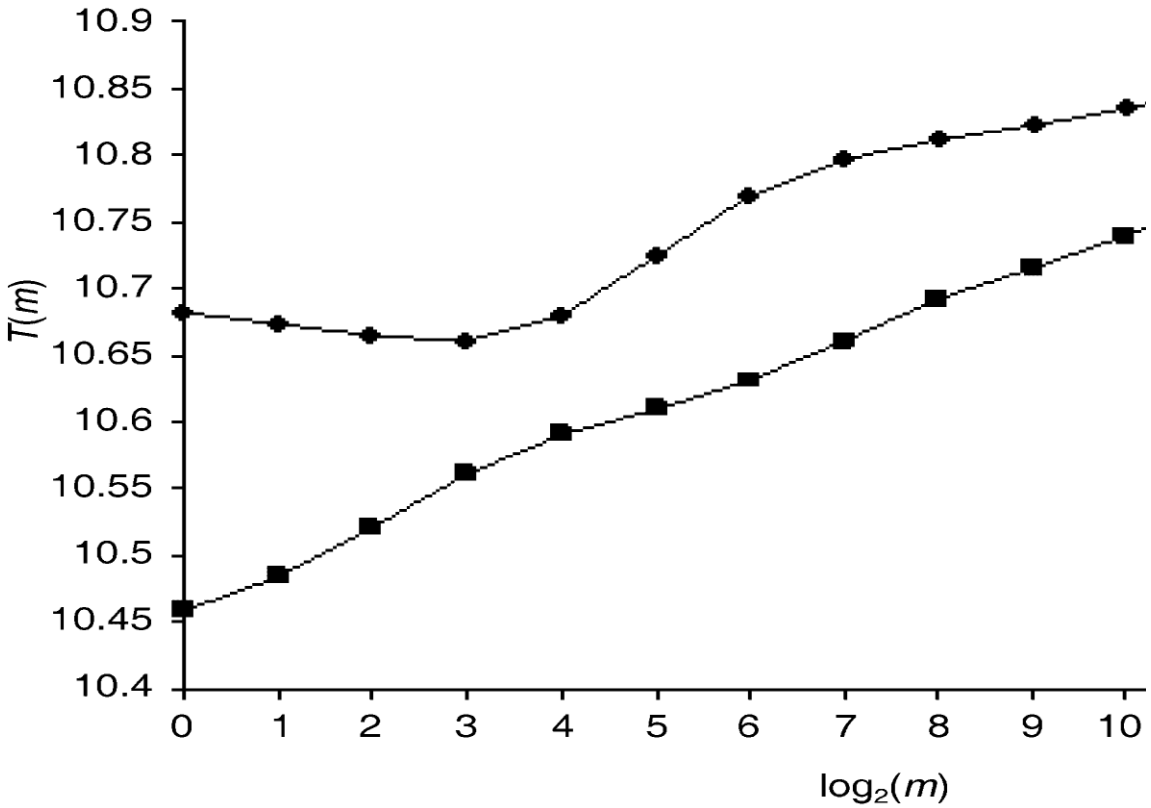

Figure-1b: Expected taxonomic distinctness (*T* (*m*)) vs. log2 *m* profiles of the Rajauli and Kawakol forest division

A total of 105 adult plant species were identified in the fourteen blocks of Nawada. These belonged to 34 families, 75 genera and 5 life forms (Table-1). Fabaceae, Moraceae, Meliaceae and Apocyanaceae were the overall diverse families (in terms of species richness) of the adult species, contributing 44.5% of all the species in the study. Trees were the most dominant life form (48.5%) followed by lianas (16.8%), herbs (10.9%), epiphytes (8.9%), shrubs (3.9 %) and the others (4.7%).

Generally, species richness among all life forms was highest in the Nda (90.5%) followed by the Ap (87.6%), Pb(77%), Sda (73%), Ha (70.25%) and Gp (68.95%). Fabaceae, Moraceae and Meliaceae and Meliaceae were the most diverse families distributed in all the fourteenblocks of Nawada. The most important families in the Nawada were Fabaceae, Moraceae , Meliaceae and Apocyanaceae. In forest areas of Wg, Rjl, Ha,Ndg, Nht, Mkr and Kac, the angiospermic plant species were in the range of 48 to 59.8%. In the forest area of other blocks the incidence of medicinal plant species were low in the range of 29.97% to 40.30 % (Table-2). *C. odorata* was the most dominant species of herb in terms of number of individuals accounting for 69% of individual herbs in the Nda and 45% of all the herbs in the forest areas of fourteen blocks.

There were a total of 4167 individuals of woody species (excluding epiphytes) identified in the forest areas of fourteen blocks. Trees were more abundant (2916 individuals/ha) followed by lianas (1603 individuals/ha) and shrubs (248 individuals/ha) (Table- 3). Tree density was greatest in the Kac (290/ha) followed by Gp (287/ha), Mkr (285/ha),Ha (280/ha), Sda (250/ha), Rh (215/ha) and Rjl (214/hac). Density of Liana was maximum in Pb(126/ha) followed by Sda (124/ha), Nda (121/ha), and Wg and Nht (108/ha each) . Other areas have low density of Liana. Similarly density of shrubs was maximum in Ab(19/ha) followed by Kal and Kac(17/ha), Rjl (18/ha), Rh (16/ha) and Sda (15/ha). Others have low density of shrubs. Shannon-Wiener index was greater in the Ap (H' = 3.80) compared to Mkr (H'= 3.70) and Rjl, Gp, Pb and Kal (H' =23.50 to 3.60). Others have H᾽ value of less than 3.0 (Table-3). Density of plant species differed significantly between the forest types (F=8.96: df = 2; p = 0.000). In all, *C. mildbraedii* was by far the most abundant species accounting for an average 10% of stems in all the habitats whereas *T. scleroxylon* was the most dominant species in terms of basal area representing 25% on the average (Table- 5). The overall dominant species in terms of the species importance value (average) were *T. scleroxylon* (28.2) and *C. mildbraedii* (23.7). The commonest species were *C. mildbraedii* and Alafia *barteri* with the average occurrence of 6.8 and 5.2 % respecttively. On forest type basis *C. mildbraedii, C.* zenkeri, *L. welwitschii, _ansiona altissima, N. papaverifera* and *T. scleroxylon* were the dominant species in all the forest areas of eighteen blocks (Table-3). *B. papyrifera, C. mildbraedii, N. papaverifera, P. africanum* and *S. oblonga* were the donant species in terms of basal area representing 25% on

the average (Table 3). The overall dominant species in terms of the species importance value (average) were *T. scleroxylon* (28.2) and *C. mildbraedii* (23.7). The commonest species were *C. mildbraedii* and _lafia *barteri* with the average occurrence of 6.8 and 5.2 % respectively.

On forest type basis *C. mildbraedii, C.* zenkeri, *L. welwitschii, _ansiona altissima, N. papaverifera* and *T. scleroxylon* were the dominant species in the in all the areas selected for present investigation (Table-3). *B. papyrifera, C. mildbraedii, N. papaverifera, P. africanum ,S. oblonga* and *T. scleroxylon* were the species that dominated the woody flora. In terms of size, majority of the trees were of the lower diameter class (10-30 cm) (Table-3). The number of individual trees in the categories decreased with increasing size of the trees. Larger diameter trees (90- 110 and > 110 cm) were not found in any areas selected for present investigation. Mean basal area recorded was in the range of 32.6±0.8 (Wg) to 64.7±2.6 m^2/ha (Mkr) (Table 5). In the same way, mean canopy cover and height were higher in the Rjl (81.3±4.3) followed by Gp(80.5±3.4), Rh (78.5±3.0), Kal (76.6±3.5, Kac (76.2±1.6), Ha (72.5±1.5) and Nht (68.5±2.8).The canopy cover of other forest areas ranged between 35.5±0.8 and 64.7±2.6. In the present investigation it was found that there was a significant positive relationship between tree size and height in all the forest types selected for present studies (r2 = 0.812; p = 0.000, r2 = 0.741; p = 0.000 and r2 =0.362; p = 0.002).

IV. Discussion

The total geographical area of Nawada district is 2494 sq. km. and the total forest area of the Nawada Forest Division is 583.65 sq. km which is 23.40% of the total geographical area of the district with coordinates $24^0 39'0^0 N 85^0 30'0^0 E$. The forests in Nawada Forest Division correspond to the 'Tropical Dry Deciduous Forests' as per Champion and Seth's classification of forests. Within this type, local variations are met with, due to variations in nature of soil and topography.

In the present study a total of 223 species of Angiosperms have been sampled from Rajaoli and Kawakol forest division of Nawada, 102 species from Rajauli forest division comprising 45.73% and 121 species from Kawakol forest division comprising 54.26% (Table-4). The taxonomic distinctness of Rajauli and Kawakol forest divisions was not different from a random distribution of values: the Δ^* values of Rajauli and Kawakol were, 5.145 and 5.275 respectively and the bootstrapped CI ranged from 4.124 to 4.575. However, the taxonomic diversity of Rajauli was slightly lower than that of Kawakol: the Δ values of Rajauli and Kawakol were, respectively, 4.950 and 5.635, and the bootstrapped CI ranged from 4.575 to 4.757 (Fig-1a and b). The expected taxonomic distinctness was higher in the Kawakol than in the Rajauli forest division (Fig-1a and b).

The species richness in both Rajauli and Kawakol forest divisions is more or less similar. However, the analysis of taxonomic distinctness, as well as those of genus and family similarities, showed that the temporary waterlogging in the Rajauli and Kawakol forest divisions does not clump phylogenetically related species. The habitat use of species of Rajauli forest division is, thus, a trait widespread in the phylogeny of Kawakol forest division. Where the environment situations are spatiotemporally heterogeneous species are adapted to dynamism and evolve strategies for responding to shifting opportunities. Consequently, the interaction and occurrence of several environmental factors in should have favoured the ability of species to withstand many ecological restrictions., even the environmental constraints resulting from drought and water logging.

Analyses of genus and family similarities also support that waterlogging in the two forest divisions may not be stressful enough to clump phylogenetically related species, since most of the genera and families were found in both the Rajauli and Kawakol forest divisions. However, local communities are characterized by fewer higher taxa than would be expected by chance, because the abiotic features that influence the ability of species to colonize and survive consistently regulate taxa composition (Leibold, 1998; Webb, 2000; Enquist *et al* ., 2002) [40, 20, 41]. Thus, local processes in these two forest divisions must be very similar and waterlogging may not be strong enough to constrain its phylogeny. Although phylogenies have a non-overlapping structure whereas functional groups tend to have an overlapping one (Von Euler & Svensson, 2001) [42], the similar taxonomic distinctness between both forest divisions suggests that water logging does not reduce the number of functional groups.

The diversity of functional groups is important to maintain the resilience of community structure and function (Walker *et al*., 1999). High functional group diversity is expected for communities with high taxonomic diversity (Petchey & Gaston, 2002) [43], because related species share more functional traits than unrelated ones (Harvey & Pagel, 1991; Silvertown *et al*., 1997) [44, 45]. As correlations between phylogenetic structure and the structure of functional groups in species assemblages have also been found (Warwick & Clarke, 1998; Von Euler & Svensson, 2001) [46, 42]. Therefore, it can be postulate that functional groups in both these forest divisions are maintained even under physiological restrictions due to water logging.

Taking into account the taxonomic diversity and the expected taxonomic distinctness, waterlogging modifies the phylogenetic structure of the two forest divisions. The lower Δ and $T(m)$ values of the Rajauli forest division pointed out that its phylogenetic structure is taxonomically more homogeneous than that of the Kawakol forest division. However, taxonomic diversity is an extension of Simpson diversity and incorporates

information on taxonomic relationships into an index measuring species dominance (Clarke and Warwick, 1998). As the taxonomic distinctness was equal and higher taxa were shared by both forest divisions, low taxonomic diversity of the Rajauli forest division indicated that water logging affects species diversity rather than phylogeny. In accordance with this interpretation were also the outcomes of expected taxonomic distinctness, which is a parametric diversity index (Ricotta, 2004; Ricotta *et al*., 2005) [23, 15]. Since, for any degree of index sensitivity to the least abundant species, lower values of *T*(*m*) was found in Rajauli than in the Kawakol forest division. Water logging in both the forest divisions decreased species diversity. The major consequence of water logging is to limit the number of species able to grow in such a condition (Sarmiento, 1996; Batalha *et al*., 2005; Cianciaruso *et al*., 2005) [47, 48, 49]. Accordingly, water logging modifies the phylogenetic structure of the both the forest divisions by decreasing the number and the abundance of species that are less tolerant to water excess, but not constraining the phylogenetic tree of its community. The present observations are in agreement with the work of Clarke & Warwick, 1998; Ricotta, 2004; Ricotta *et al*., 2005; Webb, 2000; Enquist *et al*., 2002; Webb *et al*., 2002 [22, 23, 15, 20, 21, 41, 21].

V. Conclusions

Human disturbances have influenced the biodiversity, floristic composition of the district Nawada to some extent. Invasion on the other hand did not have much effect on floristic composition of the Nawada due to the early stage of invasion. Thus, proper management intervention is required to mitigate the impact of *B. papyrifera* and *C. odorata* before it gets out of control. Logging affected the structural complexity of the forest reserve through the removal of large and tall trees as well as gap creation. The forest regions of Nawada (Magadh area) had better capacity of recruiting saplings into the adult stage. Invasion of the DIF by *B. papyrifera* and *C. odorata* affected regeneration of native species. The forest reserve of Magadh looks floristically rich and structurally complex in the face of logging, farming activities and invasion in some parts of the forest. Thus, there is the need to curb the anthropogenic activities and plant invasion so as to protect the integrity of the forest including medicinal plants.

The state comes under Indo-Gangetic plain biogeography zone and characterized by flat alluvial region, which has been under continuous and intensive cultivation. The state has about 5720 km2 of total forest cover, including 3372 km2 dense forest and 2348 km2 open forest. The forests in the state can be broadly categorized into tropical moist deciduous forest, tropical dry deciduous forest and grasslands. The tropical moist deciduous forest is dominated by 'Sal' (*Shorea robusta*) that occurs in the Himalayan foothills towards extreme north-western boundary. The tropical dry deciduous forest covers the maximum forest areas of the state, an open type of forest that remains leafless during the dry season.

Habitat destruction is the principal cause for the loss of biodiversity. Anthropogenic activities, such as encroachment and conversion of forest areas into agricultural lands, and construction of dams and roads, and overexploitation of biological resources, pose threat to the existing biodiversity of the state. There should be strict enforcement of rules and regulations to protect and conserve the biodiversity. The state government has to promote activities and efforts for the maintenance of biodiversity in the state. The biodiversity rich zones in the state may be declared as Protected Areas to conserve the existing flora. The Forest Department should create awareness by educating the local communities about the importance of conserving forests and environment and sustainable utilization of biological resources for the sustenance and posterity of human beings and make them involve in conservation activities.

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