Spatial Distribution and Size Structure Patterns of Tree Species in the Long-term Dynamic Plots of Sakaerat Deciduous Dipterocarp Forest, Northeastern Thailand

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ABSTRACT

All tree individuals (DBH ≥ 4.5 cm) in the 4 stands of each 1 ha square plots in Sakaerat deciduous dipterocarp forest (SDDF) established for the long-term dynamic studies were investigated to clarify their spatial distributional patterns in forms of I-delta (I_δ) index following the Morisita's procedure by several quadrat size expansions. Frequency distribution of tree individuals in each DBH class (5 cm interval) or size structure distributional pattern in the 4 stands were also analyzed and two negative function models (power function and exponential function) were tested to get the best fit of the two models. Results of the studies reveal that most of the major tree species in the 4 stands are found to distribute in clumping pattern by showing I_δ values above 1, while the overall individuals in every stands are in random pattern with I_δ values closed to 1, regardless of any plot size enlargement. Size structure of all tree individuals in this forest is found to display an explicit form of the negative exponential pattern explaining its relatively stable size structure even though they are quite sparsely distributed in each stand. Some dominant tree species in all 4 stands are found to have both L and B-shaped distributional patterns of size structure except for the rest ones that no specific patterns are found in this SDDF type.

Keywords : Deciduous dipterocarp forest, Sakaerat, Size structure, Spatial distribution pattern

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INTRODUCTION

Spatial pattern is the fundamental characteristic of all organisms and also an important characteristic of ecological communities (Connell, 1963). It can be related to the habitat preferences of the organisms under studies, especially in tree and other animal communities (Williams, 1976; George and Edwards, 1976; Doncaster, 1981; Lamont and Fox, 1981). Some forest tree spatial patterns in Thailand had been investigated by Ogawa *et al*. (1961). However, study on tree distribution pattern of deciduous dipterocarp forest dipterocarp forest community (SDDF) is extremely essential to understand the behavior of tree component in this particular dry forest of the northeastern region of Thailand where the environmental condition is relatively harsh for plant and tree growing. The significance of this forest community type has been already stated in the previous paper (Sahunalu, 2009). Size structure in tree population is usually used to explain population structure in case when tree age determination is difficult. Deciduous dipterocarp forest (DDF) tree components have no clear annual or growth ring mostly, making the determination of tree age to be impossible. To overcome this problem, size distribution is considered to be most practical way in explaining population structure in almost all forest community in the tropics.

It is also of keen interest to observe these two important characteristics of tree species in a long-term interval. Present study is therefore included the investigation on spatial and size distributional patterns of some leading tree species and also of all individuals in the large scale and long-term forest dynamic observation plots.

MATERIALS AND METHODS

Spatial distribution of tree species

Spatial distribution or species dispersion, another horizontal pattern of tree individuals that spatially arranged in the environmental space was investigated to elucidate the behavior of tree species in establishment on the given space. This aspect was studied by using I-delta (I_δ) index proposed by Morisita (1959). The investigation was undertaken following the enlargement of the quadrat length from the minimum to the maximum sizes in the stands. The values of I_δ equals 1 when the individual is random, <1 is uniform and >1 is clump. In this study the dispersion pattern was focused on the 5 tree species having the highest IVI orderly (Sahunalu, 2009) in each stand and on the total individuals in the whole 1 ha plot of each stand.

Size structure of trees and of the forest community

Tree size distribution or the size structure of the forest community was analyzed by dividing the DBH of all tree individuals and of each tree species (DBH ≥4.5 cm) into various DBH classes by 5 cm intervals. Frequency distribution of number of tree individuals in every size class was tested by using two distribution models: (1) negative power function model ($y = Ad^{-\alpha}$) and (2) negative exponential function model ($y = Ae^{-\alpha d}$), where y = number of individuals in each diameter class ($trees.ha^{-1}$), d = mid-point of the diameter class (cm), A and α = constant parameters and e = base of the natural logarithm. For each individual tree species (DBH ≥ 4.5 cm), size structure in forms of L-shaped or B-shaped (bell-shaped) distributional pattern was also examined in all 4 stands.

RESULTS AND DISCUSSION

Spatial pattern distribution

Study on spatial distribution of trees in the 4 stands of SDDF was focused on the trees having DBH ≥ 4.5 cm. All individuals are randomly distributed as suggested by the I_δ index of Morisita (1959) being close to 1 in all 4 stands. This similar distributional pattern is always found in other forest communities in Thailand (Ogawa *et al.,* 1961) and in some temperate forests (Williamson, 1975). The study emphasizing only on the 5 dominant tree species in each stand found that all distribute in clumping pattern as their I_δ are always greater than 1 as the size of quadrat is expanded until reaching about 60 m long (Figure 1). Bunyavejchewin *et al.* (2003) also found the clumping pattern of the 4 canopy species belonging to Dipterocarpaceae family in a seasonal dry evergreen forest in western Thailand. Many adult tree populations in Indian dry tropical forest deciduous forest were mostly in clumping distribution but might be changed following some forest disturbances (Sagar *et al.*, 2003). Using different dispersion index such as Ripley's function in an old-growth temperate hardwood forest also revealed that most species were in form of aggregation pattern (Aldrich *et al.,* 2003). Numerous tree individuals in an old-growth subalpine coniferous forest in central Japan also exhibited the aggregation form of dispersion (Miyadokoro *et al.,* 2003).

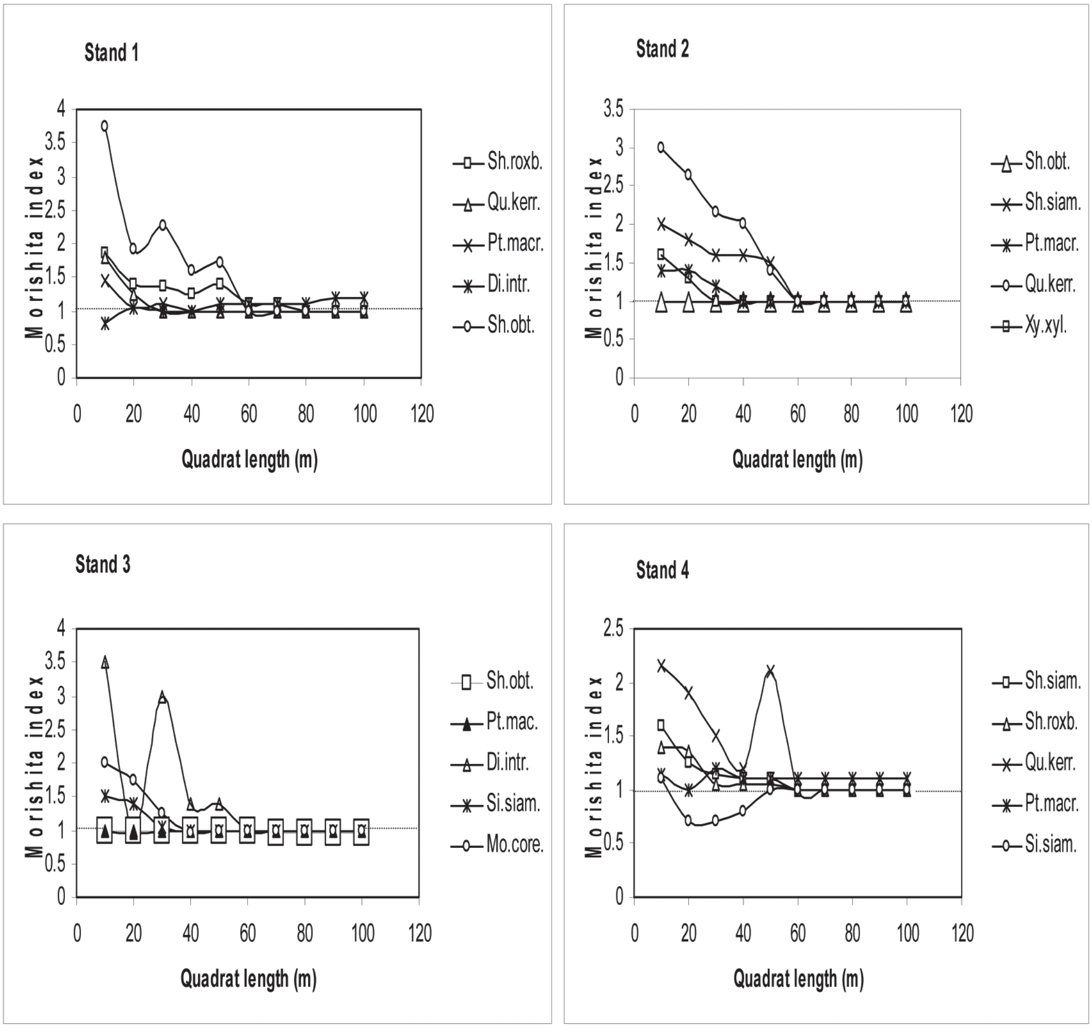

Figure 1 Morisita's index of dispersion (I_{δ}) of dominant tree species in the 4 stands of SDDF. Dash line shows the random dispersion. Species names are abbreviated from the first two letters of genera and species names of each tree species shown in Table 1.

Using similar spatial pattern index as in this study, the clumping dispersion pattern of most tree species was also found in the ever-wet lowland dipterocarp forest in Pasoh, Malaysia (Okuda *et al,*. 1997). The clumping pattern of these dominant tree species may partly explain their regenerative behaviors occurring naturally to be abundant in most favorable environment that may be due to their niche preferences. Clumping pattern is however, a phenomenon that leads to the creation of mosaic structure of the forest community instead of a regular pattern as is usually found in artificial stand or in tree plantation. Moreover, clumping in most deciduous tree species of this forest type might be due to the coppice forming habit and patchy distribution of microhabitats suitable for plant growth in dry tropical soils (Roy and Singh, 1994). According to Odum (1971), the clumped distribution is common in nature while random distribution is found only in the very uniform environments. The clumping of individuals of a species may be due to the insufficient mode of seed dispersal (Ashton, 1969; Richards, 1996) or when death of tree creates a large gap encouraging recruitment and growth of numerous saplings (Armesto *et al.*, 1986; McNewbery *et al.,* 1986; Richards, 1996). Vegetative reproduction by suckers and coppice also encourages clumping pattern as most saplings are always grown around their living main stumps.

Size structure

Tree size distribution using DBH of all individuals found in each stand in SDDF is well explained by the negative exponential model (Figure 2) rather than by the negative power function model. This model yields different parameters A and α from stand to stand, being good fit from the minimum size class as low as 4.5-9.5 cm to the maximum size class of 54.5-64.5 cm. This is corresponded to the inverse J-shaped or L-shaped distribution model traditionally used for explaining tree population distribution, particularly in the demographic studies. It is also usually used this distribution model along with the age class of trees in stand for explaining tree population age structure that always be able to detect the tree natural regeneration in a given forest community and in stands. Tree age determination is not possible in this forest community as similar to other tropical forest communities where tree ring analysis is still not advanced and reliable method of detecting age has not yet been developed for the unclear annual ring

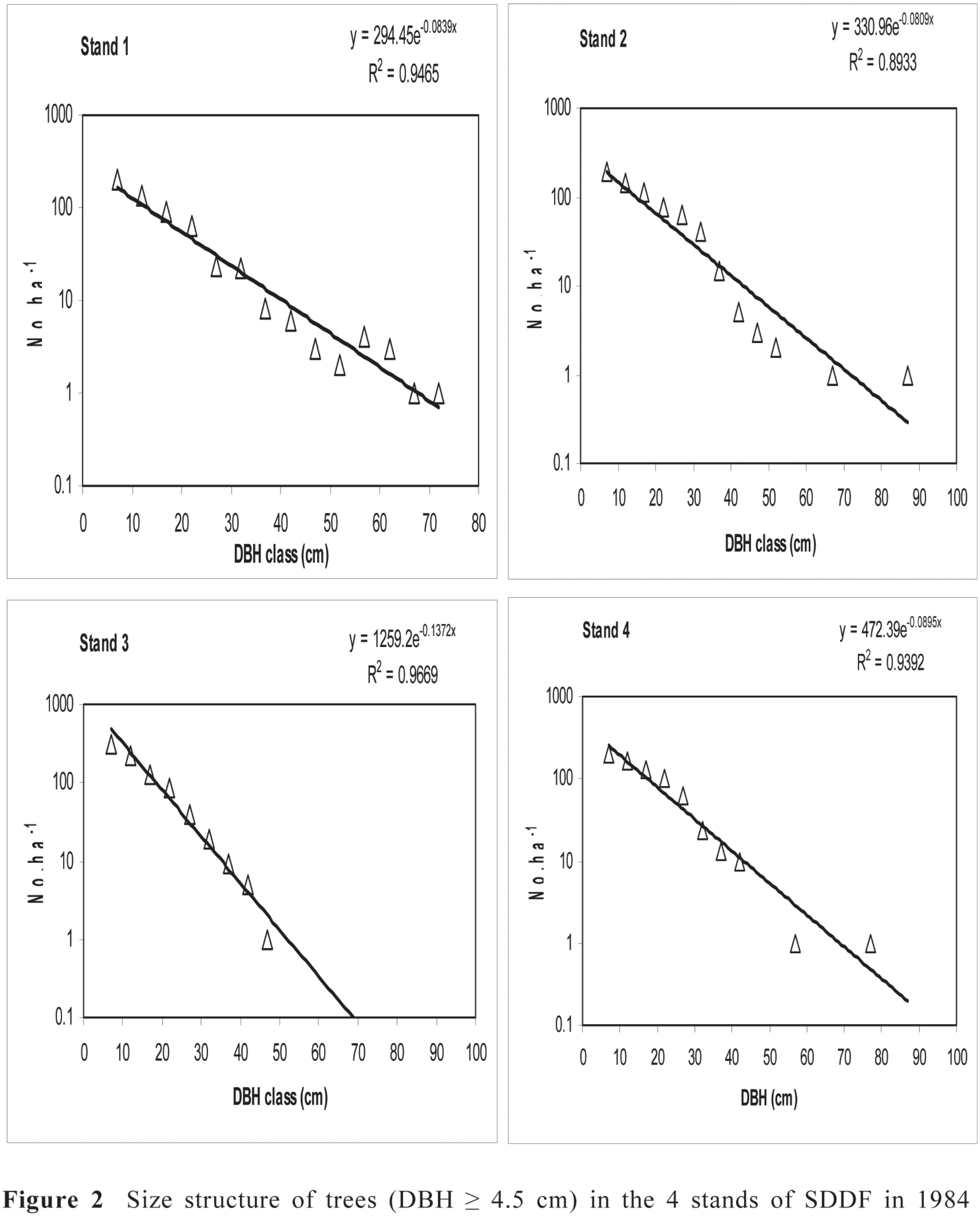

Figure 2 Size structure of trees (DBH ≥ 4.5 cm) in the 4 stands of SDDF in 1984 as determined by a negative exponential model: $y = Ae^{-\alpha x}$. Where $y = No.ha^{-1}$, x = mid-point of DBH (cm), A and α = constants, e = base of natural logarithm, R^2 = coefficient of determination.

trees. Therefore, this study does not attempt to explain the relationships between tree size and age aspect in this forest type. On the other hand, this size structure of trees is conventionally used in manipulating stands to regulate the stand structure in Silvicultural practice of uneven-aged stand management (Meyer, 1952; Smith, 1962), therefore these 4 stands may be considered as one of the uneven-aged natural forest communities in this area and in the tropical region.

The smooth decreasing trend of tree individuals along the size class increasing in forms of the exponential function as observed in these 4 stands suggests the special and variable regeneration characteristics of the forest (Knight, 1975) and forms a stand characteristic of multiple age of species composition known as uneven-aged stand in general forestry terminology. Studies on the seasonal evergreen forest community type (SERF) in the same area; Sahunalu (2002) as well as Bunyavejchewin (1986) found that the distribution model of the power function form was best explained for that forest community type. In case of DDF, it is not clear that whether because of the highly variable tree species composition or because the stands have not only a single dominant species or a single age class distribution, where it is always found the negative exponential distribution rather than the negative power distribution as suggested by Peterken and Jones (1987). In the same location at Sakaerat, Kanzaki *et al.* (1995) and Sahunalu (2002) recognized the SERF stand locating adjacent to the present studied DDF stands as a mono-dominant stand dominating by most of the *Hopea ferrea.* It is therefore possible that the mono-dominant stand is rather well fitted by the negative power function model (Sahunalu, 2002; Bunyavejchewin, 1986).

Size structures of various tree species in the 4 stands were analyzed and demonstrated in Table1. Only some major component tree species are found to have specific size structure either the L-shaped or B-shaped distributional patterns while many species having few individuals and thus lower values of IVI exhibit no distinguishing pattern. Sahunalu (2002) found several tree species in a seasonal evergreen rain forest at Sakaerat to have L-shaped as well as B-shaped distribution. Bunyavejchewin (1999) found the L-shaped distribution pattern of dominant dipterocarp tree species in a seasonal evergreen forest of the same location especially all individuals of *Hopea ferrea* but

Table 1 Size structure distribution patterns of all species in the 4 stands of SDDF in 1984.

Species	Size structure[1] Stand 1	2	3	4
Albizia odoratissima (L.f.) Benth.	-	L	L	L
Antiaris toxicaria Lesch.	-	NE	NE	-
Antidesma ghaesembila Gaerth.	-	NE	NE	NE
Antidesma laurifolium Airy Shaw	-	NE	-	-
Aporosa villosa (Wall. ex Lindl.) Baill.	-	-	-	-
Artocarpus lacucha Roxb.	NE	NE	-	NE
Bauhinia saccocalyx Pierre	NE	L	NE	-
Bauhinia sp.	-	NE	B	NE
Bombax insigne Wall	-	NE	NE	NE
Buchanania lanzan Spreng.	NE	-	NE	NE
Canarium subulatum Guillaumin	NE	-	-	NE
Careya sphaerica Roxb.	L	-	L	-
Cratoxylum formosum (Jack) Dyer	-	NE	NE	-
Dalbergia assamica Benth.	NE	NE	NE	-
Dalbergia cultrata Graham ex Benth.	L	-	NE	-
Dalbergia nigrescens Kurz	NE	NE	L	NE
Dalbergia oliveri Gamble	B	NE	-	L
Dillenia obovata (Blume) Hoogland	L	-	-	-
Diospyros ehretioides Wall. ex G. Don	L	-	-	-
Diospyros mollis Griff.	-	NE	NE	-
Diospyros oblonga Wall. ex G. Don	NE	NE	-	NE
Dipterocarpus intricatus Dyer	L	B	B	-
Erythrophleum succirubrum Gagnep.	NE	-	-	NE
Gardinia sootepensis Hutch.	-	-	-	-
Irvingia malyana Oliv. ex A.W. Benn.	-	-	-	-
Ixora ebarbata Craib	-	NE	NE	NE
Kydia calycina Roxb.	-	-	NE	NE
Lannea coromandelica (Houtt.) Merr.	-	-	NE	NE
Lithocarpus polystachyus (Wall ex A. DC.) Rehder	NE	-	NE	-
Mangifera caloneura Kurz	-	L	-	
Mitragyna rotundifolia (Roxb.) Kuntze	L	L	L	L
Morinda coreia Ham.	B	B	L	L
Nauclea officinalis (Pierre ex Pit.) Merr. & Chum	NE	NE	NE	-
Nauclea orientalis (L.) L.	NE	NE	NE	-
Parinari anamense Hance	NE	-	-	-
Phyllanthus emblica L.	-	NE	-	-
Premna pyramidata Wall. ex Schauer	NE	NE	NE	-
Pterocarpus macrocarpus Kurz	L	L	L	L
Quercus kerrii Craib	B	B	L	B
Rothmannia wittii (Craib) Bremek.	NE	-	NE	NE
Semecarpus reticulata Lecomte	NE	NE	-	NE
Shorea obtusa Wall. ex Blume	B	B	L	-
Shorea roxburghii G.Don	L	L	L	B
Shorea siamensis Miq.	L	L	NE	L

Table 1 Cont.

Species	Size structure[1] Stand			
	1	2	3	4
Sindora siamensis Teijsm. & Miq.	L	-	L	B
Siphonodon celastraneus Griff.	NE	NE	B	NE
Stereospermum neuranthum Kurz	-	-	-	-
Syzygium cumini (L.) Skeels	NE	NE	NE	-
Terminalia chebula Retz.	-	-	NE	-
Unidentified	-	-	-	-
Unidentified (Liana)	-	NE	NE	NE
Vaccinum sprengelii (G.Don) Sleumer	NE	-	NE	NE
Vitex canescens Kurz	NE	-	NE	NE
Vitex peduncularis Wall. ex Schauer	L	-	-	L
Xylia xylocarpa var. *kerrii* (Craib & Hutch.) I. C. Nielsen	L	L	L	L

[1] L = L-shaped distribution
B = B-shaped distribution
– = Undetected pattern
NE = non-existing

B-shaped distribution of *Shorea henryana* individuals if their DBH were over 20 cm, suggesting that the stands were the typical natural forest regenerating from seed in which high stem counts in smaller size classes were observed. Other dipterocarp tree species in Huay Ka Kaeng forest, Bunyavejchewin *et al.* (2003) found L-shaped distribution for *Dipterocarpus alatus* and *Vatica cinera* but B-shaped distribution for *Hopea odorata* except for *Anisoptera costata* that trees having DBH over 20 cm classes was B-shaped even the two lower size classes of this species were abundant. They suggested that those tree species with B-shaped distribution would eventually disappear from the plot. Size structure of all emergent tree, shrub and total individuals in both primary and regenerating forest in Pasoh, Malaysia, Okuda *et al.* (2003) found all in L-shaped distribution but they did not describe directly but for the canopy trees, understorey, shrub and treelet were B-shaped distribution although somewhat greater number of individuals was biased to the small sized classes. Other tree species in temperate forest communities also exhibited the same pattern of size structure for example: in old-growth mixed mesophytic forest in southeastern Ohio (McCarthy *et al.*, 2001), old-growth *Pseudotsuga-Tsuga* forest in cascade range of southern Washington (Franklin and Debell, 1988), several forest types in Sichuan, China (Tang and Ohsawa, 2002), temperate deciduous forest in Denmark (Emborg *et al.,* 2000), Japanese temperate mixed forest (Nakashizuka, 1991), old-growth *Chamaecyparis obtusa* forest (Hoshino *et al.,*2001) and old-growth coniferous forest (Miyadokoro *et al.,*2003).

Most of major tree species in DDF are considered to maintain themselves through natural regeneration in which small tree individuals of the same species will replace their adults in every site where their population show the L-shaped distribution pattern. Trees with B-shaped distribution are likely to be under the pressure of the internal and external disturbance that may occur periodically in forms of the internal stand competition among the individuals of the same and different species, susceptibility to the external damaging factors such as severe forest fire, pest and disease, drought and other environmental stress. Knowledge on these aspects is still limit for this forest community type.

CONCLUSION

Most of the major tree species in SDDF spatially distributes in forms of clumping pattern, while the overall individuals in every stands demonstrate the random pattern. All tree individuals in each stand in this forest community type similarly distribute in an explicit form of the negative exponential pattern suggesting their stable and consistent size structure as revealed by their tree diameter class discriminations. Some dominant tree species in all 4 stands exhibit their size structure in both L-shaped and B-shaped distribution except for the subordinate species that are not found to show any specific size structure distributional pattern.

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