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Community Structure, Species Composition and Population Status of NTFPs of Ziro Valley in Arunachal Pradesh, India

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Abstract

Non Timber Forest Products (NTFPs) has gained a lot of significance over the years as a means of income generation. Forests are playing a vital role in the supply of these products, however, due to their continuous extraction, the population of many species might have depleted. Very little information is known about community structure and population status of NTFPs. No specific studies have been made to find out the occurrence, availability of species and population status in the forests, supplying the resources. The present study has been carried out in community forests of the naturally occurring NTFPs in the temperate forest of the Ziro valley of Arunachal Pradesh. The main aim is to determine community structure, species composition and population status of NTFPs. Three forest stands viz., Nyilii, Dura and Gyachi were selected which are used by the *Apatani* tribe for extraction of the NTFPs. For evaluation of species composition and community characteristics, the sampling of the vegetation was done using the quadrat method. A total 137 species representing 68 families and 116 genera were recorded. Herbs represent the maximum diversity with 71 species followed by 35 shrub species and 31 tree species. The families Asteraceae and Rosaceaeae exhibited maximum representation followed by Urticaceae. The species under Fagaceae, Lauraceae, Rosaceae and Rutaceae were found to be important NTFP yielding species. Highest species richness was recorded in Nyilii having 124 species, while lowest in Dura with 102 species. Density of tree, shrub and herb ranged between 376 to 456 individuals ha^{-1}, 2848 to 3696 individuals ha^{-1} and 31.44 to 36.64 individuals m^{-2}, respectively. The total basal area was found to be highest (51.64 m^2 ha^{-1}) in Dura followed by Nyilii (25.32 m^2 ha^{-1}) and lowest in Gyachi (22.82 m^2 ha^{-1}). In all the three study stands the species diversity indices showed the trend, herbs > shrubs > trees while the evenness index showed the trend as shrubs > herbs > trees. The overall species similarity index was highest (82.35%) between Dura and Gyachi. About 80% of the total recorded species showed clumped distribution while, no regular distribution was shown by any species. The three selected stands harbor about 50 important NTFP yielding species which are being used commonly by the *Apatani* people in their day to day life. Among the three study sites, overall diversity of NTFP was found highest in the Nyilii stand while the density of population was found better in Dura and Gyachi stands. The population of many species was found to be low due to continue harvesting without any sustainable management by the communities. All the selected forest stands have the potentiality to grow the high value NTFP yielding species and if managed properly, they can support the livelihood and economy of the local communities.

Key Words: *Apatani* plateau, Eastern Himalaya, economy, forest management, species diversity

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Introduction

Forest resources are the backbone of most of the tribal and indigenous communities for their livelihood and socio-economic development. Forest products are categorized into two main groups, i.e. wood-based and non-wood based materials. The non-wood or Non-Timber Forest Products (NTFPs) are also commonly known as minor forest products (MFPs) as they are harvested in smaller quantities (Dwivedi 1993). Forests have traditionally been valued as the source of sustenance of all life forms on earth. Other than providing timber and fuel wood, all other forest products are classified as non-timber forest products. The term NTFPs was coined by de Beer and Mc Dermot in 1989. It consists of goods of biological origin other than wood produced in forests and since then many synonyms for NTFPs are being used such as wild products, natural products, minor forest products, etc. In boarder sense NTFPs include medicinal plants, wild edible plants, beverages, narcotics, fodder, building and thatching ingredients, spices, fibers, tannin, latex, etc. (Krishnamurthy 1993). In many parts of the world, NTFPs are recognized as a part of culture, identity, myths and spiritual practices and the tribal population still stores a vast knowledge on utilization of local plants as food materials and other specific uses (Sundriyal et al. 1998). Worldwide, these forest produces are being used by various communities for fulfillments of various common requirements. NTFPs contribute a lot to the livelihoods of many people worldwide who are mainly dependent on forest (GFRA 2005; 2010; Ahenkan and Boon 2010). The wide range of resources emerging from the forest has led to considerable complexity in the NTFPs sector (Nepstad and Schwartzman 1992).

NTFPs have gained a remarkable significance over the years throughout the world not only in conserving the biological diversity but also in terms of rural economy. NTFPs share very high support from the livelihood point of view. Economic and environmental significance of NTFPs has increasingly attracted the attention of academicians, environmentalists and planners in most of the developing countries (De Beer and McDermott 1996; Edwards 1996). The contribution of NTFPs toward the livelihood and economy of the larger population in developing countries could be recognized with the increasing interest and attention. Such increasing interest and attention can be marked as recognition of the contribution that NTFP to support the livelihood and economy of the larger population in developing countries (Arnold and Perez 1998). Recognizing the potentiality of NTFP in socio-economic development, particularly in rural and tribal communities, research and development activities have increased remarkably in the country. The efficient management of forests for NTFPs, can surpass the benefit from timber and agricultural products (Peters et al. 1989). Worldwide, most of the people living in the forests vicinity are dependent on the NTFPs (Sills et al. 2003). Traditional communities used NTFPs for subsistence and as the main or the only source of income (Awasthi et al. 1995; Sarmah et al. 2003). Harvesting and processing activities of NTFPs not only provide employments and sources of income but also have cultural principles and medicinal importance that contributes to community health and well-being (Falconer 1992; Kennedy 2006).

The Non-Timber Forest Products (NTFPs) and its role in the economic development of local communities and sustainable forest management has been addressed by many researchers from different parts of the world (Panayotou and Ashton 1992; Arnold and Perez 2001). NTFPs have the potential to bring about an economic revolution for the forest dwellers. Globally, more than 2 million people are dwelling in the forests and depending on NTFPs for subsistence, income and livelihood security (Vantomme 2003). About 80% of the world population in developing countries depends on NTFPs for their primary health care and food security (Nautiyal and Kaul 2003). NTFPs are used and managed in complex socio-economic and ecological environments. In Southeast Asian countries, most of the people solely depends on the NTFPs as their only source of income and livelihood (Nautiyal and Kaul 2003). The population of most of the Indian states is completely dependent on the forest and its resources. The availability and sustainability of the NTFPs are little known, but it is an acknowledged fact that rural people have relied on NTFPs for centuries (Godoy and Bawa 1993; Hammett and Chamberlain 1998). In India, 40% of forest revenue and 55% of forest based employment is provided by NTFPs (Tewari and Campbell 1995). NTFPs play an important role in the income and employment potential of the local communities (including tribal) in various parts of the country particularly in the area having good forests. Forests are providing all the necessary materials to the farming and forest dwellers. Particularly the edible plants whose leaves, fruits, seed, roots, etc. are consumed still making a significant contribution to the dietary habits of the poor people living nearby the forest (Krishnamurthy 1993).

With the increasing demand of forest products in any form other than the timber day by day, it is ultimately leading to shrinkage of forest areas. Such over exploitation not only affects the local biodiversity, but also postures threat to the income generation sources of the forest dependent population worldwide. Over-harvesting of NTFPs not only affect the income sources of the forest dependent people, but also poses a threat to the genetic diversity. Plant community characteristic plays an important role in the vegetation science over the centuries and focus on distribution, composition and classification of communities (Kashian et al. 2003). The major characteristics of the communities include structure, composition and function (Timilsina et al. 2007). Species composition and structure are the most important characteristics of forests which are evident from the forest health that signify the forest's diversity (Roberts and Gilliam 1995). Further, vegetation structure of any plant community depends upon on its floristic composition (Gleason 1926). The abiotic and biotic factors are the driving forces which influence the composition and structure of plant communities. In addition, the quality or types of habitat are also very important in determining the species richness of plant community (Harrison and Bruna 1999). Various physical, climatic and biological disturbances attributed the structure and composition of different forests, including the temperate ones (White 1979; Oliver 1981; Stewart and Rose 1990). Understanding the species composition and population status of an area are essential in determining the community structure. Species composition is the identification of all the different living things or species available in a given area. This in turn allows us to understand the interaction between the different species available. Knowledge of the diversity and distribution pattern of the species will help in assessing the ecological significance of an area. Moreover, measures of species diversity play a vital role in ecology and conservation. Evaluation of species composition and structure is fundamental in the management and conservation of forest resources.

The Ziro valley located in the Lower Subansiri district of Arunachal Pradesh is a rich repository of Non Timber Forest Products (NTFPs) and numerous NTFP yielding species are found in their natural habitat. These products are one of the most preferred and highly used forest resources by the *Apatani* people who depend on these resources for their day to day uses. The forests are rich in several NTFP yielding plants such as species of *Calamus*, *Castanopsis*, *Pinus*, *Magnolia*, *Musa*, *Phyllostachys*, *Quercus*, *Rubia*, *Rubus*, etc. Extraction of NTFPs has gained a lot of significance over the years as a means of income generation. The forests are playing a vital role in the supply of these products. However, due to the continuous extraction of these resources, the population of many species might have reduced drastically. Very little information is known about the community structure of the species and its population. No specific studies have been made to find out the occurrence and availability of species with their community structure and population status in these forest areas which supply the resources. Keeping these in view, the present study was carried out in the community forests of Ziro valley having the natural occurrence of NTFPs with the objective of determining the species composition and to analyze the community structure of the forested ecosystem. Attempts were also made to determine the population status of major NTFP species that are most preferred by the community and are good sources of livelihood support and income generation. It is assumed that the results of the study will help in the management of community forests, particularly non timber forest products which are playing significant role in day to day life of *Apatani* people.

Materials and Methods

Study site

The study sites were selected in temperate forest of the Ziro valley of Lower Subansiri district. The district is mountainous with hilly terrains, located between 26° 55′ and 28° 21′ N latitude and 92° 40′ and 94° 21′ E longitude and covers an area of 3,460 km^2 (4.13% of the total geographical area of the state) (http://lowersubansiri.nic.in). Ziro, a scenic valley (often called the Apatani Plateau) lies between the Panior and Kamla (Kuru) rivers at an altitude of 1,524 to 2,900 m asl. The region is also well known for its diverse NTFP species and as one of the centre of tourist attraction and developmental activities during recent years. The study was solely based on the *Apatani* tribes residing in Ziro plateau. Apatanis are one of the major ethnic tribal groups of Arunachal Himalaya inhabiting eco-culturally valued zone in Ziro valley, sharing 2.26% population of the Arunachal Pradesh (http://www.censusindia.gov.in). The climatic condition of the district varies from season to season. The area falls within the humid subtropical to temperate types of climate depending on the altitudinal variation. The average annual rainfall of the Ziro is recorded as minimum 6.05 mm to a maximum of 129.6 mm during the months of May-July. Depending on the variations in the altitudinal ranges the mean annual temperature ranges was recorded for a minimum 0.5°C in winter to a maximum of 24.5°C in summer. The average relative humidity is ranging from 49.28% (February) to 87.14% (September). The relative humidity always remains high throughout the year, except during winter when it slightly goes down.

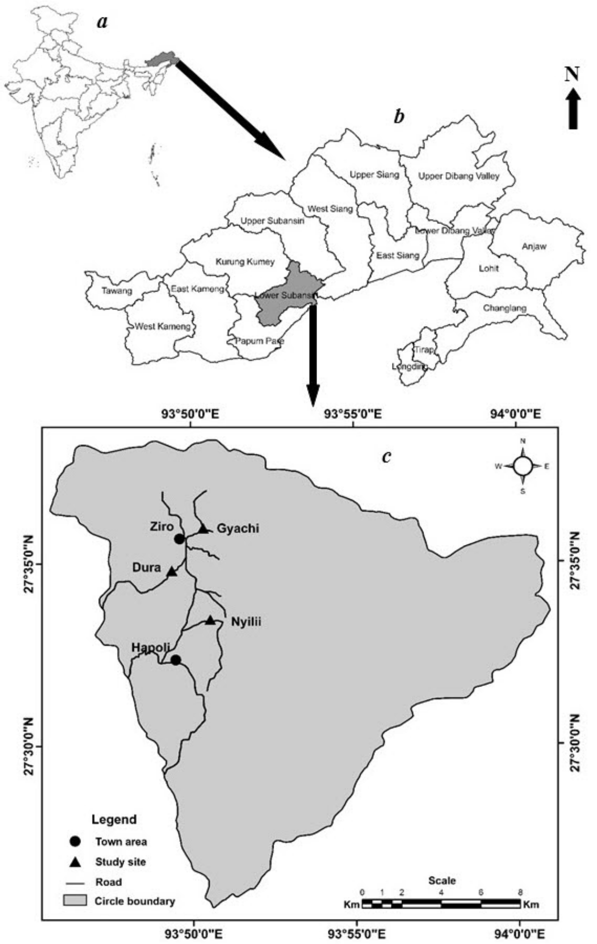

Fig. 1. Map of study area. (a) India, (b) Arunachal Pradesh and (c) Selected study sites of Ziro valley.

Apatani belong to the Tibeto-Mongolid stock and the predominant community in the Ziro valley. Literally the word *Apatani* is derived from '*Apa*' means addressing someone out of affection and '*Tani*' means the descendents of 'Abotani', who is considered as the ancestral forefather of the Apatanis. Apatanis celebrate many religious festivals of which '*Murung*', '*Myoko*' '*Yapung*' and '*Dree*' are the main. The *Apatani* practices paddy cum fish culture which is a unique practice in the state where two crops of rice (Mipya and Emoh) and one crop of fish (Ngihi) are raised together (http://lowersubansiri.nic.in). Three community forest stands were selected for the present study based on the availability and extraction of NTFPs by the *Apatani* community for their day to day uses. Among these the first study site (Nyilii) was selected in the Hong community forest, second (Dura) in Hija community forest and third one (Gyachi) in the Bulla community forest (Fig. 1).

Methods

To study the species composition and community characteristics the sampling of the vegetation was done using the quadrat method. Twenty five quadrats of 10 m×10 m were laid randomly in each study stands. Trees and shrubs were recorded within the same 10 m×10 m quadrat, whereas herbs were recorded by laying 1 m×1 m quadrat within the same quadrat area of 10 m×10 m. Specimens of each of the species were collected and herbariums were prepared following the methods outlined by Jain and Rao (1977). The species were identified with the consultation of various taxonomic literature (Kanjilal et al. 1934-1940; Haridasan and Rao 1985; 1987; Chauhan et al. 1996; Chowdhery et al. 1996; 2008; 2009) and herbarium specimens of Botanical Survey of India (BSI) Itanagar and Shillong, State Forest Research Institute (SFRI), Itanagar and North Eastern Regional Institute of Science and Technology, Nirjuli.

Community characteristics of each of the forest stands were studied using quantitative analytical methods. Important ecological parameters like basal area, density, frequency, importance value index (IVI) were worked out by following Misra (1968) and Mueller-Dombois and Ellenberg (1974). Girths of each of the adult tree species were measured at 1.37 m above the ground level and basal area were calculated using the formula $g^2/4\pi$. Importance value index (IVI) of tree species was calculated by summing the values of relative frequency, relative density and relative dominance while, for shrubs and herbs it was obtained by summing up the values of the relative frequency and relative density (Curtis 1959).

Species richness 'S' was calculated by listing all the species occurring in the study stands following Whittaker (1972). The species richness index was calculated by following Menhinick (1964) as: $d=S/\sqrt{N}$, where 'S' is the total number of species and 'N' is the number of individuals. Species diversity index H' was calculated by the method given by Shannon and Weiner (1963) as: $H'=-\Sigma\,(ni/N)\ln(ni/N)$, where H' is the Shannon Weiner diversity Index, 'ni' is importance value index of the i^{th} species and 'N' is the total importance value index of the community. Simpson's dominance index was calculated

Table 1. List of family, genera and species of the three selected study sites of Ziro valley of Arunachal Pradesh

Family	No. of genera	No. of species	Family	No. of genera	No. of species
Acanthaceae	2	2	Magnoliaceae	1	2
Actinidiaceae	1	2	Malvaceae	1	1
Adoxaceae	2	2	Melastomataceae	2	3
Anacardiaceae	2	2	Moraceae	1	2
Apiaceae	1	1	Myricaceae	1	1
Araceae	2	5	Myrisinaceae	3	3
Araliaceae	4	5	Oleaceae	1	1
Arecaceae	2	2	Orchidaceae	2	2
Aristolochiaceae	1	1	Oxalidaceae	1	1
Asparagaceae	2	2	Pinaceae	1	1
Asteraceae	7	7	Piperaceae	1	1
Athyriaceae	2	2	Plantaginaceae	1	2
Balsaminaceae	1	2	Poaceae	5	5
Berberidaceae	3	3	Polygalaceae	1	1
Betulaceae	2	3	Polygonaceae	2	2
Bignoniaceae	1	1	Polypodiaceae	1	1
Caryophyllaceae	1	1	Portulaceae	1	1
Dipteridaceae	1	1	Primulaceae	1	1
Eleagnaceae	1	3	Pteridaceae	1	1
Ericaceae	1	1	Ranunculaceae	1	1
Fabaceae	1	1	Rosaceae	7	8
Fagaceae	3	5	Rubiaceae	2	2
Gentianaceae	1	1	Rutaceae	1	2
Geraniaceae	1	1	Saururaceae	1	1
Gleichinaceae	1	1	Scrophulariaceae	2	2
Hypoxidaceae	2	3	Selaginaceae	1	1
Juglandaceae	1	1	Solanaceae	1	1
Lauraceae	5	5	Ternstrominaceae	1	1
Liliaceae	1	1	Theaceae	2	2
Lindsaceae	1	1	Thelypteridaceae	1	1
Lomariopsidaceae	1	1	Urticaceae	5	7
Loranthaceae	1	1	Verbenaceae	1	1
Lycopodiaceae	1	1	Violaceae	1	1
Lythraceae	1	1	Zingiberaceae	1	2

following Simpson (1949) as: $D=\Sigma (ni/N)^2$, where 'D' is Simpson's index, 'ni' is importance value index of the i^{th} species and 'N' is the total importance value index of the community. Sorenson's similarity index was calculated by following the formula of Sorenson's similarity index (Sørenson 1948) as: $S=(2C/A+B)\times 100$, where 'A' is the total number of species on site A, 'B' is the total number of species on site B and 'C' is the total number of common species in both A and B. Pileou's evenness index (E) was calculated following Pielou's index (Pielou 1969) as: $E=H'/\ln S$, where 'E' is Pileou's evenness index, H' is Shannon Weiner diversity index and S=total number of species. Spatial distribution pattern of various plant species was calculated following Whitford index (Whitford 1949) as: WI=Abundance/Frequency. The values <0.025, 0.025-0.050 and >0.050 indicate regular, random and clumped distribution, respectively.

Results

Floristic diversity

The community forests serving as the sources of various resources for the *Apatani* communities in Ziro valley were found to be rich and diversified in floristic composition. The analysis of floristic diversity in the three selected study stands indicated occurrence of a total 137 species belonging to 68 families representing 116 genera. Out of these, 31 were tree species representing 26 genera under 16 families, 35 species were shrubs under 31 genera and 19 families and 71 were herbs representing 61 genera under 41 families. List of taxonomic diversity in terms of family, genera and species of the selected study stands has been given in Table 1. Among all the species 3 were represented by Pteridophytes and 1 by Gymnosperm. Out of the 37 Angiospermic families, 8 belong to the monocotyledons while the rest was dicotyledon. The 10 most dominant Angiospermic families namely Araceae, Araliaceae Asteraceae Fagaceae, Lauraceae, Melastomataceae, Myrsinaceae, Rosaceae, Rutaceae and Urticaceae comprises 3 or more than 3 species each. Asteraceae and Rosaceaeae exhibited maximum representation with 7 species each followed by others (Table 1). Among the dominant families the Fagaceae, Lauraceae, Rosaceae and Rutaceae were found important having NTFP yielding species. Besides, Anacardiaceae Arecaceae, Liliaceae, Magnoliaceae, Moraceae, Piperaceae, Rubiaceae, Saururaceae, Zingiberaceae, etc. were the other important families having NTFP yielding species (Table 1).

Species richness

Among the selected study stands Nyilii (Hong community forest) showed the highest numbers of species with 124 species under 105 genera and 64 families, with maximum representation of herbs (66 spp.) followed by shrubs (34 spp.) and tree (24 spp.) (Table 2). In Gyachi (Bulla community forest) a total of 103 species was found representing 91 genera and 57 families, where 57 species of herbs, 25 shrubs and 21 tree species were present. The Dura (Hija community forest) showed least species richness, but with a total of 102 species under 89 genera and 56

Table 2. General community characteristics of different study sites of Ziro valley of Arunachal Pradesh

Parameters/study sites	Nyilii	Dura	Gyachi
Trees			
Number of species	24	23	21
Number of genera	21	21	18
Number of family	15	14	12
Species richness index	2.25	2.23	2.17
Stand density (individuals ha^{-1})	456	424	376
Basal area (m^2 ha^{-1})	25.32	51.64	22.82
Shannon diversity index	2.92	2.93	2.82
Simpson dominance index	0.07	0.06	0.08
Pielou's evenness index	0.92	0.93	0.92
Shrubs			
Number of species	34	28	25
Number of genera	30	26	23
Number of family	18	18	16
Species richness index	2.55	1.78	1.74
Stand density (individuals ha^{-1})	2,848	3,696	3,040
Shannon diversity index	3.42	3.27	3.09
Simpson dominance index	0.04	0.04	0.05
Pielou's evenness index	0.97	0.99	0.97
Herbs			
Number of species	66	51	57
Number of genera	56	44	50
Number of family	38	30	35
Species richness index	2.18	1.72	2.03
Stand density (individuals m^{-2})	36.64	35.12	31.44
Shannon diversity index	3.97	3.75	3.85
Simpson dominance index	0.02	0.03	0.03
Pielou's evenness index	0.95	0.95	0.95

families with 51 herbs, 28 shrubs and 23 tree species. In all the three forest stands, the diversity of herb species was maximum followed by shrubs and trees (Table 2).

Species richness index

The Menhinick species richness index was recorded highest at all layers in Nyilii stand as compared to Dura and Gyachi stands. In Nyilii the shrub layer indicated the highest value (2.55), followed by trees (2.25) and herbs (2.18), respectively. On the other hand, in Dura the value of trees was higher (2.23), followed by shrubs (1.78) and herbs (1.72). In the Gyachi also the value was maximum for trees (2.17), followed by herb layer (2.03), and shrubs (1.74) (Table 2). The species richness index of the selected study sites showed the trend as shrub > tree > herb in Nyilii, tree > shrub > herb in Dura and tree > herb > shrub in Gyachi. The species richness index of tree layers in all the study stands exhibited almost similar while for shrubby layer the Nyilii stand showed a much higher index. Among the herbaceous layers Dura stand showed the least species richness (Table 2).

Density

The tree species density was recorded highest (456 individuals ha^{-1}) in Nyilii followed by Dura with 424 individuals ha^{-1} and lowest (376 individuals ha^{-1}) in Gyachi (Table 2). For shrubs the highest density was recorded in Dura with 3,696 individuals ha^{-1} followed by Gyachi (3,040 individuals ha^{-1}) and lowest in Nyilii (2,848 individuals ha^{-1}) (Table 2). In case of herbaceous species the maximum stand density was recorded in Nyilii (36.64 individuals m^{-2}) followed by Dura (35.12 individuals m^{-2}) and minimum in Gyachi (31.44 individuals m^{-2}) (Table 2). The forest canopy in all the selected forest stands was mostly composed of the tree species like *Alnus nepalensis*, *Castanopsis hystrix*, *Exbucklandia populnea*, *Lithocarpus elegans*, *Magnolia champaca*, *Myrica esculenta*, *Phoebe cooperiana*, *Pinus wallichiana*, *Pyrus pashia*, *Quercus lamellosa*, *Saurauia nepaulensis*. Among the tree species the density was found to be highest for *Alnus nepalensis*, *Castanopsis hystrix*, *Magnolia champaca*, *Pinus wallichiana* in all the three study stands with more than 20 individuals ha^{-1}. Although the density of *Callicarpa macrophylla* was recorded more than 20 individuals ha^{-1}, but found to be restricted to only in one stand i.e. in Nyilii community forest. On the other hand species like *Betula alnoides*, *Camellia lutescens*, *Quercus griffithii*, *Quercus lamellosa*, *Juglans regia*, *Saurauia griffithii* exhibited the lowest density with less than 10 individuals ha^{-1} in all the three stands (Table 3). Among the shrubs, species like *Calamus acanthospathus*, *Laurocerasus undulata*, *Mahonia napaulensis*, *Rubia manjith*, *Rubus ellipticus*, *Rubus rosaefolius*, *Strobilanthes helicta*, *Sambucus javanica*, etc. were recorded as densely occurring species in all the sites with more than 100 individuals ha^{-1}. *Chimonocalamus griffithianus* also indicated higher density, but only in two sites. Accordingly *Docynia indica*, *Elaeagnus caudata* and *Embelia ribes* were found occurring only in one or two stands with limited density (Table 4). In the herbaceous species the highest density was found for the species like *Amorphophalus* sp., *Athyrium* sp., *Cymbopogon* sp., *Fragaria vesca*, *Fagopyrum esculentum*, *Hydrocotyle* spp., *Houttuynia cordata*, *Impatiens urticifolia*, *Imperata* sp., *Lycopodium clavatum*, *Poa* sp., *Primula denticulata*, *Oenanthe javanica*, *Selaginella martensii*, *Urtica dioica*, etc. on the ground level (Table 5) with more than 6,000 individuals ha^{-1}. The three grass species under the genera *Imperata*, *Poa* and *Cymbopogon* showed the maximum density among all the herbs in all the respective study stands with more than 12,000 individuals ha^{-1}. However the species like *Crassocephalum crepidioides*, *Galeola falconeri*, *Goodyera procera*, *Piper pedicellatum*, *Podophyllum hexandrum*, *Rotala rotundifolia*, *Torenia asiatica*, *Viscum articulatum* exhibits the lowest density having less than 4,000 individuals ha^{-1} and were not common in all the sites (Table 5).

Basal area

The total basal area was found to be highest in Dura (51.64 m^2 ha^{-1}) followed by Nyilii (25.32 m^2 ha^{-1}) and lowest in Gyachi (22.82 m^2 ha^{-1}) (Table 2). Tree species like *Castanopsis hystrix*, *Pinus wallichiana* and *Magnolia champaca* contributed the maximum basal area in all the three study stands with the value (5.44, 7.99, 3.68), (3.45, 5.86, 2.82) and (6.04, 11.77, 7.50), respectively. However the highest basal area was exhibited by *Magnolia champaca* in the Dura forest with 11.77 m^2 ha^{-1} (Table 3). Among the tree species, *Brassaiopsis glomerulata* which was found with low density (< 10 individuals ha^{-1}) also exhibited least basal area in all the selected study stands (0.13, 0.04, 0.14 m^2 ha^{-1}). The other species which contributed to a minimum basal area

Table 3. Density (individuals ha^{-1}), basal area (m^2 ha^{-1}) and IVI of tree species recorded at different study stands of Ziro valley of Arunachal Pradesh

Tree species	Family	Nyilii			Dura			Gyachi		
		D	BA	IVI	D	BA	IVI	D	BA	IVI
Alnus nepalensis D. Don	Betulaceae	28	1.16	16.18	24	0.58	12.47	24	1.01	16.98
Betula alnoides Buch.-Ham. ex D. Don	Betulaceae	8	0.16	4.56	8	0.57	5.26	-	-	-
Betula utilis D. Don	Betulaceae	-	-	-	16	0.16	7.49	-	-	-
Brassaiopsis glomerulata (Blume) Regel	Araliaceae	12	0.13	6.41	16	0.04	8.40	8	0.14	5.19
Callicarpa macrophylla Vahl	Verbenaceae	28	0.33	11.79	-	-	-	-	-	-
Camellia lutescens Dyer	Theaceae	8	0.19	3.59	-	-	-	-	-	-
Castanopsis armata (Roxb.) Spach	Fagaceae	-	-	-	20	1.14	12.61	12	0.38	8.56
Castanopsis hystrix Hook. f. & Thomson ex A. DC	Fagaceae	44	5.44	40.91	28	7.99	28.89	36	3.68	33.11
Choerospondias axillaris (Roxb.) B.L.Burtt & A.W.Hill	Anacardiaceae	12	0.27	5.87	24	1.80	13.69	12	0.81	9.21
Cinnamomum bejolghota (Buch.-Ham.) Sweet	Lauraceae	28	0.81	15.86	16	0.80	9.87	8	0.10	5.04
Eurya nitida Korth.	Theaceae	8	0.15	4.52	8	0.16	4.47	-	-	-
Exbucklandia populnea (R. Br.ex Griff.) R. W. Br.	Lauraceae	24	1.88	18.12	16	0.92	10.10	20	0.83	15.14
Ficus auriculata Lour.	Moraceae	12	0.12	6.37	8	8.98	21.55	8	0.22	4.33
Heteropanax sp.	Araliaceae	-	-	-	8	0.16	4.47	-	-	-
Juglans regia Linn.	Juglandaceae	12	0.37	7.36	8	0.29	4.72	-	-	-
Lithocarpus elegans (Blume) Hatus. ex Soepadmo	Fagaceae	20	0.77	12.87	-	-	-	12	0.45	8.87
Litsea cubeba (Lour.) Pers.	Lauraceae	-	-	-	28	0.45	13.16	16	0.53	11.52
Magnolia champaca (Linn.) Baill. ex Pierre	Magnoliaceae	52	6.04	43.95	36	11.77	39.24	48	7.50	54.28
Magnolia oblonga (Wall. ex Hook.f. & Thomson) Figlar	Magnoliaceae	12	0.33	7.20	-	-	-	12	0.39	8.60
Myrica esculenta Buch.-Ham. ex. D. Don	Myricaceae	20	0.34	11.16	12	1.01	8.20	8	0.19	5.43
Persea sp.	Lauraceae	-	-	-	20	0.44	10.11	-	-	-
Phoebe cooperiana P.C. Kanjilal and Das	Lauraceae	20	0.81	11.93	-	-	-	16	0.61	11.87
Pinus wallichiana A. B. Jackson	Pinaceae	28	3.45	24.11	48	5.86	30.62	16	2.82	21.55
Pterospermum acerifolium (Linn.) Willd.	Malvaceae	16	1.08	11.03	-	-	-	-	-	-
Pyrus pashia Buch.-Ham.ex D. Don	Rosaceae	-	-	-	12	0.54	7.28	24	0.88	16.41
Quercus lamellosa Smith	Fagaceae	8	0.49	5.86	-	-	-	-	-	-
Quercus griffithii Hook. f. & Thomson ex Miq.	Fagaceae	8	0.14	4.48	8	0.78	5.67	24	0.57	16.29
Rhus chinensis Mill.	Anacardiaceae	-	-	-	24	6.25	23.45	12	0.42	8.74
Saurauia napaulensis DC.	Actinidiaceae	20	0.28	9.84	24	0.33	10.84	28	0.38	16.52
Saurauia griffithii Dyer	Actinidiaceae	12	0.14	6.45	-	-	-	12	0.14	7.51
Schima wallichii Choisy	Ternstrominaceae	16	0.44	9.59	12	0.62	7.44	20	0.77	14.87
Total		456	25.32	300	424	51.64	300	376	22.82	300

D, Density; BA, Basal area; IVI, Importance value index.

Table 4. Density (individuals ha^{-1}) and IVI of shrub species recorded at different study stands of Ziro valley of Arunachal Pradesh

Shrub species	Family	Nyilii		Dura		Gyachi	
		Density	IVI	Density	IVI	Density	IVI
Berberis wallichiana DC.	Berberidaceae	80	5.93	80	5.16	80	6.34
Calamus acanthospathus Griffith	Arecaceae	128	8.66	96	6.60	128	9.15
Chimonocalamus griffithianus (Munro) Hsueh & T.P.Yi	Poaceae	32	3.21	160	8.33	96	6.86
Crotalaria pallida Aiton	Fabaceae	48	3.77	112	7.03	80	7.57
Dipteris wallichii (R.Brown) T.Moore	Dipteridaceae	192	11.95	192	10.19	240	14.07
Docynia indica (Wallich) Decne.	Rosaceae	32	3.21	-	-	-	-
Elaeagnus caudata Schltdl. ex Momiy.	Elaeagnaceae	48	4.81	-	-	-	-
Elaeagnus pyriformis Hook. f.	Elaeagnaceae	48	3.77	80	5.16	32	3.52
Elaeagnus sp.	Elaeagnaceae	96	7.54	-	-	-	-
Embelia ribes Burm.f.	Myrsinaceae	64	4.33	-	-	-	-
Ficus sarmentosa Buch -Ham. ex. Sm.	Moraceae	80	5.93	128	7.46	96	6.86
Laurocerasus undulata (Buch.-Ham. ex D.Don) Roem.	Rosaceae	112	7.06	-	-	64	4.57
Ligustrum sp.	Oleaceae	-	-	144	7.90	160	8.97
Maesa indica (Roxb.) A.DC.	Myrsinaceae	16	1.60	112	6.03	96	10.57
Mahonia napaulensis DC.	Berberidaceae	128	10.74	208	9.63	176	10.73
Melastoma malabathricum Linn.	Melastomataceae	80	4.89	112	6.03	-	-
Mussaenda treutleri Stapf	Rubiaceae	64	5.37	64	4.73	96	8.10
Myrsine semiserrata Wall.	Myrsinaceae	80	3.85	96	4.60	80	3.87
Osbeckia nutans Wallich ex C.B.Clarke	Melastomataceae	80	5.93	144	7.90	160	8.97
Photinia integrifolia Lindl.	Rosaceae	80	4.89	96	5.60	80	5.10
Polygala arillata Buch.-Ham. ex D. Don	Polygalaceae	32	3.21	-	-	-	-
Rosa brunonii Lindley	Rosaceae	48	2.73	80	4.16	-	-
Rubia manjith Roxb. ex Fleming	Rubiaceae	192	11.95	272	12.36	256	14.59
Rubus ellipticus Smith	Rosaceae	64	3.29	160	8.33	64	3.34
Rubus rosaefolius Smith ex Baker	Rosaceae	176	10.35	320	13.66	176	10.73
Sambucus javanica Blume	Adoxaceae	96	6.50	128	7.46	-	-
Schefflera elliptica (Blume) Harms	Araliaceae	64	5.37	64	4.73	48	5.28
Smilax sp.	Liliaceae	64	4.33	112	5.03	-	-
Strobilanthes helicta T. Anderson	Acanthaceae	192	12.99	304	14.23	304	17.41
Thunbergia coccinea Wallich	Acanthaceae	80	4.89	-	-	-	-
Vaccinium sp.	Ericaceae	80	4.89	128	6.46	160	8.97
Viburnum nervosum D. Don	Adoxaceae	96	7.54	96	6.60	160	10.20
Wallichia oblongifolia Griffith	Arecaceae	32	3.21	64	4.73	-	-
Zanthoxylum acanthopodium DC.	Rutaceae	64	5.37	64	4.73	96	6.86
Zanthoxylum oxyphyllum Edgeworth	Rutaceae	80	5.93	80	5.16	112	7.39
Total		2,848	200	3,696	200	3,040	200

Table 5. Density (individuals ha^{-1}) and IVI of herbaceous species recorded at different study stands of Ziro valley of Arunachal Pradesh

Herb species	Family	Nyilii		Dura		Gyachi	
		Density	IVI	Density	IVI	Density	IVI
Amorphophallus sp.	Araceae	7,200	3.91	6,800	3.47	2,800	2.37
Arisaema consanguineum Schott	Araceae	4,400	2.76	6,000	4.40	2,800	2.37
Arisaema erubescens (Wall.) Schott	Araceae	5,200	2.98	-	-	-	-
Arisaema intermedium Blume	Araceae	1,600	1.60	-	-	2,000	1.75
Arisaema jacquemontii Blume	Araceae	4,000	2.65	1,600	1.99	2,800	2.37
Aristolochia sp.	Aristolochiaceae	1,200	1.11	-	-	-	-
Athyrium sp.	Athyriaceae	8,000	4.13	5,200	3.40	3,200	2.87
Bignonia sp.	Bignoniaceae	2,400	1.82	-	-	-	-
Christella parasitica H.L	Thelypteridaceae	5,200	3.36	-	-	3,200	2.87
Crassocephalum crepidioides (Benth.) S.Moore	Asteraceae	2,400	1.82	-	-	4,000	3.12
Curculigo orchioides Gaertn.	Hypoxidaceae	6,400	3.69	4,000	3.06	3,600	2.63
Cymbopogon sp.	Poaceae	32,400	13.12	-	-	41,600	17.68
Cyperus sp.	Poaceae	-	-	38,400	15.16	-	-
Dicranopteris linearis (Burm. f.) Underw.	Gleicheniaceae	2,400	1.82	5,600	3.52	6,800	5.50
Dicrocephala bicolor (Roth) Schltdl.	Asteraceae	2,000	1.32	2,000	1.34	4,000	2.75
Diplazium esculentum (Retz.) Sw.	Athyriaceae	6,800	3.80	4,000	2.68	2,400	1.87
Elatostema platyphyllum Wedd.	Urticaceae	3,600	1.76	9,200	4.93	3,600	1.89
Elatostema sp.	Urticaceae	6,000	3.19	5,200	2.63	4,400	3.25
Erigeron bonariensis Linn.	Asteraceae	5,200	3.36	6,400	4.90	3,600	2.63
Fagopyrum esculentum Moench	Polygonaceae	6,000	3.19	-	-	-	-
Fragaria vesca Linn.	Rosaceae	9,600	4.57	10,400	5.27	6,400	3.89
Galeola falconeri Hook.f.	Orchidaceae	2,000	1.71	-	-	-	-
Galinsoga quadriradiata Ruiz & Pav.	Asteraceae	4,400	3.15	8,000	4.97	2,800	2.74
Geranium nepalense Sweet	Geraniaceae	-	-	-	-	2,400	1.50
Gnaphalium hypoleucum DC.	Asteraceae	2,800	1.15	3,600	1.79	2,400	1.50
Gonostegia hirta (Blume ex Hassk.)Miq.	Urticaceae	3,600	2.54	6,800	4.63	5,200	4.25
Goodyera procera (Ker Gawl.) Hook.	Orchidaceae	2,400	1.43	-	-	4,400	2.88
Hedychium coccineum Buch.-Ham. ex Sm.	Zingiberaceae	2,400	1.04	4,400	2.79	-	-
Hedychium spicatum Smith	Zingiberaceae	4,800	2.87	7,200	4.74	2,800	1.63
Houttuynia cordata Thunb.	Saururaceae	6,800	4.19	14,800	6.91	13,200	7.16
Hydrocotyle himalaica P.K.Mukherjee	Araliaceae	4,800	2.87	6,400	4.90	5,200	3.14
Hydrocotyle sibthorpioides Lam.	Araliaceae	10,800	4.89	6,800	4.24	5,600	3.26
Impatiens scabrida DC.	Balsaminaceae	4,400	2.76	2,800	2.72	4,400	2.88

Table 5. Continued

Herb species	Family	Nyilii		Dura		Gyachi	
		Density	IVI	Density	IVI	Density	IVI
Impatiens urticifolia Wallich	Balsaminaceae	6,000	3.19	6,000	3.25	6,000	3.39
Imperata sp.	Poaceae	20,800	9.57	28,800	12.43	24,800	11.59
Lepisorus sp.	Polypodiaceae	3,600	2.54	-	-	2,800	2.37
Lycopodium clavatum Linn.	Lycopodiaceae	6,400	3.30	10,000	5.54	7,200	4.14
Mimulus tenellus var. *nepalensis* (Benth.) Tsoong	Schropulariaceae	1,200	0.72	-	-	3,200	2.87
Molineria capitulata (Lour.) Herb.	Hypoxidaceae	7,200	4.30	2,800	1.95	4,000	3.49
Molineria sp.	Hypoxidaceae	5,600	3.08	5,600	3.13	4,400	2.88
Nephrolepis cordifolia (L.) C. Presl	Lomariopsidaceae	3,600	2.15	2,800	2.34	5,200	3.88
Oenanthe javanica (Blume) DC.	Apiaceae	7,600	4.80	4,400	2.79	5,600	4.00
Ophiopogon japonicus (Thunb.) Ker Gawl.	Asparagaceae	4,000	2.26	6,800	4.24	3,600	2.26
Osbeckia stellata Buch.- Ham.ex Ker Gawl.	Melastomataceae	2,000	2.10	3,200	2.07	3,600	3.37
Oxalis corniculata Linn.	Oxalidaceae	3,600	2.15	2,400	1.45	-	-
Pilea scripta (Buch.-Ham.ex D.Don) ex Wedd.	Urticaceae	2,800	1.15	-	-	-	-
Piper pedicellatum C.DC.	Piperaceae	2,000	0.93	2,000	1.72	-	-
Plantago asiatica ssp. *erosa* (Wall.) Z.Yu Li	Plantaginaceae	4,400	2.76	6,800	4.24	3,600	2.63
Plantago major Linn.	Plantaginaceae	3,200	2.04	-	-	-	-
Poa sp.	Poaceae	41,200	15.52	33,200	13.30	26,000	11.60
Podophyllum hexandrum Royle	Berberidaceae	800	1.00	-	-	-	-
Polygonum runcinatum Buch.-Ham. ex D.Don	Polygonaceae	4,000	1.87	-	-	2,400	1.87
Portulaca oleracea Linn.	Portulaceae	4,400	2.37	-	-	2,800	2.00
Pouzolzia hirta Blume ex Hassk.	Urticaceae	4,400	3.15	6,000	4.40	5,600	4.37
Primula denticulata Smith	Primulaceae	6,000	3.58	6,000	3.25	6,000	3.39
Pteris vittata Linn.	Pteridaceae	5,200	2.98	4,400	2.79	6,000	4.87
Ranunculus sp.	Ranunculaceae	2,400	1.04	3,200	2.07	2,800	2.00
Rotala rotundifolia (Buch.-Ham.ex Roxb.) Koehne	Lythraceae	-	-	3,200	2.83	2,000	1.75
Selaginella martensii Spring	Selaginellaceae	9,600	5.34	9,600	4.66	8,000	4.03
Senecio sp.	Asteraceae	3,200	1.65	5,600	3.52	4,000	2.38
Solanum dulcamara Linn.	Solanaceae	-	-	4,400	2.02	2,400	2.24
Sonchus arvensis Linn.	Asteraceae	-	-	2,400	1.84	3,600	1.89
Sphenomeris chinensis (Linn.) Maxon	Lindsaeceae	3,200	2.04	5,600	3.90	4,400	3.25
Stellaria media (L.) Vill.	Caryophylllaceae	2,400	1.04	4,000	2.68	1,200	0.75
Swertia angustifolia Buch.-Ham. ex D.Don	Gentianaceae	2,000	2.10	3,600	2.95	4,800	4.49

Table 5. Continued

Herb species	Family	Nyilii		Dura		Gyachi	
		Density	IVI	Density	IVI	Density	IVI
Torenia asiatica Linn.	Scrophulariaceae	3,200	1.65	-	-	-	-
Tupistra sp.	Asparagaceae	4,000	2.26	-	-	2,800	2.00
Urtica dioecia Hill	Urticaceae	6,000	3.97	1,600	1.22	2,400	1.87
Urtica parviflora Roxb.	Urticaceae	4,000	3.04	6,400	4.90	3,200	3.61
Viola sikkimensis W.Becker	Violaceae	3,600	2.54	2,800	2.34	4,400	3.99
Viscum articulatum Burm.f.	Loranthaceae	1,600	1.21	2,000	1.72	-	-
Total		366,400	200	351,200	200	314,400	200

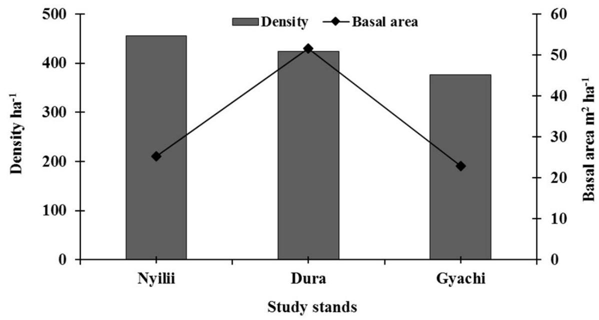

Fig. 2. Stand density (individuals ha^{-1}) and basal area (m^2 ha^{-1}) of tree species in the selected study stands.

were *Betula utilis*, *Camellia lutescens*, *Eurea nitida* and *Saurauia griffithii* with below 0.2 m^2 ha^{-1} (Table 3). Besides, density was recorded highest in Nyilii however, the basal area was recorded maximum in the Dura study site (Fig. 2).

Dominance

In Nyilii, the main dominant tree species were *Magnolia champaca* (43.95), *Castanopsis hystrix* (40.91), *Pinus wallichiana* (24.11), *Exbucklandia populnea* (18.12), *Alnus nepalensis* (16.18), *Lithocarpus elegans* (12.87) and *Phoebe cooperiana* (11.93). The dominant shrubs were *Strobilanthes helicta* (12.99), *Rubia manjith* (11.95), *Dipteris wallichii* (11.95), *Mahonia napaulensis* (10.74) while species like *Selaginella martensii* (5.34), *Oenanthe javanica* (4.80), *Fragaria vesca* (4.57), *Houttuynia cordata* (4.19), *Hydrocotyle sibthorpioides* (4.89) were the dominant herbs (Table 3-5). In Dura also, *Magnolia champaca* (39.24), *Pinus wallichiana* (30.62) and *Castanopsis hystrix* (28.89) *Rhus chinensis* (23.45), *Ficus auriculata* (21.55) and *Choerospondias axillaris* (13.69) were found as the dominant tree species. The dominating shrub species were *Strobilanthes helicta* (14.23), *Rubus rosaefolius* (13.66), *Rubia manjith* (12.36), while *Houttuynia cordata* (6.91), *Lycopodium clavatum* (5.54), *Fragaria vesca* (5.27), *Elatostema platyphyllum* (4.93) and *Selaginella martensii* (4.66) were the dominant herbs (Table 3-5). In Gyachi forest also *Magnolia champaca* (54.28), *Castanopsis hystrix* (33.11), *Pinus wallichiana* (21.55), *Alnus nepalensis* (16.98), *Quercus griffithii* (16.29), *Pyrus pashia* (16.41), *Exbucklandia populnea* (15.14) and *Phoebe cooperiana* (11.87), were found as the most dominant among the tree species. The shrub species having maximum IVI include *Strobilanthes helicta*

(17.41), *Dipteris wallichii* (14.07), *Rubus rosaefolius* (10.73), *Maesia indica* (10.57). The herbaceous layer was dominated by *Houttuynia cordata* (7.16), *Dicranopteris linearis* (5.50), *Pteris vittata* (4.87) and *Pouzolzia hirta* (4.37) (Table 3-5). Even though there were slight variations in the stand density, but overall the most dominant tree species were found to be *Alnus nepalensis*, *Castanopsis hystrix*, *Exbucklandia populnea*, *Magnolia champaca* and *Pinus wallichiana* in all the selected study stands. Accordingly the *Mahonia napaulensis*, *Rubus rosaefolius*, *Rubia manjith* and *Strobilanthes helicta* were the dominant shrubs while *Houttuynia cordata*, *Elatostema platyphyllum* and *Oenanthe javanica* were the dominant herbs common to all the sites (Table 3-5).

Dominance-diversity pattern was used to describe the mathematical relationship between species richness and dominance of those species. The present study exhibited that tree species were almost similar in all the selected study stands and maximum IVI values were mainly focused on fewer species in all the stands (Fig. 3). The study showed log normal distribution with high equitability and low dominance in the community.

Diversity indices

The Shannon Weiner diversity index was found higher in shrub and herb layers in Nyilii except tree layer which was found highest in Dura (2.93). The diversity index for trees, shrubs and herbs were recorded as 2.92, 3.42 and 3.97, respectively. In Dura the diversity index was 2.93, 3.27 and 3.75, while in Gyachi the values were found as 2.82, 3.09 and 3.85 for trees shrubs and herbs, respectively (Table 2). Among the three different habitats the diversity of herbs were found high followed by shrubs and trees showing the diversity indices in the trend, herbs > shrubs > trees which

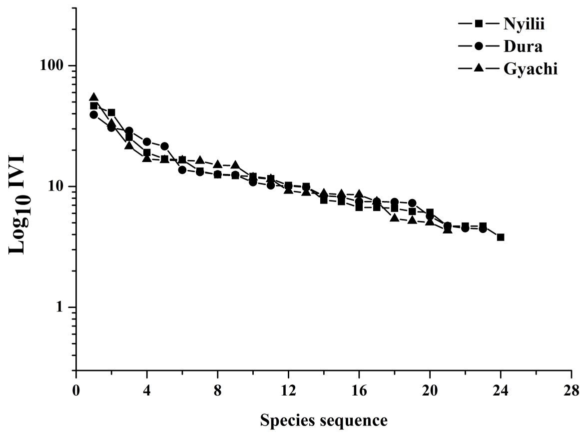

Fig. 3. Dominance-diversity curve of tree species of the selected study sites.

Table 7. Distribution pattern (%) of trees, shrubs and herbs in different study sites of Ziro valley of Arunachal Pradesh

Study sites	Habit	Clumped	Random	Regular
Nyilii	Trees	79.17	20.83	-
	Shrubs	100.00	-	-
	Herbs	100.00	-	-
Dura	Trees	86.96	13.04	-
	Shrubs	100.00	-	-
	Herbs	100.00	-	-
Gyachi	Trees	85.71	14.29	-
	Shrubs	100.00	-	-
	Herbs	100.00	-	-

Table 6. Sorenson's similarity index for different components of the selected study stands

Study sites/habit		Dura				Gyachi			
		A	T	S	H	A	T	S	H
Nyilii	A	78.76	-	-	-	81.42	-	-	-
	T	-	68.09	-	-	-	75.56	-	-
	S	-	-	77.42	-	-	-	79.31	-
	H	-	-	-	78.63	-	-	-	86.89
Dura	A	-	-	-	-	82.35		-	-
	T	-	-	-	-	-	72.73	-	-
	S	-	-	-	-	-	-	88.46	-
	H	-	-	-	-	-	-	-	85.98

A, all species; T, trees; S, shrubs; H, herbs.

Table 8. Density (individuals ha^{-1}) and IVI of various NTFP species at different study stands of Ziro valley of Arunachal Pradesh

Plant species	Habit	Nyilii		Dura		Gyachi	
		Density	IVI	Density	IVI	Density	IVI
Alnus nepalensis D. Don	Tree	28	16.18	24	12.47	24	16.98
Athyrium sp.	Herb	8,000	4.13	5,200	3.40	3,200	2.87
Berberis wallichiana DC.	Shrub	80	5.93	80	5.16	80	6.34
Calamus acanthospathus Griff.	Shrub	128	8.66	96	6.60	128	9.15
Castanopsis armata (Roxb.) Spach	Tree	-	-	20	12.61	12	8.56
Castanopsis hystrix Hook. f. & Thomson ex A. DC.	Tree	44	40.91	28	28.89	36	33.11
Chimonocalamus griffithianus (Munro) Hsueh & T.P. Yi	Shrub	32	3.21	160	8.33	96	6.86
Choerospondias axillaris (Roxb.) B.L. Brutt & A.W.Hill	Tree	12	5.87	24	13.69	12	9.21
Cinnamomum bejolghota (Buch.-Ham.) Sweet	Tree	28	15.86	16	9.87	8	5.04
Crassocephalum crepidioides (Benth.) S. Moore	Herb	2,400	1.82	-	-	4,000	3.12
Dicranopteris linearis (Burm.f.) Underw.	Herb	2,400	1.82	5,600	3.52	6,800	5.50
Diplazium esculentum (Retz.) Sw.	Herb	6,800	3.80	4,000	2.68	2,400	1.87
Elatostema platyphyllum Wedd.	Herb	3,600	1.76	9,200	4.93	3,600	1.89
Embelia ribes Burm.f.	Shrub	64	4.33	-	-	-	-
Exbucklandia populnea (R.Br.ex Griff.) R. W. Br.	Tree	24	18.12	16	10.10	20	15.14
Fagopyrum esculentum Moench.	Herb	6,000	3.19	-	-	-	-
Ficus auriculata Lour.	Tree	12	6.37	8	21.55	8	4.33
Ficus sarmentosa Buch.-Ham. ex. Sm.	Shrub	80	5.93	128	7.46	96	6.86
Fragaria vesca Linn.	Herb	9,600	4.57	10,400	5.27	6,400	3.89
Houttuynia cordata Thunb.	Herb	6,800	4.19	14,800	6.91	13,200	7.16
Juglans regia Linn.	Tree	12	7.36	8	4.72	-	-
Litsea cubeba (Lour.) Pers.	Tree	-	-	28	13.16	16	11.52
Magnolia champaca (L.) Baill. ex Pierre	Tree	52	43.95	36	39.24	48	54.28
Magnolia oblonga (Wall. ex Hook. f. & Thomson) Figlar	Tree	12	7.20	-	-	12	8.60
Mahonia napaulensis DC.	Shrub	128	10.74	208	9.63	176	10.73
Molineria capitulata (Lour.) Herb.	Herb	7,200	4.30	2,800	1.95	4,000	3.49
Myrica esculenta Buch.-Ham. ex D. Don	Tree	20	11.16	12	8.20	8	5.43
Oenanthe javanica (Blume) DC.	Herb	7,600	4.80	4,400	2.79	5,600	4.00
Oxalis corniculata Linn.	Herb	3,600	2.15	2,400	1.45	-	-
Phoebe cooperiana P.C. Kanjilal & Das	Tree	20	11.93	-	-	16	11.87
Pinus wallichiana A.B. Jackson	Tree	28	24.11	48	30.62	16	21.55

Table 8. Continued

Plant species	Habit	Nyilii		Dura		Gyachi	
		Density	IVI	Density	IVI	Density	IVI
Piper pedicellatum C.DC.	Herb	2,000	0.93	2,000	1.72	-	-
Plantago asiatica ssp. *erosa* (Wall.) Z.Yu Li	Herb	4,400	2.76	6,800	4.24	3,600	2.63
Podophylum hexandrum Royle	Herb	800	1.00	-	-	-	-
Portulaca oleracea Linn.	Herb	4,400	2.37	-	-	2,800	2.00
Pouzolzia hirta Blume ex Hassk.	Herb	4,400	3.15	6,000	4.40	5,600	4.37
Primula denticulata Sm.	Herb	6,000	3.58	6,000	3.25	6,000	3.39
Pyrus pashia Buch.-Ham. ex D. Don	Tree	-	-	12	7.28	24	16.41
Quercus lamellosa Sm.	Tree	8	5.86	-	-	-	-
Rhus chinensis Mill.	Tree	-	-	24	23.45	12	8.74
Rubia manjith Roxb. ex Fleming	Shrub	192	11.95	272	12.36	256	14.59
Rubus ellipticus Smith	Shrub	64	3.29	160	8.33	64	3.34
Rubus rosaefolius S.Vidal	Shrub	176	10.35	320	13.66	176	10.73
Schefflera elliptica (Blume) Harms	Shrub	64	5.37	64	4.73	48	5.28
Strobilanthes helicta T. Anderson	Shrub	192	12.99	304	14.23	304	17.41
Swertia angustifolia Buch.-Ham.ex D.Don.	Herb	2,000	2.10	3,600	2.95	4,800	4.49
Wallichia oblongifolia Griff.	Shrub	32	3.21	64	4.73	-	-
Zanthoxylum acanthopodium DC.	Shrub	64	5.37	64	4.73	96	6.86
Zanthoxylum oxyphyllum Edgew.	Shrub	80	5.93	80	5.16	112	7.39

indicate the rich diversity and dominance of herbaceous species.

Simpson's dominance index for trees and herbs were recorded highest in Gyachi 0.08, and 0.03, respectively. Simpson's dominance index of trees was highest in Gyachi (0.08) lowest in Dura (0.06), while in case of shrubs it was recorded highest in Gyachi (0.05) and lowest in both Nyilii (0.04) and Dura (0.04). For herbs, dominance index was highest in both Gyachi (0.03) and Dura (0.03) and lowest in case of Nyilii (0.02) (Table 2). Dominance index showed the trend as trees > shrubs > herbs.

Pielou's evenness index for trees, shrubs and herbs were recorded highest in Dura 0.93, 0.99 and 0.95, respectively. However, it was recorded highest for trees in Dura (0.93) and lowest in both Nyilii (0.92) and Gyachi (0.92). On the other hand, it was recorded maximum for shrubs in Dura (0.99) and minimum in both Nyilii (0.97) and Gyachi (0.97) (Table 2). The evenness index for herbaceous species showed similar values in all the selected study stands. The evenness index showed the trend as shrubs > herbs > trees.

Similarity index

The overall species Similarity index was highest between Dura and Gyachi (82.35%) while lowest between the Nyilii and Dura (78.76%) study sites (Table 6). The value of similarity for trees and herb species was maximum between the Nyilii and Gyachi stand (75.56% and 86.89%) and the minimum between the Nyilii and Dura (68.09% and 78.63%), while shrub species showed maximum similarity index between Dura and Gyachi (88.46%) and least between the Nyilii and Dura (77.42%) study sites (Table 6).

Distribution pattern

Out of the total recorded tree species, 79.17% of the species showed clumped distribution in Nyilii while 20.83% exhibited random distribution. Conversely, 86.96% of the tree species exhibited clumped distribution and 13.04% showed the random distribution in Dura stand. Whereas, 85.71% of the tree species showed clumped distribution and 14.29% of the species exhibited random distribution in Gyachi (Table 7). However, not a single species showed the regular distribution in the selected study stands. While, in case of shrub and herb layers all the species showed 100% clumped distribution in all the study stands (Table 7).

Population status of NTFP species

The detailed phytosociological analysis in the selected study stands revealed the occurrence of more than 60 NTFP yielding species, where about 50 important NTFP yielding commonly used by the local communities were found (Table 8). Out of the total recorded plant species, trees were represented by 17 (55%) species, shrubs by 14 (40%) species and herbs by 18 (25%) species (Fig. 4). Whereas, overall 36% of the total plant species were using by the *Apatani* people in their day to day life (Fig. 4). Among the tree except *Castanopsis armata*, *Juglans regia*, *Litsea cubeba*, *Magnolia oblonga*, *Phoebe cooperiana*, *Pyrus pashia*, *Quercus lamellosa* and *Rhus chinensis* all others were found to be distributed in all the three stands. As already presented in community structure the *Magnolia champaca*, *Castanopsis hystrix* and *Pinus wallichiana* were found to be dominated in all the three study stands with higher population density (>25 individuals ha^{-1}). *Magnolia champaca* showed highest density (>35 individuals ha^{-1}) and IVI (>40) in all the selected study stands. However, in Dura stand the density have been found highest for *Pinus wallichiana* (48 individuals ha^{-1}) higher than *Magnolia champaca* (36 individuals ha^{-1}). Among the other important NTFP tree species the *Choerospondias axillaris* the fruit yielding species and *Cinnamomum bejolghota* a ritually important species have been found in all the study stands, but with a comparatively lower density (<16 individuals ha^{-1} and <15 individuals ha^{-1}, respectively). The lowest density (8 individuals ha^{-1})

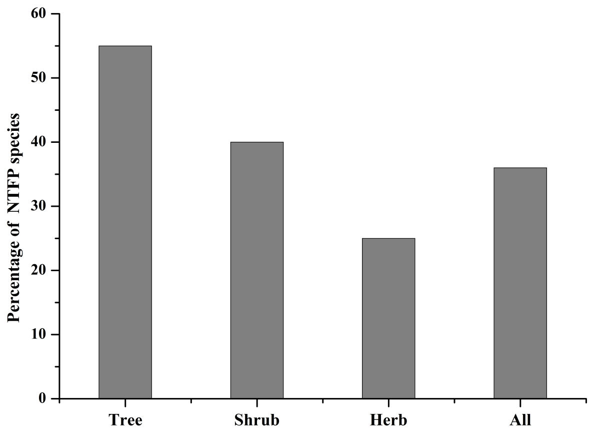

Fig. 4. Major NTFP species used by the *Apatani* people of Ziro valley of Arunachal Pradesh.

and IVI (5.86) were recorded for *Quercus lamellosa*. The rich diversity of tree NTFPs species was found highest in Gyachi and Dura and lowest in Nyilii stand. The four species, namely *Castanopsis armata*, *Litsea cubeba*, *Pyrus pashia*, *Rhus chinensis* which were being used as NTFP for their fruits were not recorded from the Nyilii stand. *Litsea cubeba* a commercial potential medicinal tree was found with a density of 28 and 16 individuals ha^{-1}. Likewise, *Pyrus pashia* extensively used for its tasty edible fruits showed a lower density with 12 and 24 individuals ha^{-1} in Dura and Gyachi, respectively. Among the study stands the lowest density and IVI was observed in *Juglans regia* (8 individuals ha^{-1} and IVI 4.72). Among the calculated IVI of all the species, the highest was found for *Magnolia champaca* in all the study sites (54.28 in Gyachi, 43.95 in Nyilii and 39.24 in Dura) followed by *Castanopsis hystrix* (40.91 in Nyilii) and *Pinus wallichiana* (30.62 in Dura) (Table 8). The other species found with IVI value >16 were *Alnus nepalensis*, *Ficus auriculata* and *Rhus chinensis*. The calculated basal area indicated that *Magnolia champaca* possess the maximum basal area in all the stands (6.04, 11.77 and 7.50 in Nyilii, Dura and Gyachi, respectively) followed by *Castanopsis hystrix* (5.44, 7.99 and 3.68) and *Pinus wallichiana* (3.45, 5.86 and 2.82). It was noted that the basal area for all these three species found higher in Dura study site than the other study stands (Table 3).

Among the shrubby NTFP yielding species, occurrence of many socioeconomically important species like *Berberis wallichiana*, *Calamus acanthospathus*, *Chimonocalamus griffithianus*, *Rubia manjith*, *Rubus* spp. were found. Species with higher density and IVI were *Calamus acanthospathus*, *Rubia manjith*, *Rubus rosaefolius* and *Strobilanthes helicta*. *Rubia manjith* one of the economically valuable plants extracted for dye was found with good density and IVI in all the three sites having the highest value in Dura forest stand (272 individuals h^{-1} and IVI 12.36) (Table 8). However the maximum density among all the species was indicated by *Strobilanthes helicta* a medicinally important plant with 304 individuals ha^{-1} each in Dura and Gyachi stand. *Chimonocalamus griffithianus* and *Wallichia oblongifolia* the two highly used NTFPs were found in the study sites with comparatively lower population density. The density of *Chimonocalamus griffithianus* was highest in Dura (160 individuals ha^{-1}) followed by Gyachi (96 individuals ha^{-1}) and Nyilii (32 individuals ha^{-1}), while for *Wallichia oblongifolia* the density was highest in Dura stand (64 individuals ha^{-1}) (Table 8). Another socioeconomically feasible species and the only cane recorded in the study sites i.e. *Calamus acanthospathus* was found with 96 to 128 individuals ha^{-1}. Among the shrub layer, occurrence of other high value medicinal species, namely *Berberis wallichiana*, *Embelia ribes*, *Mahonia napaulensis* and *Zanthoxylum acanthopodium* were recorded with different population status. *Embelia ribes* was only distributed in Nyilii with comparatively low density (64 individuals ha^{-1}) (Table 8).

Many culturally and economically important herbs were also recorded in the present study. Out of total 71 herbaceous species more than 20 important NTFP yielding species were recorded in the three study stands. The species like *Diplazium esculentum*, *Elatostema platyphyllum*, *Houttuynia cordata*, *Oenanthe javanica*, *Pouzolzia hirta* used as vegetables were found to be growing in all the stands (Table 8). *Houttuynia cordata* exhibited highest density with more than 12,000 individuals ha^{-1} followed by *Oenanthe javanica* (>6,000 individuals ha^{-1}), *Diplazium esculentum* (>5,000 individuals ha^{-1}), *Pouzolzia hirta* (>4,000 individuals ha^{-1}), *Elatostema platyphyllum* (>6,000 individuals ha^{-1}). Besides, the fruit yielding species *Fragaria vesca* was recorded at all sites with >6,000 individuals ha^{-1} (Table 8). Among the three sites, the Dura stand was found comparatively a better habitat for herbaceous NTFPs where the density of the majority of the species was found with higher value. The important vegetable plant *Piper pedicellatum* which is being mostly preferred by the communities was found in the Nyilii and Dura but with very low density (2,000 individuals ha^{-1}). *Podophyllum hexandrum* high value medicinal plant was recorded only from the Nyilii study stand with low density among all the species (800 individuals ha^{-1}) (Table 8). The distribution of some other important herbaceous NTFP species like *Fagopyrum esculentum*, *Plantago erosa*, *Piper pedicellatum* and *Portulaca oleracea* was exhibited higher in Nyilii study stand in comparison to Dura and Gyachi. *Swertia angustifolia* another high value medicinal plant was recorded from all the sites having a density of 2,000 to 5,000 individuals ha^{-1}. Based on the IVI value the *Houttuynia cordata* was found to be most dominant among all the NTFP species in all the study sites (4.19, 6.91 and 7.16, respectively). The IVI value of *Piper pedicellatum* and

Podophyllum hexandrum was found <2 indicating the poor status of occurrence (Table 8).

Discussion

This study on NTFP yielding species from three selected forest stands was found helpful in understanding their diversity, distribution and population characters. The majority of the locally used plant species, particularly the non-timber forest products have been regularly collected by the people of the locality since their settlement in the area. These selected study stands showed a good floristic diversity representing a typical temperate vegetation that was characterized by the dominance of species under the genera *Pinus*, *Alnus*, *Castanopsis*, *Quercus*, *Rubus*, *Rosa*, *Fragaria*, *Primula*, *Rubia*, *Inula*, *Ranunculus*, *Saurauia*, etc. The occurrence of a total of 137 species under 68 families and 116 genera in the entire area with a minimum representation of 100 species in each study stand indicates a rich floristic diversity. The observed floristic diversity was higher than other such studies by Behera et al. (2002) from temperate forest of Lower Subansiri district of Arunachal Pradesh, Paul (2008) from the temperate broad leaved forest of Tawang and West Kameng districts of Arunachal Himalaya, Doležal and Šrůtek (2002) from Mt Velký Gápel', Slovakia, Semwal et al. (2010) from Kedarnath Wildlife Sanctuary, Central Himalaya and Kukshal et al. (2009) from temperate regions of northwest Himalaya. However, the present plant species richness was lesser than earlier studies by Behera and Kushwaha (2007) from temperate forest of Lower Subansiri district of Arunachal Pardesh, Sharma and Kant (2014) from the Sangla valley of northwest Himalaya, Zegeye et al. (2011) from temperate forest of northwestern Ethiopia and Shimono et al. (2010) from the higher altitudes of Qinghai- Tibetan Plateau. The species richness of the selected study stands showed the trend as herb layer > shrub layer > tree layer and was found similar to the observations by Khera et al. (2001) from the mid elevational forest of Nainital, Central Himalaya. Species occurrence in the present study varies from stand to stand according to their preferences towards the prevailing environmental conditions. The plant families Fagaceae, Betulaceae, Magnoliaceae, Lauraceae among the tree, Rutaceae, Rosaceae, Eleagnaceae, Rubiaceae for the shrubs and Poaceae, Araliaceae, Araceae, Hypoxidaceae, Asteraceae and Urticaceae for herbs were found dominant families with more than 3 species in each category. However, Araceae, Asteraceae, Fagaceae and Rosaceae were represented by at least 5 species in each strand. Among the families which were utilized for NTFPs; the families Rosaceae, Urticaceae, Araceae, Fagaceae, Poaceae, Zingiberaceae, Lauraceae, Rubiaceae, Moraceae appear on top with more than two major economically important species. The occurrence of many primitive families like Magnoliaceae, Rananculaceae, Fagaceae, Lauraceae, Rosaceae were also found which are associated with livelihood of the local inhabitants. Occurrence of six fern families, namely Selaginaceae, Pteridaceae, Lomariopsidaceae, Lycopodiaceae, Polypodiaceae and Thelypteridaceae indicated the dominancy of fern population in the study sites. Pinaceae, represented by *Pinus wallichiana*, the only Gymnospermic family, but with a high socioeconomic and ecological value in the area. Behera et al. (2002) and Paul (2008) reported that Asteraceae, Ericaceae and Rosaceae were the most dominant families from temperate/subalpine forests of Arunachal Himalaya. However, Rosaceae, Pteridaceae, Lamiaceae, Piniaceae and Asteraceae were reported to be the most dominant families in the wet temperate forest of Pakistan (Raja et al. 2014).

Tree density ranged from 376 to 456 individuals ha^{-1} which was within the range of reported value 192 to 1,852 individuals ha^{-1} from temperate forest of Arunachal Himalaya (Paul 2008) and 420 to 1,640 individuals ha^{-1} from temperate forests of Kumaon Himalaya (Saxena and Singh 1982). Several authors have also reported tree density within the range of 270 to 1,670 individuals ha^{-1} from the high altitude regions of India (Ghildiyal et al. 1998; Baduni and Sharma 1996; Sharma et al. 2009; Bharali et al. 2011). The present shrub density ranged from 2,848 to 3,696 individuals ha^{-1} which was within the range value of 504 to 3,576 individuals ha^{-1} reported by Paul (2008), while, it was found to be higher than the reported shrub density 1,387 to 2,617 from temperate forest of West Siang district of Arunachal Pradesh (Bharali et al. 2011), 376 to 595 individuals ha^{-1} from sub-tropical forest of districts Jammu and Samba of Jammu province of Jammu and Kashmir, 105 to 1,030 individuals ha^{-1} from Sangla valley of northwest Himalaya (Sharma et al. 2014). The herbaceous species density recorded (314,400 to 366,400) in the present study was in accordance with the reported herbaceous density 14,380 to 45,000 individuals ha^{-1} by Paul (2008) from temperate forest of western Arunachal Pradesh and 28,333 to 38,300 individuals ha^{-1} from temperate forest of West Siang district of Arunachal Himalaya (Bharali et al. 2011).

The present recorded basal area ranged between 22.82 to 51.64 m^2 ha^{-1} is within the range of 16.17-71.23 m^2 ha^{-1} from temperate forest of Uttarkasi (Rajwar 1991); 10.38-31.70 m^2 ha^{-1} from temperate forest of Garhwal Himalaya (Kumar et al. 2009); 54.2-74.6 m^2 ha^{-1} temperate forest of West Siang district of Arunachal Pradesh (Bharali et al. 2011); 24.8-68.4 m^2 ha^{-1} from *Pinus* sp. dominant highlands of Chiapas, México (Galindo-Jaimes et al. 2002); 8.94-69.84 m^2 ha^{-1} from sub-alpine zone of west Himalaya (Gairola et al. 2008). However, basal area recorded in the present study is much lower than the reported value of 9.22 to 137.35 m^2 ha^{-1} from Arunachal Himalaya (Paul 2008). Variation in the basal area of the present study may be due density, diversity of trees and favorable micro climatic condition for growth. Moreover, the presence or absence of higher number of individuals having a larger girth contributes towards the variation in the basal area of the respective study stands.

The Shannon-Wiener index of trees, shrubs and herbs were much less than the value reported by Behera et al. (2002) in temperate-subalpine forest (5.82) however, nearly same in case of subtropical pine forest (3.25). The present diversity index of trees, shrubs and herbs were more than the findings of Sharma and Raina (2013) and Khali and Bhatt (2014) from temperate forest of Jammu province of north-western Himalayas, Jammu and Kashmir and Gharwal Himalaya. The calculated values in the present study are almost same as reported elsewhere (Doležal and Šrůtek 2002; Kunwar and Sharma 2004). Lower value of Shannon-Wiener diversity index of life form of the selected study stands indicated that the ecological structure is less complex (Odum 1971). Simpson's dominance index for trees, shrubs and herbs were found to be higher than the value reported by Behera et al. (2002) in temperate/subalpine forest (0.3) and subtropical pine forest (0.78) of Arunachal Pradesh. Paul (2008) and Bharali et al. (2011) also reported higher dominance index from the temperate broad leaved forest of Arunachal Pradesh. However, the present Simpson index is lower than the reports of Sharma and Raina (2013).

Fairly similar geographic location and climate condition exhibited more than 70% similarity of value between the study sites. Species having wide geographical distribution attributed to the highest similarity between the study sites. While, lowest similarity index between the Nyilii and Dura study sites may be because of change in micro climatic and edaphic conditions between these two stands attributed to the turnover of plant species. Saxena and Singh (1982) and Khali and Bhatt (2014) have pointed out that site characteristics played a significant role in the distribution of plant species. Dominance-diversity curve for tree species showed that most of the IVI in all the stands were mainly concentrated in few dominant species. However, Behera et al. (2002) and Paul (2008) reported that single species contributed maximum IVI and density in temperate/subalpine and subtropical forest of Arunachal Pradesh. The evenness index of trees, shrubs and herbs in the present study ranged from 0.92 to 0.99. Uniyal et al. (2010) and Bharali et al. (2011) have also reported such high evenness index from temperate forest of Gharwal Himalaya and mixed *Rhododendron* Forest of Arunachal Himalaya. Higher values of evenness index indicate an even distribution of individuals of various species.

In all the selected study stands nearly 80% of the tree species showed clumped distribution while only a few species exhibited random distribution. None of the species showed the regular distribution. The present distribution pattern of the plant species may be due to lack of competition for the resources among the individuals of the species for the growth and survival. Similar results were reported by Paul (2008) in a temperate broad leaved forest of *Rhododendron* from western Arunachal Pradesh. The present distribution pattern in the different species nearly resembles with findings of Paul (2008) Bharali et al. (2011) from Arunachal Himalaya. However, the present percentage of clumped distribution of the species were much higher than that of reported by Khali and Bhatt (2014) from temperate forest of Gharwal Himalaya. Many reports on the contagious distribution of species are available supporting it as a common distributional pattern of forest species (Mehta et al. 1997; Kumar and Bhatt 2006; Singh et al. 2009). Odum (1971) also stated the clumped distribution pattern is the most common for species in nature which is due to the significant change in microclimatic conditions, topography, edaphic factors, slopes, inter and intra specific competition.

Out of the total species recorded, more than 50 important NTFP yielding species have been found comprising all the habit form. Among which *Castanopsis armata*, *Castanopsis hystrix*, *Choerospondias axillaris*, *Cinnamomum bejolghota*, *Litsea cubeba*, *Magnolia champaca*, *Pinus wallichiana*, *Pyrus pashia* and *Rhus chinensis* are the tree species having socio-economic importance. The density of distribution of these species revealed that, except *Castanopsis armata*, *Magnolia champaca* and *Pinus wallichiana* all other species have very limited and poor representation in the forests with the density less than 15 individuals ha^{-1}. The other two very important species, namely *Phoebe cooperiana* and *Litsea cubeba* used as NTFP for their fruits are also found with a better representation in population density with >15 individuals ha^{-1}. Species like *Juglans regia* and *Ficus auricualata* that are found supportive to the communities represented with low density and frequency and were restricted to one or two sites only. Many tree species found in the study sites have high rituals and religious values and are an unavoidable part of *Apatani* culture (Bamin and Gajurel 2015).

Among the shrubby layers about 12 high values NTFP species like *Berberis wallichiana*, *Calamus acanthospathus*, *Chimonocalamus griffithianus*, *Embelia ribes*, *Mahonia napaulensis*, *Rubia manjith*, *Rubus* spp. and *Zanthoxylum acanthopodium* have been recorded that can contribute to the economy of the poor people. Among these the density of population of the two species *Rubia manjith* and *Calamus acanthospathus* was found better in all the three sites. The *Rubia manjith* which have high market demand for its dye yielding property was although found with the maximum density among all the shrubs in the Gyachi forest (272 individuals ha^{-1}), the density was comparatively lower in the other two forests indicating the Gyachi forest a better site for its growth. However the population density was found very low then the value recorded by Gajurel (2012). The *Calamus acanthospathus* a cane species of commerce and highly used by the communities indicated a good population density in all the sites (96-128 individuals ha^{-1}). Likewise *Wallichia oblongifolia* which was in two sites showed a high population density in the Dura forest with the value of 64 individuals ha^{-1} than the Nyilii forest with 32 individuals ha^{-1}. The other two socioeconomically important species used for spices and medicine, namely *Zanthoxylum acanthopodium* and *Zanthoxylum oxyphyllum* were also recorded from all the three sites with an average population density (64-112 individuals ha^{-1}). Although the populations of the majority of the shrub or small tree species were found at all the sites, the species like *Docynia indica*, *Elaeagnus caudata*, *Embelia ribes* and *Thunbergia coccinea* were restricted to only in Nyilii forest indicating better diversity of NTFP species in the Nyilii forest.

The diversity of herbaceous species in the ground vegetation was also found highest among all the habit forms. More than 70 species of herbs with many economically important NTFPs have been found distributed in the study sites. Occurrence of species which are very commonly preferred by the communities, like species under the genus of *Piper*, *Smilax*, *Pouzolzia*, *Oenanthe*, *Diplazium*, *Podophyllum*, *Houttuynia*, *Elatostema*, *Swertia*, etc. were found in the sites with different population status. Among all the herbs the density and frequency were found very high in some unused species like some grasses and ferns with more than 10,000 individuals ha^{-1} indicating the dominance of these species that may suppress the growth of the many useful herbs like *Elatostema platyphyllum*, *Houttuynia cordata*, *Oenanthe javanica*, *Pouzolzia hirta*, *Piper pedicellatum*, *Plantago erosa* which are highly preferred vegetable of the communities as well other important species. Among these useful plants with the highest density of distribution was exhibited by the vegetable plant, i.e. *Houttuynia cordata* with $>10,000$ individuals ha^{-1} at all the sites. However, all other vegetable species like *Oenanthe javanica*, *Pouzolzia hirta*, *Elatostema platyphyllum*, *Piper pedicellatum*, *Plantago erosa*, etc. exhibited comparatively low density ($<8,000$ individuals ha^{-1}) indicating poor population. However *Elatostema platyphyllum* showed a better population density in the Dura forest with more than 9,000 individuals ha^{-1}. On the other hand the most preferred vegetable plant, the *Piper pedicellatum* was recorded from two stands but with very low population density. As the species preferred moist, humid soil with abundant growth in tropical and subtropical forests, mostly below 1,500 m (Gajurel et al. 2008), the present study sites were not found suitable for the growth of the species. Two high value medicinal plants *Podophyllum hexandrum* and *Swertia angustifolia* were also recorded from the study sites with low population status. Interestingly noted that these two species are commonly found in pure temperate forests in the state, mostly beyond 2000 m (Gajurel 2012) and occurrence of these species in the present study site also clarify that the nature of the three community forests is temperate.

Conclusion

The present study reveals that all the three forest stands comprise numerous important NTFPs having socio-economic value and supporting the livelihood of the communities. Among the three study sites overall diversity of NTFP species has been found in the Nyilii forest stand, but the density of population has been found better in Dura and Gyachi forest stands. All these forests have a potentiality to grow the higher value NTFP yielding species and if managed properly, they can support the economy of the poor communities. Among the high value plants the population and regeneration of *Rubia manjith*, *Houttuynia cordata*, *Calamus acanthospathus*, etc. were found good while the population status of *Piper pedicellatum*, *Podophyllum hexandrum*, *Pouzolzia hirta*, etc. were very low. The low population of many species was because of the microclimatic condition as well continuous extraction by the communities. Sustainable management practices for these low populated species preferring better habitat would be more supportive of the communities for better socioeconomic condition.

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References

Ahenkan A, Boon E. 2010. Commercialization of non-timber forest products in Ghana: Processing, packaging and marketing. J Food Agric Environ 8: 962-969.

Arnold JEM, Pérez MR. 2001. Can non-timber forest products match tropical forest conservation and development objectives? Ecol Econ 39: 437-447.

Arnold JEM, Perez RM. 1998. The role of non-timber forest products in conservation and development. In: Incomes from the forest. Methods for the development and conservation of forest products for local communities (Wollenberg E, Ingles A, eds). Centre for International Forestry Research, Bogor, Indonesia. pp 17-42.

Awasthi AK, Singh RD, Pal A. 1995. Ethnoecological analysis of Gond tribal system in Sidhi district, Madhya Pradesh, India. J Hum Ecol 6: 81-88.

Baduni NP, Sharma CM. 1996. Effect of aspect on the structure of some natural stands of *Cupressus torulosa* in Himalayan moist temperate forest. Proc Indian Natn Sci Acad B62: 345-352.

Bamin Y, Gajurel PR. 2015. Traditional use and conservation of some selected plants used in festivals and rituals in Apatani Plateau of Arunachal Pradesh, India. Int J Conserv Sci 6: 189-200.

Behera MD, Kushwaha SPS, Roy PS, Srivastava S, Singh TP, Dubey RC. 2002. Comparing structure and composition of coniferous forests in Subansiri district, of Arunachal Pradesh. Curr Sci 82: 70-76.

Behera MD, Kushwaha SPS. 2007. An analysis of altitudinal behavior of tree species in Subansiri district, Eastern Himalaya. Biodivers Conserv 16: 1851-1865.

Bharali S, Paul A, Khan ML, Singha LB. 2011. Species diversity and community structure of a temperate mixed *Rhododendron* forest along an altitudinal gradient in West Siang district of Arunachal Pradesh, India. Nat Sci 9: 125-140.

Chauhan AS, Singh KP, Singh DK. 1996. A Contribution to the Flora of Namdapha Arunachal Pradesh. Botanical Survey of India, Kolkata, India, 422 pp.

Chowdhery HJ, Giri GS, Pal GD, Pramanik A, Das SK. 1996. Materials for the Flora of Arunachal Pradesh. Vol. 1. Ranunculaceae–Dipsacaceae. Flora of India, Series 2. Botanical Survey of India, Kolkata, India, 693 pp.

Chowdhery HJ, Giri GS, Pal GD, Pramanik A, Das SK. 2009. Materials for the Flora of Arunachal Pradesh. Vol. 3. Hydrocharitaceae – Poaceae. Flora of India, Series 2. Botanical Survey of India, Kolkata, India, 349 pp.

Chowdhery HJ, Giri GS, Pal GD, Pramanik A, Das SK. 2008. Materials for the Flora of Arunachal Pradesh. Vol. 2. Asteraceae – Ceratophyllaceae. Flora of India, Series 2. Botanical Survey of India, Kolkata, India, 491 pp.

Curtis JT. 1959. The vegetation of Wisconsin. An ordination of plant communities. University Wisconsin Press, Madison,

USA, 657 pp.
De Beer JH, McDermott MJ. 1996. The economic value of non-timber forest products in Southeast Asia. 2nd ed. Netherlands Committee for IUCN, Amsterdam, Netherlands, 197 pp.
Doležal J, Šrůtek M. 2002. Altitudinal changes in composition and structure of mountain-temperate vegetation: a case study from the Western Carpathians. Plant Ecol 158: 201-221.
Dwivedi AP. 1993. Forests: the non-wood resources. International Book Distributors, Dehradun, India, 352 pp.
Edwards DM. 1996. The trade in non-timber forest products from Nepal. Mt Res Dev 16: 383-394.
Falconer J. 1992. Non-timber forest products in Ghana's forest zone: issues for forest conservation. In: Conservation of west and central African rainforests (Cleaver KM, Munasinghe M, Dyson M, Egli N, Peuker A, Wencelius F, eds). The World Bank, Washington, DC, USA, pp 177-181.
Gairola S, Rawal RS, Todaria NP. 2008. Forest vegetation patterns along an altitudinal gradient in sub-alpine zone of west Himalaya, India. Afr J Plant Sci 2: 42-48.
Gajurel PR. 2012. Mainstreaming of conservation and sustainable use of medicinal plant diversity in three Indian state. Final Technical Report on Botanical and Ecological survey of four MPCA in Arunachal Pradesh. Submitted to State Medicinal Plants Board. Department of Environment and Forests. Government of Arunachal Pradesh. (Unpublished). pp 14.
Gajurel PR, Rethy P, Kumar Y, Singh B. 2008. Piper species (Piperaceae) of North East India: Arunachal Pradesh. 1st ed. Bishen Singh Mahindra Pal Singh, Dehradun, India, 202 pp.
Galindo-Jaimes L, González-Espinosa M, Quintana-Ascencio P, García-Barrios L. 2002. Tree composition and structure in disturbed stands with varying dominance by *Pinus* spp. in the highlands of Chiapas, México. Plant Ecol 162: 259-272.
GFRA. 2005. Global Forest Resources Assessment. Progress towards sustainable forest management. FAO, Forestry paper 147. Food and Agriculture Organization of the United Nations, Rome, Italy, 350 pp.
GFRA. 2010. Global Forest Resources Assessment. Progress towards sustainable forest management. FAO, Forestry paper 163. Food and Agriculture Organization of the United Nations, Rome, Italy, 378 pp.
Ghildiyal SK, Baduni NP, Khanduri VP, Sharma CM. 1998. Community structure and composition of oak forests along altitudinal gradient in Garhwal Himalaya. Indian J For 21: 242-247.
Gleason HA. 1926. The individualistic concept of the plant association. B Torrey Bot Club 53: 7-26.
Godoy RA, Bawa KS. 1993. The economic value and sustainable harvest of plants and animals from the tropical forest: assumptions, hypotheses, and methods. Econ Bot 47: 215-219.
Hammett AL, Chamberlain JL. 1998. Sustainable use of non-traditional forest products: alternative forest-based income opportunities. In: Natural resources income opportunities on private lands conference (Kays JS, Goff GR, Smallidge PJ, Grafton WN, Parkhurst JA, eds). Hagerstown, Maryland, pp 141-147.
Haridasan K, Rao RR. 1985. Flora of Meghalaya. Vol. 1. Bishen Singh Mahndra Pal Singh, Dehradun, India, 450 pp.
Haridasan K, Rao RR. 1987. Flora of Meghalaya. Vol. 2. Bishen Singh Mahndra Pal Singh, Dehradun, India, 937 pp.
Harrison S, Bruna E. 1999. Habitat fragmentation and large-scale conservation: what do we know for sure? Ecography 22: 225-232.
http://www.censusindia.gov.in. Office of the Registrar General and Census Commissioner, India. Ministry of Home Affairs, Government of India. Accessed on 14 April, 2017.
http://www.lowersubansiri.nic.in. Lower Subansiri district. Official website. Arunachal Pradesh, India. Accessed on 17 September, 2014.
Jain SK, Rao RR. 1977. A handbook of field and herbarium methods. Today and Tomorrow's Printers and Publishers, New Delhi, India, 157 pp.
Kanjilal UN, Kanjilal PC, Das A, De RN, Bor NL. 1934-1940. Flora of Assam. Vol. 1-5. Government Press, Shillong, Meghalaya, India.
Kashian DM, Barnes BV, Walker WS. 2003. Ecological species groups of landform-level ecosystems dominated by jack pine in northern Lower Michigan, USA. Plant Ecol 166: 75-91.
Kennedy SMJ. 2006. Commercial non-timber forest products collected by the tribals in the Palni hills. Indian J Tradit Know 5: 212-216.
Khali M, Bhatt VP. 2014. Community structure of montane forest along the altitudinal gradient in Garhwal Himalaya, India. J Ecol Nat Environ 6: 205-214.
Khera N, Kumar A, Ram J, Tewari A. 2001. Plant biodiversity assessment in relation to disturbances in mid-elevational forest of Central Himalaya, India. Trop Ecol 42: 83-95.
Krishnamurthy T. 1993. Minor forest products of India. Oxford and IBH Publishing Co. Pvt. Ltd, New Delhi, India, 393 pp.
Kukshal S, Nautiyal BP, Anthwal A, Sharma A, Bhatt AB. 2009. Phytosociological investigation and life form pattern of grazing lands under pine canopy in temperate zone, northwest Himalaya, India. Res J Bot 4: 55-69.
Kumar M, Bhatt V. 2006. Plant biodiversity and conservation of forests in foot hills of Garhwal Himalaya. Lyonia 11: 43-59.
Kumar M, Sharma CM, Rajwar GS. 2009. The effects of disturbance on forest structure and diversity at different altitudes in Garhwal Himalaya. Chinese J Ecol 28: 424-432.
Kunwar RM, Sharma SP. 2004. Quantitative analysis of tree species in two community forests of Dolpa district, mid-west Nepal. Himalayan J Sci 2: 23-28.
Mehta JP, Tiwari SC, Bhandari BS. 1997. Phytosociology of woody vegetation under different management regimes in Garhwal Himalaya. J Trop Forest Sci 10: 24-34.
Menhinick EF. 1964. A comparison of some species-individuals diversity indices applied to samples of field insects. Ecology 45:

859-861.
Misra R. 1968. Ecology work book. Oxford and IBH Publishing Company, New Delhi, India, 244 pp.
Mueller-Dombois D, Ellenberg H. 1974. Aims and methods of vegetation ecology. John Wiley and Sons, New York, USA, 547 pp.
Nautiyal S, Kaul AK. 2003. Non-timber forest products of India. 1st ed. Jyoti Publishers and Distributors, Dehradun, India, 538 pp.
Nepstad DC, Schwartzman S. 1992. Non-timber products from tropical forests: evaluation of a conservation and development strategy (Adv Econ Bot 9). The New York Botanical Garden, Bronx, New York, USA.
Odum EP. 1971. Fundamentals of Ecology. 3rd ed. W.B. Saunders Company, Philadelphia, 574 pp.
Oliver CD. 1981. Forest development in North America following major disturbances. Forest Ecol Manag 3: 153-168.
Panayotou T, Ashton P. 1992. Not by timber alone. Economics and ecology for sustaining tropical forests. Island Press, Washington D.C., USA, pp 103-125.
Paul A. 2008. Studies on diversity and regeneration ecology of rhododendrons in Arunachal Pradesh. Ph.D. thesis. Assam University, Silchar, Assam, India.
Peters CM, Gentry AH, Mendelsohn RO. 1989. Valuation of an Amazonian rainforest. Nature 339: 655-656.
Pielou EC. 1969. An introduction to mathematical ecology. Wiley-Interscience, New York, USA, 286 pp.
Raja R, Bokhari TZ, Younis U, Dasti AA. 2014. Multivariate analysis of vegetation in wet temperate forests of Pakistan. IOSR J Pharm Biol Sci 9: 54-59.
Rajwar GS. 1991. Structure and diversity of a montane forest in a part of Bhagirathi valley, Garhwal Himalaya. In: Central Himalaya: Ecology environmental resources and developments (Maithani DD, ed). Daya Publishing House, New Delhi, India.
Roberts MR, Gilliam FS. 1995. Patterns and mechanisms of plant diversity in forested ecosystems: implications for forest management. Ecol Appl 5: 969-977.
Sarmah R, Pant RM, Majumder M, Adhikari D. 2003. Marketing of agricultural and non-timber forest products around Namdapha National Park in Arunachal Pradesh. Arunachal Rev 5: 8-14.
Saxena AK, Singh JS. 1982. A phytosociological analysis of woody species in forest communities of a part of Kumaun Himalaya. Vegetatio 50: 3-22.
Semwal DP, Uniyal PL, Bhatt AB. 2010. Structure, composition and dominance-diversity relations in three forest types of a part of Kedarnath Wildlife Sanctuary, Central Himalaya, India. Not Sci Biol 2: 128-132.
Shannon CE, Weiner W. 1963. The mathematical theory of communication. University of Illinois Press, Urbana, USA, 144 pp.
Sharma CM, Ghildiyal SK, Gairola S, Suyal S. 2009. Vegetation structure, composition and diversity in relation to the soil characteristics of temperate mixed broad-leaved forest along an altitudinal gradient in Garhwal Himalaya. Indian J Sci Technol 2: 39-45.
Sharma N, Kant S. 2014. Vegetation structure, floristic composition and species diversity of woody plant communities in sub-tropical *Kandi* Siwaliks of Jammu, J & K, India. Int J Basic Appl Sci 3: 382-391.
Sharma N, Raina AK. 2013. Composition, structure and diversity of tree species along an elevational gradient in Jammu province of north-western Himalayas, Jammu and Kashmir, India. J Bio Env Sci 3: 12-23.
Sharma P, Rana JC, Devi U, Randhawa SS, Kumar R. 2014. Floristic diversity and distribution pattern of plant communities along altitudinal gradient in Sangla Valley, northwest Himalaya. Sci World J http://dx.doi.org/10.1155/2014/264878.
Shimono A, Zhou H, Shen H, Hirota M, Ohtsuka T, Tang Y. 2010. Patterns of plant diversity at high altitudes on the Qinghai-Tibetan Plateau. J Plant Ecol 3: 1-7.
Sills EO, Lele S, Holmes TP, Pattanayak SK. 2003. Nontimber forest products in the rural household economy. In: Forests in a market economy (Sills EO, Abt KL, eds). Kluwer Academic Publishers, The Netherlands, pp 259-281.
Simpson EH. 1949. Measurement of diversity. Nature 163: 688.
Singh H, Kumar M, Sheikh MA. 2009. Distribution pattern of oak and pine along altitudinal gradients in Garhwal Himalaya. Nat Sci 7: 81-85.
Sørenson T. 1948. A method of establishing groups of equal amplitude in plant sociology based on similarity of species content and its application to analyses of the vegetation on Danish commons. Biol Skr Dan Vid Sel 5: 1-34.
Stewart GH, Rose AB. 1990. The significance of life history strategies in the developmental history of mixed beech (*Nothofagus*) forests, New Zealand. Vegetatio 87: 101-114.
Sundriyal M, Sundriyal RC, Sharma E, Purohit AN. 1998. Wild edibles and other useful plants from the Sikkim Himalaya, India. Oecologia Mont 7: 43-54.
Tewari DD, Campbell JY. 1995. Developing and sustaining non-timber forest products. Some policy issues and concerns with special reference to India. J Sust Forest 3: 53-79.
Timilsina N, Ross MS, Heinen JT. 2007. A community analysis of sal (*Shorea robusta*) forests in the western Terai of Nepal. Forest Ecol Manag 241: 223-234.
Uniyal P, Pokhriyal P, Dasgupta S, Bhatt D, Todaria NP. 2010. Plant diversity in two forest types along the disturbance gradient in Dewalgarh Watershed, Garhwal Himalaya. Curr Sci 98: 938-943.
Vantomme P. 2003. Compiling statistics on non-wood forest products as policy and decision-making tools at the national level. Int Forest Rev 5: 156-160.
White PS. 1979. Pattern, process, and natural disturbance in vegetation. Bot Rev 45: 229-299.

Whitford PB. 1949. Distribution of woodland plants in relation to succession and clonal growth. Ecology 30: 199-208.
Whittaker RH. 1972. Evolution and measurement of species diversity. Taxon 21: 213-251.
Zegeye H, Teketay D, Kelbessa E. 2011. Diversity and regeneration status of woody species in Tara Gedam and Abebaye forests, northwestern Ethiopia. J For Res 22: 315-328.