The Study of Tree Species Diversity in Dry Forest of East Nusa Tenggara, Indonesia

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ABSTRACT

We examined structure, diversity and importance value index (IVI) of tree species in dry forests of Binafun, Bonmuti, Letkole and Oelbanu, Mutis Timau Conservation Forest Management Unit, East Nusa Tenggara province, Indonesia. To obtain data on the composition and diversity of vegetation carried out through the analysis of tree species using sampling plots in a rectangular shape, with a size of 100 m x 100 m at 100 m intervals. Results of tree species list showed that there were 94 species belong to 45 families and 72 genera. Tree species richness ranged from 1.81 to 10.06, tree density about 166 individual/ha-545 individuals/ha and basal area ranged from 5.78 m^2/ha to 27.79 m^2/ha. *Eucalyptus urophylla* was the most abundant tree in the research sites (except Letkole) and well distributed. Species richness, density, Shannon–Wiener index and basal area are important factors in determining the tree species diversity in research sites. The results in this research should be useful to the dry forest management and conservation managers and researchers.

Keywords: Structure, diversity, importance value index, Mutis Timau Conservation Forest Management Unit, basal area.

INTRODUCTION

Tropical forests provide many ecosystem services such as species conservation, prevention of soil erosion, and preservation of habitat for plants and animals (Armenteras *et al*., 2009). Trees, an important component of vegetation, must therefore be constantly monitored and managed in order to direct successional processes towards maintaining species and habitat diversity (Attua and Pabi, 2013) and it's also fundamental to tropical forest biodiversity (Evariste *et al*., 2010). Biodiversity is essential for human survival and economic well being and for the ecosystem function and stability (Singh, 2002). According to Noss (1990), biodiversity is not simply the number of different genes, species, ecosystems, or any other group of things in a defined area. The composition, structure and function determine and also constitute the biodiversity of an area. Knowing species diversity is a useful tool in plant ecology and forestry to compare the composition of different species. Tree species diversity in tropical forests differ greatly from location to location mainly due to variation in biogeography, habitat, and disturbance (Neumann and Starlinger, 2001). Characterization of the structure and species composition of tree communities is the first step in understanding forest ecology and dynamics. For example, such information has been useful for comparing and understanding historical and ecological relationships among forests (Ashton *et al*., 2004). The analysis of tree community structure and diversity is still challenging for researchers in tropical ecology (Bawa *et al*., 2004), because tropical forests are the richest biological communities on earth and these forests have been recognized to harbor a significant proportion of global biodiversity (Myers *et al*., 2000).

Prior to forest management operations, biodiversity inventories are used to determine the nature and distribution of biodiversity resources of the region being managed. Such biodiversity inventories are best integrated with the timber resource inventories in order that forest management operations can be planned (Rennolls and Laumonier, 2000). The rapid inventory of tree species that provides information on diversity will represent an important tool to enhance our ability to maximize biodiversity conservation (Baraloto *et al*., 2013) and will help us to understand the patterns of tree species composition and diversity. Understanding tree composition and structure of forest is a vital instrument in assessing the sustainability of the forest, species conservation, and management of forest ecosystems (Kacholi, 2014).

Here, we present the first study on composition and structure of tree species communities in dry forest of East Nusa Tenggara, Indonesia. The present study is significant in producing useful baseline data in order to conserve, manage, valuable data of dry forest assessment and improve our knowledge in identification of ecologically useful tree species of dry forest in Indonesia. The objective of this study was to compared composition and diversity of tree species and quantified the importance value index of tree species, diversity

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index and tree species distribution in the tropical dry forest of Binafun, Bonmuti, Letkole and Oelbanu, Mutis Timau Conservation Forest Management Unit, East Nusa Tenggara province, Indonesia.

MATERIALS AND METHODS

The study was carried out at the Mutis Timau Conservation Forest Management Unit, which is covered on Kupang regency, Timor Tengah Selatan regency and Timor Tengah Utara regency (Lat. 90 20' 00" - 90 45' 10" South and long. 123042'30" – 1240 20' 00" E) in eastern Indonesia (Fig.1).

The research sites represents the dry forests of East Nusa Tenggara, Indonesia, and surrounding areas are the wettest areas on the island of Timor, the rain fell almost every month with the highest frequency of rainfall occurs during November to July, temperatures range between 14^0C - 29^0C, and in extreme conditions can decrease up to 9^0C. High-speed high winds occurred in November until March. About 71% area are hilly (15–30% slope) to mountainous (>30% slope) (Mulyani *et al.,* 2013). The high-intensity rainfall (2 000–3 000 mm/year) during the rainy season (Fisher *et al*., 1999).

The study area was divided into four study sites *i.e*. Binafun dry forest area, Bonmuti dry forest area, Letkole dry forest area and Oelbanu dry forest area for studying the status of plant diversity and community structures species of the study sites. To obtain data on the composition and diversity of vegetation carried out through the analysis of vegetation using sampling plots in a rectangular shape, with a size of 100 m x 100 m at 100 m intervals. The replications of plot in four study sites were 2 plots. In each plot, all tree species were measured for species name, height, and diameter at breast height (DBH) ≥ 20 cm (1.3 meters). Morphologically, specimen identifications were confirmed with the collection of Herbarium at Kupang Forestry Research Agency, Ministry of Forestry, East Nusa Tenggara, Indonesia.

The species richness and total species richness were calculated as the number of species per plot and the total species number at each site, respectively. The density of a species was the number of trees of that species per hectare. The relative density of a species was calculated as its density divided by the total density of all species and multiplied by 100. The frequency of a species was the number of plots in which that species was found. The relative frequency of a species was calculated as the frequency of a species divided by the total number of sampling plots and multiplied by 100 (Koonkhunthod *et al*., 2007).

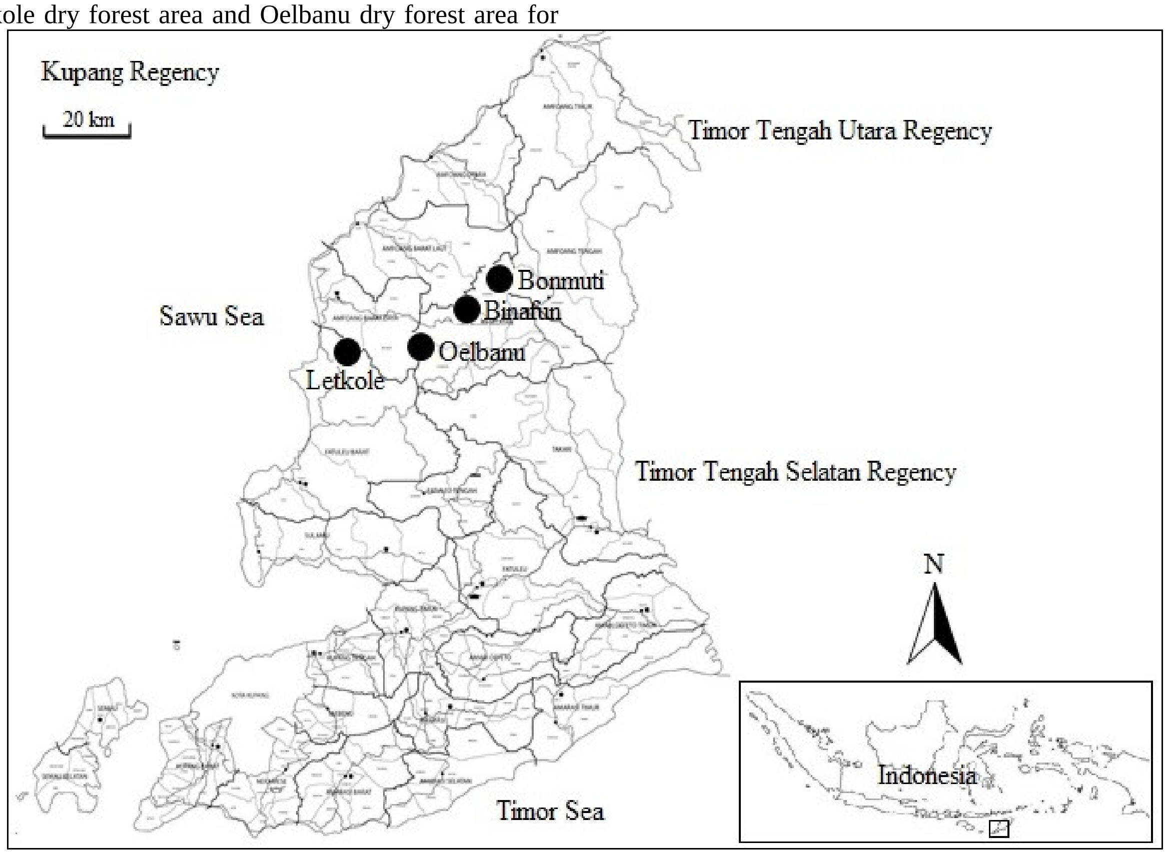

Fig. 1. Map of research sites

The Importance value Index (IVI) for a species is a composite of three ecological parameters including density, frequency and basal area, which measure different features and characteristics of a species in its habitat (Soerianegara and Indrawan, 1988). Basal area per tree is the cross-sectional area of a tree at breast height. It was calculated from diameter at breast height. Ecologically, density and frequency of a species measure the distribution of a species within the population while basal area measures the area occupied by the stems of trees. Diversity of trees at each site was estimated by the Shannon–Wiener index = H' (Shannon, 1948). The Shannon diversity index computed as:

$$H' = \sum_{i=1}^{s} \left(\frac{ni}{N}\right) \ln\left(\frac{ni}{N}\right)$$

Where, N = number species and ni = number of individuals in a species in sample quadrats. And Principal Components Analysis (PCA) was used to summarize the relationship of tree species structure parameters for all sites by using XLStat 2014 software.

RERSULTS AND DISCUSSION

Based on the research, a total of 2097 individuals belonging to 94 species among 72 genera and 45 families from eight 1-ha plots were enumerated in the research sites. In the present research, species richness in the research sites showed a wide variation, ranging from a low value of 1.81 in plot 1 of Oelbanu, to a very high 10.06 in plot 2 of Letkole. The highest stand density was observed in plot 2 of Oelbanu (545 individuals/ha), whereas the lowest stand density was observed in plot 1 of Oelbanu (166 individual/ha). The basal area in all the study plots ranged from 5.78 m^2/ha (plot 2 of Bonmuti) to 27.79 m^2/ha (plot 1 of Binafun) and the mean basal area for the each sites was 27.53 m^2/ha, 12.295 m^2/ha, 21.135 m^2/ha and 18.93 m^2/ha for Binafun, Bonmuti, Letkole and Oelbanu, respectively (Table 1). These data contribute to dry forest structure in the research sites. According to Ingram *et al*., (2005), in Madagascar, the low basal area values in the forests were related to high accessibility by the nearby community and lack of enough protection, which could account for observed values too. Generally, in many dry forest, lower basal area is mainly characterized by high abundance of young trees (Pardini*et al*., 2005).

Diversity of tree species in the study plots calculated using the ShannoneWeiner index (H') showed that the highest diversity was in plot 2 Letkole (3.9) and the lowest diversity was in plot 1 Oelbanu (1.5), ranged between 0. 81 and 4.1 (Sundarapandian and Swamy, 2000). Species diversity was significantly influenced by forest structure and species composition (Huang *et al*., 2003). Knowing species diversity is a useful tool in plant ecology and forestry to compare the composition of different species. Tree species diversity in tropical forests differ greatly from location to location mainly due to variation in biogeography, habitat, and disturbance (Neumann and Starlinger., 2001). Biodiversity indices are generated to bring the diversity and abundance of species in different habitats to a similar scale for comparison and the higher the value, the greater the species richness. The higher values of the diversity indices revealed a forest with high tree species diversity and abundance (Adekunle *et al*., 2013).

Table 1. Characteristics of tree species in the research sites

Research sites	Species richness	Density	Basal area	Shannon–Wiener index
Binafun				
Plot 1	8.18	352	27.79	3.3
Plot 2	7.81	219	27.27	3.2
Average	7.99	285.5	27.53	3.25
Bonmuti				
Plot 1	4.56	273	18.81	3.24
Plot 2	4.75	225	5.78	3.28
Average	4.65	249	12.295	3.26
Letkole				
Plot 1	9.93	515	18.27	3.8
Plot 2	10.06	534	24	3.9
Average	9.99	524.5	21.135	3.85
Oelbanu				
Plot 1	1.81	166	18.49	1.5
Plot 2	8.06	545	19.37	3.07
Average	4.93	355.5	18.93	2.28

The five most highest rank of density was measured for all research sites (Fig. 2). Totally, *Eucalyptus urophylla* had the highest density of 68.83%, 57.67% and 43.99% in Binafun, Bonmuti and Oelbanu, respectively. Also *Ficus ampelos* in Letkole (13.35%). Generally, *E. urophylla* has highest density than others species, because the nature surrounding mount Mutis Timau Conservation Forest Management Unit is considered to be one of the few remaining pure stands of *E. urophylla* in Indonesia (Robinson and Supriadi, 1981) and the species has no major edaphic requirements, it is appropriate for reforestation, both in flooded soils and in dry soils of low tropical lands. *E. urophylla* occurs in open, often secondary, mountain forest and performs best on deep, moist, well-drained soils. It grows in the vegetal formations of dry deciduous forest and moist evergreen forest (Pepe *et al*., 2004).

In the present study, the value of important index (IVI) for tree species (Table 2) in the Binafun suggested that *Elattostachys verrucosa* (151.64), *E. urophylla* (79.13), and *Prunus sp* (65.71) were the dominant species. These species were followed by *Zizyphus timoriensis* (60.36) and *Celtis wightii* (59.34). However, among the site of Bonmuti, *Phaleria laurifolia* (105.31), *E. urophylla* (103.78), and *Hibiscus timoriensis* (89.81) were the dominant species, followed by *Elattostachys verrucosa* (79.83), and *Celtis cinnamomea* (79.79). In the site of Letkole, *Aglaia heptandra* (98.44), *Melaleuca leucadendron* (87.9), and *Drypetes macrophylla* (82.52) were the dominant species with the highest IVI values, followed by *Wikstroemia androsaemifolia* (60.97) and *Celtis cinnamomea* (56.19). Where as in site of Oelbanu, *Ceriops tagal* (188.28), *Dryobalanops aromatic* (159.09), and *E. urophylla* (126.2) were the dominant species followed by *Schleichera oleosa* (77.76), and *Vitex parviflora* (51.21) were the codominant species. These high value of IVI is largely due to its higher relative frequency, density, and dominance compared to other species.

The presence of many species with lower IVI values at Binafun (*Canarium asperum*=2.89, *Podocarpus amara*=3.26, *Ficus glomerata*=3.41, *Cordia spp*=5.04), Bonmuti (*Aglaia heptandra*=5.35, *Ficus ampelos*=6.68, *Gyrocarpus americanus*=8.54, *Ficus callosa*=8.75), Letkole (*Albizzia procera*=1.82, *Kleinhovia hospital*=2.04, *Ficus benjamina*=2.06, *Cudrania cochinchinensis*=2.08) and Oelbanu (*Viburnum sp*=4.25, *Syzygium javanica*=7.75, *Terminalia catappa*=9.36, *Ficus benjamina=9.39*) are indication that the majority of species are rare in the research sites, its may causedby competition within the dry forest

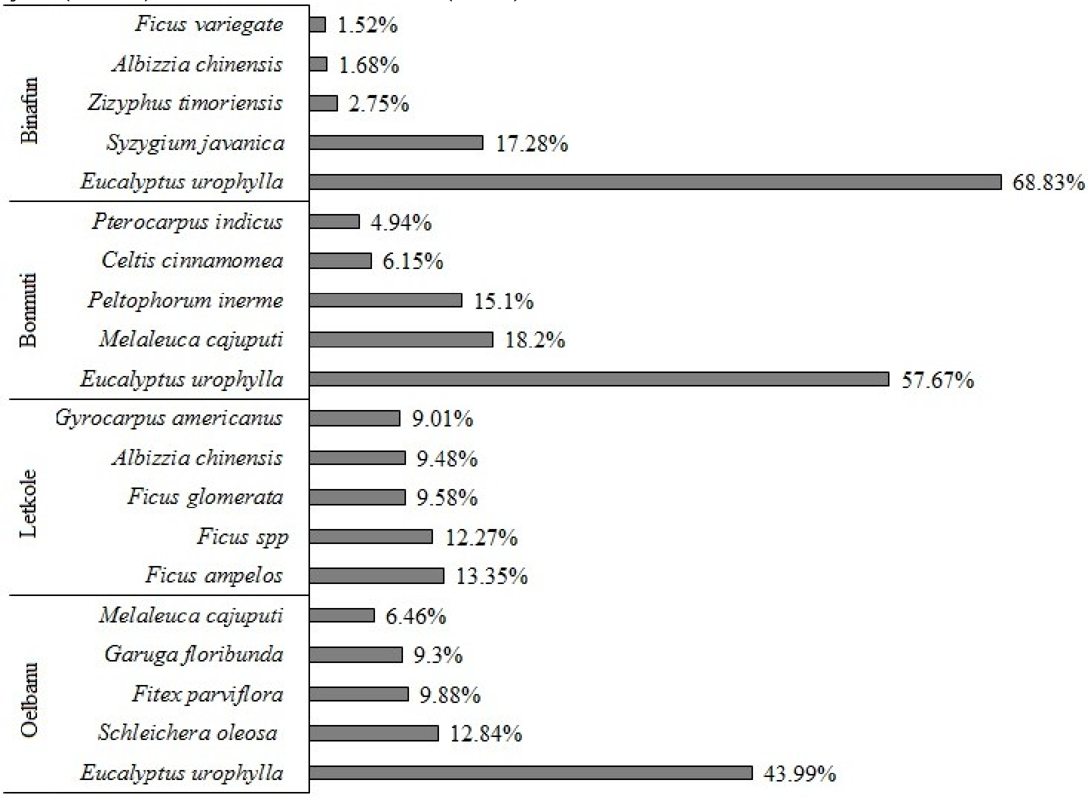

Fig. 2. The most common tree species in the research sites (%)

Table 2. The important value index (IVI) of tree speciesin the research sites

Scientific name	Family	IVI			
		Binafun	Bonmuti	Letkole	Oelbanu
Acacia oraria	Mimosaceae			3.56	
Aglaia heptandra	Meliaceae		5.35	98.44	
Albizzia chinensis	Fabaceae	16.35	38.69	11.64	
Albizzia lebekioides	Fabaceae			2.8	
Albizzia procera	Fabaceae			1.82	
Albizzia saponaria	Fabaceae			2.47	
Alstonia scholaris	Apocynaceae			17.05	17.38
Alstonia villosa	Apocynaceae	42.17			
Bambusa spinosa	Poaceae				24.38
Bauhinia malabarica	Leguminosae			4.45	
Broussonetia papyrifera	Moraceae			4.19	
Canarium asperum	Burseraceae	2.89	12.04		
Casuarina junghuhniana	Casuarinaceae				28.91
Celtis cinnamomea	Ulmaceae	17.13	79.79	56.19	
Celtis wightii	Ulmaceae	59.34		14.05	
Ceriops tagal	Rhizophoraceae				188.28
Cordia spp	Boraginaceae	5.04		3.96	20.81
Cudrania cochinchinensis	Moraceae			2.08	
Desmodium cephalotis	Cephalotaceae	6.043			
Dryobalanops aromatica	Dipterocarpaceae				159.09
Drypetes longifolia	Putranjivaceae			6.83	
Drypetes macrophylla	Putranjivaceae			82.52	
Dysoxylum gaudichaudianum	Meliaceae	49.98		55.31	
Elattostachys verrucosa	Sapindaceae	151.64	79.83	4.17	
Eleocarpus peyiolatus	Elaeocarpaceae	17.73	15.19		
Eucalyptus urophylla	Myrtaceae	79.13	103.78		126.2
Eugenia littorale	Myrtaceae		51.18	2.97	
Eugenia polyantha	Myrtaceae			4.01	
Euodia macrophylla	Rutaceae	23.56	56.48		
Exocarpus latifolia	Santalaceae			3.65	
Ficus ampelos	Moraceae	12.88	6.68	43.7	
Ficus benjamina	Moraceae			2.06	9.39
Ficus callosa	Moraceae	5.85	8.75		
Ficus flaveola	Moraceae		31.83		
Ficus fulva	Moraceae	8.994			10.28
Ficus gibbosa	Moraceae			10.5	
Ficus glomerata	Moraceae	3.41		24.39	46.58
Ficus hispida	Moraceae			11.63	
Ficus nervosa	Moraceae		12.76		
Ficus racemosa	Moraceae			5.11	
Ficus spp	Moraceae	10.5		36.61	
Ficus variegata	Moraceae	14.05	61.57	7.27	
Garuga floribunda	Burseraceae			6.73	24.73
Gnetum gnemon	Gnetaceae			9.07	
Gyrocarpus americanus	Hernandiaceae	10.56	8.54	30.81	25.49
Harissonia perforata	Simaroubaceae	7.53			
Hibiscus tiliaceus	Malvaceae				16.32

Continue Table 2.

Scientific name	Family	IVI			
		Binafun	Bonmuti	Letkole	Oelbanu
Hibiscus timoriensis	Malvaceae		89.81		
Homalium tomantosum	Salicaceae			4.12	
Hymenodictyon excelsum	Rubiaceae			4.25	
Jambolifera trifoliata	Rutaceae				13.16
Kleinhovia hospita	Malvaceae			2.04	
Lagerstroemia sp	Lythraceae		64.17	4.66	
Lantana camara	Verbenaceae			8.79	
Leea sp.	Vitaceae			19.46	
Litsea diversifolia	Lauraceae			5.46	19.57
Macaranga tanarius	Euphorbiaceae	16.2		9.23	
Maesa latifolia	Primulaceae			9.71	
Mallotus philippinensis	Euphorbiaceae			7.38	
Mangifera indica	Anacardiaceae				10.97
Melaleuca cajuputi	Myrtaceae		55.64		12.22
Melaleuca leucadendron	Myrtaceae	14.24		87.9	
Mischocarphus sundaicus	Sapindaceae			18.33	
Nauclea orientalis	Rubiaceae			14.5	
Nephelium juglandifolium	Sapindaceae			5.26	
Omalanthus populneus	Euphorbiaceae	16.36			
Oroxylum indicum	Bignoniaceae			8.74	
Peltophorum inerma	Fabaceae			15.07	19.91
Phaleria laurifolia	Thymelaeaceae	45.7	105.31	12.65	
Photinia sp	Rosaceae			17.85	
Phyllanthus sp.	Phyllanthaceae			12.82	
Pipturus argenteus	Urticaceae	18			
Pittosporum timorense	Pittosporaceae				20.67
Podocarpus amara	Podocarpaceae	3.26			
Podocarpus imbricata	Podocarpaceae	23.4			
Polyscias rumphiana	Araliaceae			2.1	
Prunus sp	Rosaceae	65.71		4.16	
Pterocarpus indicus	Fabaceae		18.14		
Pterocymium tinetorium	Malvaceae			12.21	
Pygeum parviflorum	Rosaceae			6.65	
Schleichera oleosa	Sapindaceae			8.91	77.76
Sesbania grandiflora	Fabaceae	17.38	23.06		
Sterculia foetida	Sterculiaceae			14.2	
Syzygium javanica	Myrtaceae	48.1			7.75
Tamarindus indica	Fabaceae				20.54
Tarenna pubiflora	Rubiaceae			15.65	
Terminalia catappa	Combretaceae			13.46	9.36
Terminalia mollis	Combretaceae	34		2.14	
Timonius sericaus	Rubiaceae			3.89	11.92
Viburnum sp	Adoxaceae	41.92	26.36		4.25
Vitex parviflora	Verbenaceae				51.21
Wikstroemia androsaemifolia	Thymelaeaceae			60.97	
Wrightia calycina	Apocynaceae			10.39	
Zizyphus timoriensis	Rhamnaceae	60.36	44.98	6.68	20.68

poor dispersability of tree species, natural or anthropogenic disturbance and existence of a resource gradient, which causes species to occupy different positions within it resulting in abundance distribution variation (Schwarz *et al*., 2003).

The PCA ordination of the eight plots on the basis of species basal cover is presented in Figure 3. The PCA axis 1 accounted for 66.13% variation in species composition while PCA axis 2 accounted for 23.64% variation. The PCA axis 1 was related with species richness (SR), density (Dens), Shannon–Wiener index (H') and the PCA axis 2 represented the basal area (BA). This significant relationships area indicated that parametersare important in determining the diversity of the dry forest communities in research areas, particularly at plot 1 of Letkole (H'), plot 2 of Oelbanu (density and species richness), plot 2 of Letkole (species richness) and plot 1 of Binafun (basal area).

According to Orth and Colette (1996), the H' index has strong values for species with recoveries of same importance and it takes low values, when some species have strong recoveries. Our study showed that plot 1 of Letkole has a high value of H' index (3.8), its mean the existence of variability of biodiversity in the study site. Low diversity index in plot 1 of Oelbanu (1.5) could be explained by the fact that it is dominated by a single species *E. urophylla*. This species contributes nearly 43.99% of the total number of trees in the plot. Regarding heterogeneity,many authors think that the structural heterogeneity of the forests and their high species richness are often interpreted in terms of forest dynamics and relationship with the resulting phenomena of succession (Trichon, 1997).

Species richness is a regional attribute (Wagner *et al*., 2014), in the sense that species are produced mostly by the evolutionary divergence of populations in isolation, which requires spatial heterogeneity on scales sufficient to reduce gene flow for long periods (Ricklefs, 2015).

Moreover, mechanisms by which species richness within a region feeds back on the rate of species production within that region have, as yet, received little attention. One possibility is that increasing species richness intensifies interspecific competition and limits the number of species that can coexist locally, thereby restricting immigration from outside the region or preventing allopatric sister species produced within a region from achieving secondary sympatry (Pigot and Tobias, 2013). Recent studies have demonstrated a strong relationship between total species richness and temperature, precipitation, and net primary productivity (Hawkins et al., 2003), e.g., in South Africa (Sanders *et al*., 2007), Tanzania (Karger *et al*., 2011), and India (Sharma *et al*., 2009).

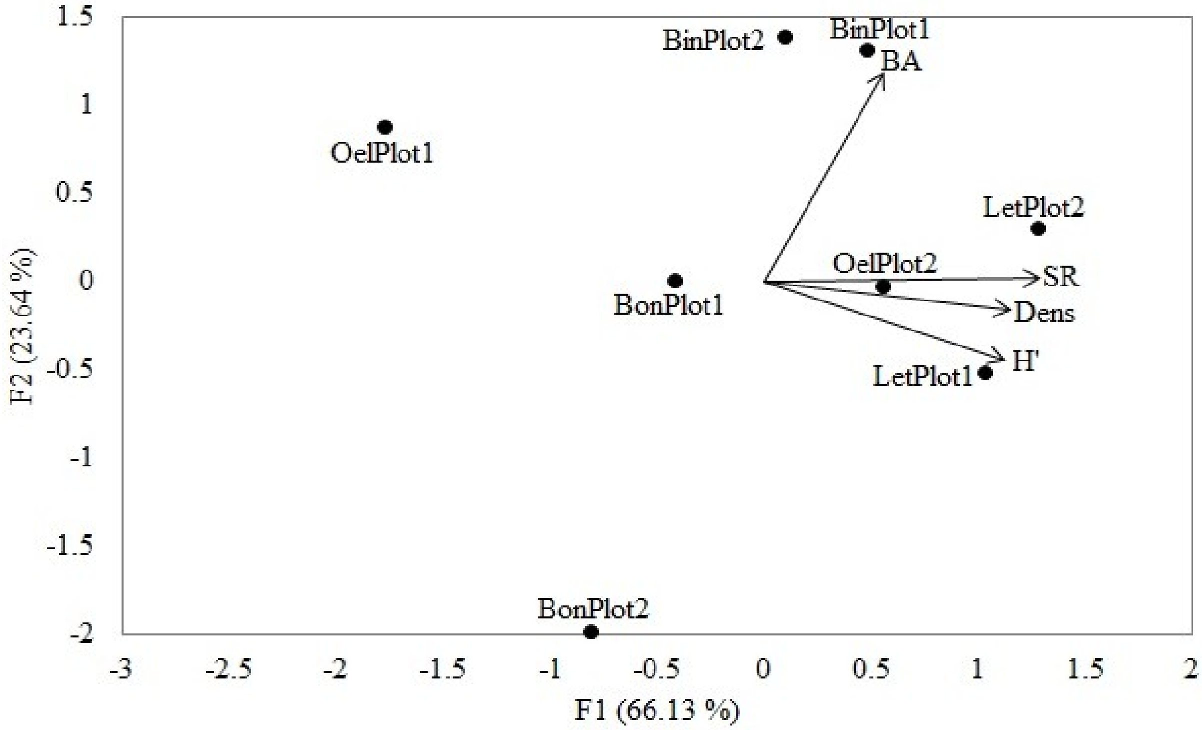

Fig. 3. PCA for tree species richness (SR), density (Dens), Shannon–Wiener index (H') and basal area (BA) in the research sites

However, in the present study of Silva-Flores *et al*., (2014) at Mexico, the relationship between diversity and temperatures in degrees Celsius was almost negative and nonlinear, its may caused by significant heterogeneity in slopes among data sets and the combination of slopes across studies were significantly lower than the range of slopes prediction (Hawkins *et al*., 2007).

CONCLUSION

It could be concluded that *E. urophylla* were very abundant in the research sites (except Letkole) and were widely distributed. The lowest distribution of of *Albizzia procera, Kleinhovia hospital, Ficus benjamina* and *Cudrania cochinchinensis* in Letkole were scarcely caught in the research period. However, there is no single dominance tree species in Letkole. Species richness, density, Shannon–Wiener index and basal area important in determining the tree species diversity in research sites. The results of research in this research should be useful to the dry forest management and conservation managers and researchers for effective dry forest management. In the future, measures of variability, such as standard deviations and ranks, may be much more useful in describing, comparing forest communities (Jongman *et al*., 1995) and empirical data derived from landscape studies on species composition and abundance patterns are needed in order to test more complex concepts related to tropical plant communities, of which the metacommunity theory is an example (Chase, 2005).

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