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Programme: Master of Science in Forestry

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FORESTRY AND WOOD TECHNOLOGY DISCIPLINE
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This Project Thesis has been prepared and submitted for the partial fulfillment of M.Sc Degree in Forestry under Forestry and Wood Technology Discipline, Khulna University, Khulna

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Intra-and Inter-Specific Spatial Association and Diversity of Tree Species in Lawachara National Park, Moulvibazar

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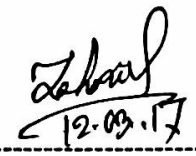
DECLARATION

I, here, by declare that the thesis work is based on my original work except for quotations and citations, which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Khulna University or other institutions.



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APPROVAL

This is to certify that S.M Zahirul Islam, Student ID: - MS-140519 has prepared this thesis entitled **"Intra-and Inter-Specific Spatial Association and Diversity of Tree Species in Lawachara National Park, Moulvibazar"**. I do hereby approve the style and content of the thesis. This thesis has been prepared in partial fulfillment of the requirement for M. Sc Degree in Forestry.

12.03.17

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ACKNOWLEDGEMENT

At very beginning I would like to show my deep gratitude to the Almighty Allah who has given me the opportunity for the submission of the thesis. I would like to express my heartful gratitude to my supervisor Dr. Md. Nabiul Islam Khan, Professor, Forestry and Wood Technology Discipline, Khulna University, whose generous, attention, advice, suggestion, particularly unwavering encouragement always kept me towards an appropriate focus to complete the study clearly.

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ABSTRACT

Intra-and inter-specific competition, spatial association and plant diversity are important insights to investigate in maintaining and understanding the mechanisms that facilitate species coexistence. In this Study, Pair correlation function and Mark correlation Function were used to analyze spatial distribution patterns and spatial associations of top 10 dominant tree species in a 1-ha plot of a semi-evergreen forest in Lawachara National Park, Bangladesh. It was observed that a total 60 woody species were recorded in the 1 ha sampling plot, the top 20 species contributed 83% of importance value (IV). The top five dominant species were respecttively Chapalish- *Artocarpus chaplasha* Roxb (18.031% IV)., Dewa- *Artocarpus lakucha* Roxb. (9.329 % IV), Badam- *Terminalia catappa* L. (7.168 % IV), Kakra- *Glochidion lanceolaris* Roxb. (5.708 % IV) and Khudijam- *Syzygium fruticosum* (Roxb.) DC (5.596 % IV). The values of Shannon's index H' and Pielou's index J' (evenness) were 3.37 bit and 0.82 respectively. The expected maximum number of species (67) was found very close to the total numbers of observed tree species (60). The results showed that top 10 dominant tree species were positively associated (coexistence) with each other. However, all the species maintained regularity within 2.5- 5 m radius as neighbourhood and after 5 m distance complete spatial randomness was observed. Trees having similar dbh (matured ones) like to be 20 m apart from each other and remain away from each other. Considering all the species, trees having similar diameter can be neighbours within 15 m radius (species co-existence). Cluster dendrogram and bivariate pair correlation of top 20 species suggested a formation of six clusters having species preferences in the neighbourhood.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background and Justification of the Study

In forest, trees provide resources and habitats for almost all other species (Feroz et al, 2014; Huang et al., 2003; Whitmore, 1998; Hall and Swaine MD, 1976;). Although, Biodiversity is a major concern in nature conservation (Wilson, 1992), species association and biodiversity are interlinked. Species diversity and species association are the two important components of biodiversity (Itô, 1997) that provide information of stand history, population dynamics, species co-existence and competition (Greig-Smith, 1979; Stoll & Bergius, 2005). Species co-existence depend on the intra-and inter-specific competition that lead to different spatial association and pattern such as random, regular and clumped in a community (Lan et al., 2012). Therefore, Intra-and inter-specific spatial association in plant communities is of particular interest to ecologists because of its potential role in explaining the coexistence of tree species in species-rich forests (Bunyavejchewin et al., 2003).

However, numerous mechanisms have been proposed to explain tropical tree species spatial association and species diversity at local scales (Lan et al., 2009; Wright, 2002). The most commonly used measurement techniques of species diversity are the Shannon function, species richness (number of species), and evenness (the distribution of abundance among the species). In addition, pair correlation function and mark correlation function also widely used methods for understanding the intra-and-inter-specific spatial association, species co-existence and competition (Khan et al., 2013; Lan et al., 2009). Analyzing the species diversity and intra-and inter-specific spatial association of species may help to determine the mechanisms important in structuring forest communities such as establishment, growth, competition, reproduction, senescence and mortality (Feroz et al, 2014; Sterner et al., 1986).

We conducted our study in Lawachara National Park, a semi evergreen forest of Bangladesh to understand the mechanism of intra-and-inter-specific spatial association and species co-existence.

1.2 Objective of the Study

The objectives of our study were

- to describe the vegetation structure of tree species in Lawachara National Park.
- to quantify the spatial distribution pattern of trees and association among tree species.
- to quantify the tree species diversity.

CHAPTER TWO

2.0 MATERIALS AND METHODS

2.1 Description of the study site

Lawachara National Park (LNP) is located in Kamalganj Upzila of Maulvibazar District nearly 160 km northeast of Dhaka and approximately 60 km south of Sylhet city. It lies between $24°30' - 24°32'$ N and $91°37' - 91°39'$ E and is nearly eight km east of Srimongal, on way to Kamalganj. The National Park and proposed extension comprise forests of southern and eastern parts of West Bhanugach Reserve Forest (RF). The NP was notified (a copy annexed) in 1996 as per the Wildlife (Preservation) (Amendment) Act, 1974, with a total forest area of 1250 ha (IPAC, 2012; Islam & Feeroz, 1992).

LNP is very rich in biodiversity (Ahsan, 2001; Islam & Feeroz, 1992). It is found that about 107 species were recorded in Lawachara National Park in previous time (IPAC, 2012).Therefore, the spatial association and diversity is very high due to the large number of deciduous trees mixed with evergreen smaller trees and bamboos. At present, there were found few patches of about 50 ha of naturally growing species that gave the indication mark of the degradation of biodiversity. Although, the major threats of biodiversity degradation in Lawachara National Park are illegal logging, artificial plantation with exotic species land encroachment and deforestation (Ferdous, 2015). Therefore, it is necessary to study existing natural patches to understand the present ecological condition such as Intra-and-inter-specific spatial association and plant diversity to conserve the biodiversity of Lawachara National park.

The government implemented different plantation programme with Agar, Mahagoni, Akashmoni, chapalish, lohakhat etc. in the degraded areas of Lawachara national park (IPAC, 2012). But our concern was about the present ecological condition such as Intra-and inter-specific spatial association and plant diversity and structure of such a natural patch of forest in Lawachara national park.

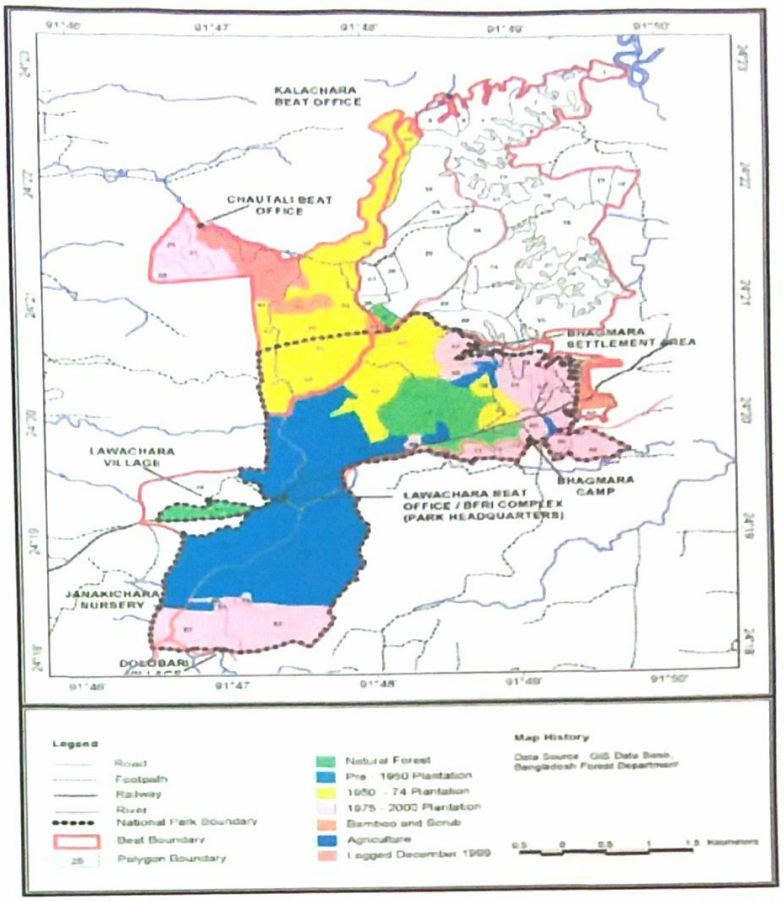


Fig. (2.1): Map of the study site (Lawachara National Park) with forest covers and land use patterns (Source: Bangladesh Forest Department).

2.2 Sample plot layout and mapping of tree location in the field

A study plot of one ha sample plot (100 m×100 m) was selected at natural patches in study sites. Then, the plot had sub divided into 100 subplots (10 m×10 m) to accurately measure the tree positions. The x- and y- coordinates (tree position), DBH (diameter at breast height, i.e. 1.3 m from the ground) and height of all the trees (DBH >10 cm) were recorded in study site with proper identification of species. This x- and y- coordinates were measured by making field grids of 10 m by 10 m and by measuring the distances from the trees to the grid borders and adding radius (DBH / 2) of each tree to record the xy-coordinates approximately at the stem center.

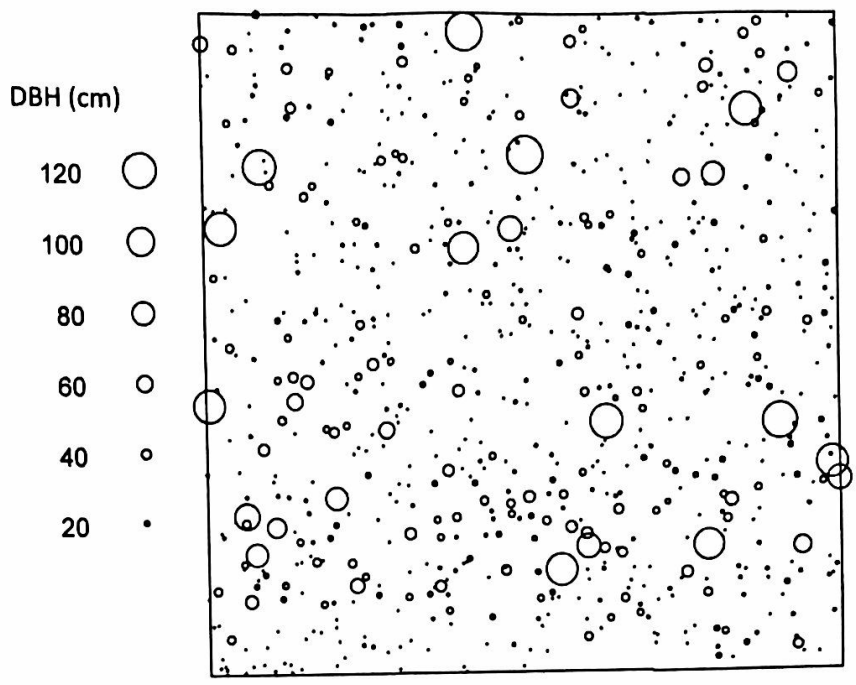


Fig. (2.2): Spatial map of tree dbh (cm) in 100 m X 100 m plot (total 60 species)

2.3 Species dominance

The dominance of a species was defined by its importance value IV expressed as follows (Feroz et al., 2014):

$$IV = \left(\frac{n_i}{\sum_{i=1}^{s} n_i} \times 100 + \frac{a_i}{\sum_{i=1}^{s} a_i} \times 100 + \frac{f_i}{\sum_{i=1}^{s} f_i} \times 100 \right) / 3$$

Where n_i is the number of individuals of the i^{th} species, a_i is the basal area at a height of DBH (Diameter at breast Height) of trees belonging to the i^{th} species, f_i is the number of quadrats in which the i^{th} species appears and S is the total number of species.

2.4 Species diversity

Species richness and diversity were analyzed using the vegan community ecology package (Oksanen et al., 2013) in the R Statistical Programming Software version 3.2.2 (Baddeley & Turner, 2005).

2.5 Species–area relationship and species accumulation curve

The Species accumulation curve was analyzed with the freely available Biodiversity R statistical software (Kindt & Coe, 2005) that was developed for the R 3.2.2 statistical language and environment and often uses the vegan community ecology package (Oksanen et al., 2013).

2.6 Spatial association analysis

2.6.1 Pair-correlation function

The pair-correlation function was used to detect intra-and inter-specific competition and measure the spatial association of the univariate and bivariate patterns. The pair correlation function is the ratio of the observed mean density of trees in the rings to the expected mean density of trees in the rings. The pair correlation function for univariate patterns (i.e., composed of same species such as species 1 and species 1 trees) is the ratio of the observed mean density of species 1 trees in the rings around species 1 trees to the expected mean density of species 1 trees in these rings (Lan et al., 2012).

The pair correlation function for bivariate patterns (i.e., composed of different species such as species 1 and species 2 trees) is the ratio of the observed mean density of species 2 trees in the rings around species 1 trees to the expected mean density of species 2 trees in these rings (Lan et al., 2012). The bivariate (cross) pair correlation function was used to study the species-species associations (direct plant-plant interactions).

The univariate and bivariate pair correlation function g (r) is used to detect the species distribution pattern (i.e., random, aggregated, or regular) at which distances r these patterns occur. It is detected that spatial randomness occurs where the points are independently and

randomly distributed over the entire plot, the pair correlation function yields g (r) = 1, under aggregation g(r) >1, and under regularity g (r) <1 respectively (Lan et al., 2012).

The Pair-correlation function in the ''spatstat'' package of R version 3.2.2 was used to perform this calculation (Baddeley & Turner, 2005).

2.6.2 Mark Correlation Function

The mark correlation function (MCF) $k_{mm}(t)$ (Getzin et al., 2008) was used to detect whether interspecific competition affects tree growth and association that using DBH to analyze the distance-dependent size correlation of trees. The dbh marks of two trees is quantified by the equation f(m1, m2) = m1 _ m2, where m1 and m2 are DBH values of two neighbouring trees. $k_{mm}(t)$ is defined as the normalized mean value of f(m1, m2) for all marks at distance t. This function is considered random, positive and negative respectively if $k_{mm}(t) = 1$, $k_{mm}(t) > 1$ or $k_{mm}(t) < 1$. The markcorr function in the ''spatstat'' package of R version 3.2.2 was used to perform this calculation (Baddeley & Turner, 2005).

2.7 Dendrogram

The dendrogram for analyzing the degree of interspecific association of species was constructed following Vegan, Cluster, Ecodist and Proxy packages in the R Statistical Programming Software version 3.2.2 (Baddeley & Turner, 2005).

CHAPTER THREE

3.0 Result and Discussion

3.1 Result

3.1.1 Species Composition

A total 60 woody individuals were recorded in the 1 ha sampling plot the top 20 species contributed 83% of importance value (Table 1).The top five dominant species were respecttively Chapalish- *Artocarpus chaplasha* Roxb (18.031% IV), Dewa- *Artocarpus lakucha* Roxb. (9.329 % IV), Badam- *Terminalia catappa* L. (7.168 % IV), Kakra- *Glochidion lanceolaris* Roxb. (5.708 % IV) and Khudijam- *Syzygium fruticosum* (Roxb.) DC (5.596 %) (Table 1). Therefore, it was observed that the natural patch is dominated by *Artocarpus chaplasha* Roxb (18.031% IV) because of strong light demander, moderately drought hardy and high regeneration capacity. However, all species composition indicated that they have strong positive association among them (fig).

Table 1: Importance value (IV) of top 20 species of 60 species (Covered 83.1 % of Total IV)

SL	Species	Botanical name	IV (%)
1	Chapalish	*Artocarpus Chaplasha* Roxb.	18.031
2	Dewa	*Artocarpus lakucha* Roxb.	9.329
3	Badam	*Terminalia catappa* L.	7.168
4	Kakra	*Glochidion lanceolaris* Roxb.	5.708
5	Khudijam	*Syzygium fruticosum* (Roxb.) DC.	5.596
6	Banaritha	*Accacia Concinna* Willd.	5.081
7	Dumur	*Ficus hispida* L.	4.728
8	Jolpai	*Eleaocarpus robustus* Roxb.	3.636
9	Pitafol	*Pongamia pinnata* L.	3.400
10	Pisti	*Micromelum minutum* G. Forst.	3.063
11	Menda	*Litsea glutinosa* Lour.	2.843
12	Neur	*Bursera serrata* Wall. ex Colebr.	2.229
13	Rata	*Amoora wallichii* King.	2.064
14	Shimul	*Bombax ceiba*	1.733
15	Jawoa	*Holigrana longifolia* Roxb.	1.615
16	Katasingha	*Castanopsis hystrix*	1.474
17	Kalojam	*Syzygium cumini* (L.) Skeels.	1.445

18	Kaufol	*Gracinia cowa* Roxb.	1.394
19	khami	*Castanopsis tribuloides* A. DC.	1.287
20	Bahera	*Terminalia bellirica (Gearln.)* Roxb.	1.276
			83% of Total IV

3.1.2 Species Diversity

The values of Shannon's index $H'$and Pielou's index J' (evenness) were respectively 3.37 bit and 0.82 (Fig. 3.1). It is observed that, the study area is stable with very high species diversity, because the expected maximum number of species (67) is very close to the total numbers of species (60) (Fig. 3.2).

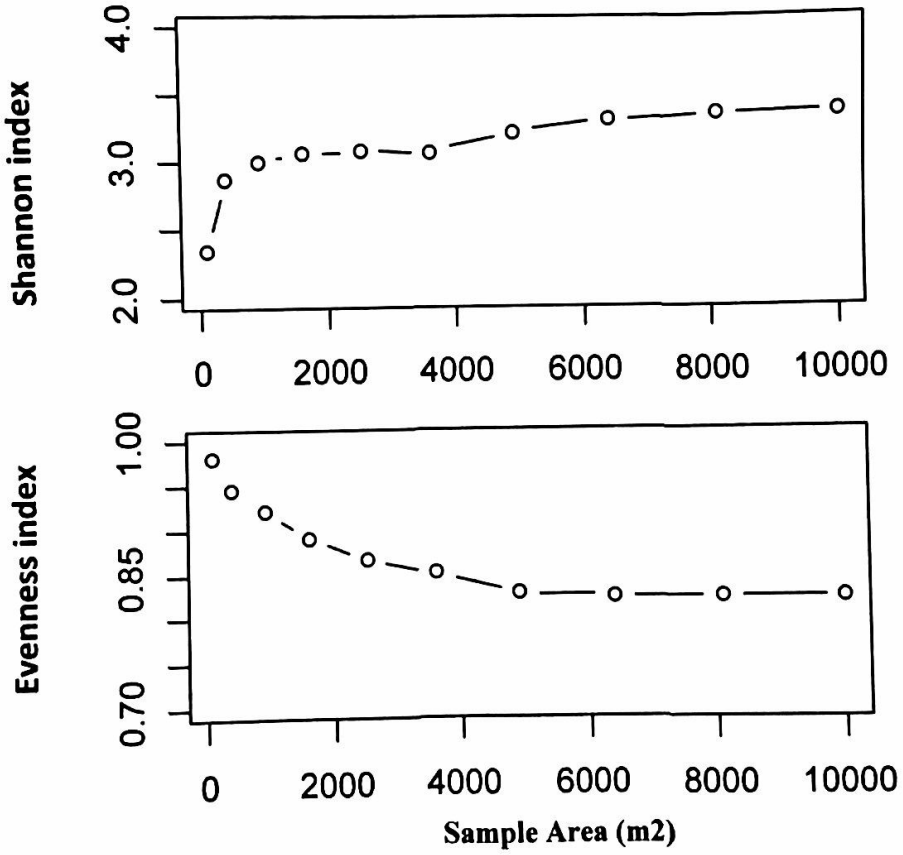


Fig. (3.1): Shannon Index and Evenness Index of Study Site

The values of H'increased rapidly up to 200 m^2 and then the values tended to be became stable after 5000 m^2 despite an increase of area, whereas the values of J' gradually decreased with increasing area and tend to stable after 5000 m^2 of sample area (Fig. 3.1). Therefore, this

result suggests that 5000 m^2 of sample area in this forest would be sufficient for measuring H' and J'.

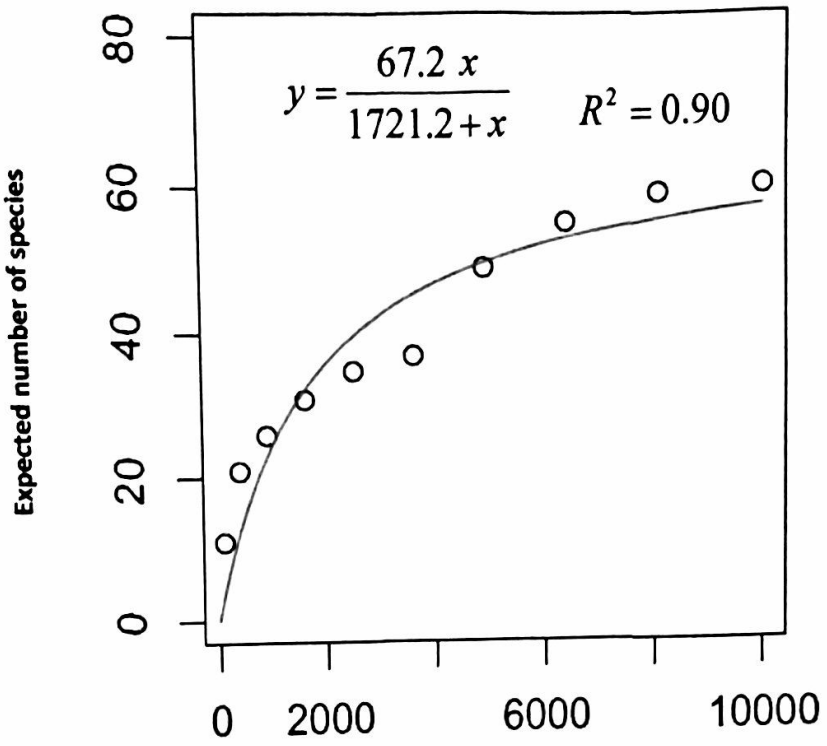
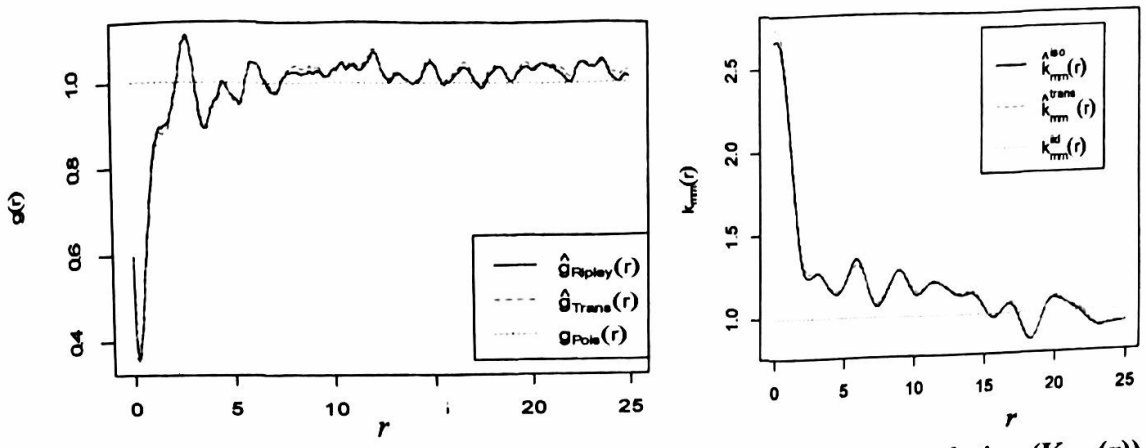


Fig.(3.2): Species area relation using cumulative sample area

3.1.3 Species distribution patterns

Spatial distribution pattern of top 10 dominant tree species in the 1 ha plot were analyzed with the univariate and bivariate pair correlation function. It was observed that all the species maintained regularity within 2.5- 5 m radius as neighbourhood and after 5 m distance complete spatial randomness (Fig.3.3).Trees having similar dbh (matured ones) like to be 20 m apart from each other (Fig.3.3). Among the five most dominant species Chapalish showed a clustered pattern and trees can form clusters within 5 m radius (Table 2). Similar trend was also observed in Khudijam.The other species Dewa, Badam, Kakra, Dumur, Banarth, Jolpai, Pitafol and Pisti however showed a random spatial pattern and trees of similar size can be neighbours (Table 2).



Pair correlation function g(r) **Mark correlation ($K_{mm}(r)$)**

Fig.(3.3): Pair correlation function g(r) and Mark correlation ($K_{mm}(r)$) for all the 60 species

3.1.4 Species associations

Species associations among the top 10 dominated species were analyzed for scales 0– 25 m by using univariate, bivariate pair correlation function and Mark correlation function. It was observed that trees having similar diameter can be neighbours within 15 m radius (species co-existence), showing a positive intra- and inter-specific spatial association. The strongest positive intraspecific and interspecific association observed among the most 10 dominated species (Table 2). Cluster dendrogram and bivariate pair correlation of top 20 species also suggested a formation of six clusters having species preferences as neighbourhood (Fig.3.4).

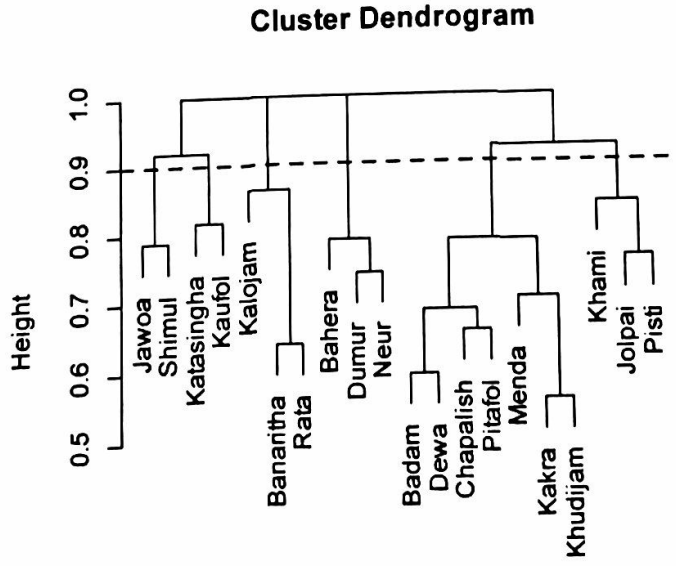


Fig. (3.4): Inter-specific spatial association Cluster Dendrogram of Top 20 Dominated Species in LNP Using Bray-Curtis distance after logarithmic transformation.

Table 2: Spatial association pattern of top 10 dominant tree species

Species Association 5 m Distance										
	Chapalish	Dewa	Badam	Kakra	Khudijam	Banaritha	Dumur	Jolpai	Pitafol	Pisti
Chapalish	Cl	Re	Re	Rn	Rn	Rn	Rn	Rn	Rn	Rn
Dewa		Rn	Rn	Re	Re	Rn	Rn	Rn	Rn	Rn
Badam			Rn	Rn	Rn	Re	Rn	Rn	Rn	Rn
Kakra				Rn	Rn	Rn	Re	Cl	Rn	Rn
Khudijam					Cl	Rn	Rn	Cl	Rn	Re
Banaritha						Re	Re	Rn	Rn	Rn
Dumur							Re	Rn	Rn	Rn
Jolpai								Cl	Rn	Cl
Pitafol									Rn	Rn
Pisti										Rn
Species Association 15 m Distance										
	Chapalish	Dewa	Badam	Kakra	Khudijam	Banaritha	Dumur	Jolpai	Pitafol	Pisti
Chapalish	Rn	Rn	Rn	Rn	Rn	Rn	Rn	Rn	Rn	Rn
Dewa		Rn	Rn	Rn	Rn	Cl	Rn	Rn	Rn	Rn
Badam			Rn	Rn	Rn	Rn	Rn	Rn	Rn	Rn
Kakra				Rn	Rn	Rn	Rn	Rn	Rn	Rn
Khudijam					Rn	Rn	Rn	Rn	Rn	Rn
Banaritha						Rn	Rn	Rn	Rn	Rn
Dumur							Rn	Rn	Rn	Rn
Jolpai								Rn	Rn	Rn
Pitafol									Rn	Rn
Pisti										Rn
Species Association 20 m Distance										
	Chapalish	Dewa	Badam	Kakra	Khudijam	Banaritha	Dumur	Jolpai	Pitafol	Pisti
Chapalish	Rn	Rn	Rn	Rn	Rn	Rn	Rn	Rn	Rn	Rn
Dewa		Rn	Rn	Rn	Cl	Rn	Rn	Rn	Rn	Rn
Badam			Rn	Rn	Rn	Rn	Rn	Rn	Rn	Rn
Kakra				Rn	Rn	Rn	Rn	Rn	Rn	Rn
Khudijam					Rn	Rn	Rn	Rn	Rn	Rn
Banaritha						Rn	Rn	Rn	Rn	Rn
Dumur							Rn	Rn	Rn	Rn
Jolpai								Rn	Rn	Rn
Pitafol									Rn	Rn
Pisti										Rn

Rn = Random, Re = Regular and Cl= Clumped

3.2 Discussion

In this study, considering all the species, trees maintains regularity within 2.5- 5 m radius as neighbourhood and after 5 m distance complete spatial randomness was observed.Although, few previous studies of spatial pattern of tropical trees (Bunyavejchewin et al., 2003; Condit et al., 1996; He et al., 1997; Plotkin et al., 2000)have concluded that most species are clumped in early stage of life, and a few are randomly distributed. Spatial patterns of tree species shift from high clumping to lower intensity clumping or random distribution when moving from juveniles to adults(He et al., 1997).In this study, the five most dominant species Chapalish showed a clustered pattern and trees can form clusters within 5 m radius. Trees having similar dbh (matured ones) like to be 20 m apart from each other. Similar trend was observed in Khudijam.However, all species showed tendency having similar diameter can be neighbours within 15 m radius (species co-existence).

The values of Shannon's index *H'* and Pielou's index *J'* (evenness) were respectively 3.37 bit and 0.82.The value of *H'* and *J'* in the Lawachara National Park are similar to reported value of a subtropical evergreen broadleaf forest in Guangzhou, South China (Wu et al., 2010) and tropical wet evergreen forest in Chittagong hill tracts (Feroz et al., 2014).

In conclusion, our results clearly show that the degree of spatial randomness increase with increase distance of adults tress in most species. The values of Shannon's index *H'*,Pielou's index *J'* (evenness) and Species area curvesuggesting that tree species in LNP are well distributed.In this study we measured tree species having DBH>5 cm only. Further studies should incorporate seedlings having DBH<5 cm to explore the effects of seedlings on species dominance and spatial association.

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