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Original Research Paper

The Species Diversity and Patch Characteristics in Subtropical Evergreen and Deciduous Broad-Leaved Mixed Forest

Renyan Duan, Ganlin Wu*, Minyi Huang, Xiaoquan Kong and Zhigao Wang
School of Life Science, Anqing Normal University, Anqing, Anhui 246011, P.R. China
*Corresponding author: Ganlin Wu

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ABSTRACT

Forest communities are composed of different developmental types (gap patch (G), building patch (B), mature patch (M) and degenerate patch (D). The mean basal area, mean volume of each individual, mean *DBH*, standing volume, and mean height, all significantly increased along the process of forest cycle (G-B-M-D) (p<0.05). Different sized individuals and different functional groups only appeared in specific patch types. Bigger individuals mainly occurred in the late phase (M and D). Generalist species (GES) mainly existed in the G, while infrequent species (INF) and fern mainly appeared in the M. β diversity index of non-adjacent patch phases was higher than that of the two adjacent patch phases, and in the G, species richness and diversity were the highest among four different patches (G, B, M and D). A possible mechanism that could explain the diversity maintenance in subtropical evergreen and deciduous broad-leaved mixed forest was put forward.

INTRODUCTION

The investigation of patch dynamics under the natural disturbance is very important to know community structure and dynamic change (Chávez & Macdonald 2010, Yu & Sun 2013). When small scale interference creates a gap, gap development directly affects species composition and diversity in different patches (Lertzman et al. 1996, Prévost & Raymond 2012). The progress of gap development is called a forest cycle. According to the different types of patch development, forest patches are mainly divided into four entirely different patches: gap patch (G), building patch (B), mature patch (M) and degenerate patch (D) in natural forests (Duan et al. 2013). With patch development, the air temperature, soil temperature, light density, and other microclimatic factors (such as humidity, nutrition, pH) may change (Duan et al. 2013, Yu & Sun 2013), which is beneficial to the coexistence of different functional groups, which have diverse species composition and size individuals (Chávez & Macdonald 2010).

According to our knowledge, only Zang et al. (2005) class the patches to four patch dynamics (G, B, M and D) and study the species diversity and community characteristics in different patches in Hainan Island, South China. However, data are still rare. We need to provide more documents. So, further studies are still essential. We need to study community characteristics and species diversity in G, B, M and D in other forests, including the subtropical evergreen and deciduous broad-leaved mixed forest. The hypotheses to be tested were followed (1) Due to environmental heterogeneity in patches of forest cycle (Canham et al. 1990) and some species have specificity to the environment (Zanne1 & Chapman 2005, Aoyagi et al. 2013), some species only might occur in particular patches. (2) Because ecological factors have different combinations and changes with patch development (Canham et al. 1990, Aoyagi et al. 2013), different species (or functional groups) and different sized individuals will have distinct frequencies in four different patch phases and species diversity in the forest cycle will show some fluctuation.

Subtropical evergreen and deciduous broad-leaved mixed forest is the dominant community of temperate forest in China. Due to natural disturbance, there exist different patches. In the old-growth subalpine coniferous forest, species diversity and community characteristics among four different patches were discussed to understand the maintenance mechanism of species diversity.

MATERIALS AND METHODS

We selected a subtropical evergreen and deciduous broad-leaved mixed forest on Dabieshan Mountain (31°022' N, 116°062' E, and 680 MSL) in eastern China. In the zone, the mean annual precipitation is 2,509 mm and mean annual temperature is 10-14°C. The soil is typical yellow-brown soil. The experimental sample (100m×100m) was dominated by *Cyclobalanopsis glauca*, mixed with co-dominant *Bothrocaryum controversum*. The main sub-dominant

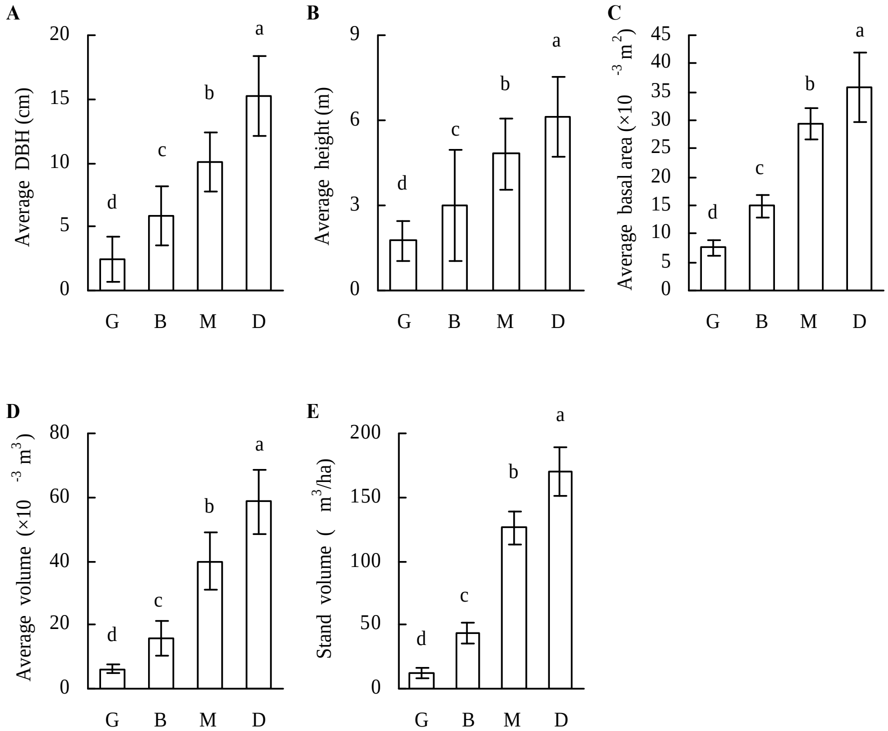


Fig. 1: Variations of selected factors in different patch types in evergreen and deciduous broad-leaved mixed forest.
Note: Values with different letters indicate statistically significant differences at p<0.05 between different patch types (G, B, M and D).

canopy species included *Quercus glandulifera*, *Lindera glauca, Celtis biondii*, *Carpinus viminea*, *Albizzia kalkora*, and *Pterostyrax corymbosus*. Common herbs and vines included *Cardamine flexuosa*, *Ficus sarmentosa*, *Salvia farinacea, Paederia scandens, Arthraxon hiapidus* and *Polygonum bungeanum*.

One ha (100m×100m) was divided into 400 grid quadrates (5m×5m). All species were identified, and trees (height ≥ 1.3 m) were measured for diameters at breast height. The average tree height (H) is 9.1 m, and the average height is 12.1 m in the canopy trees (HC). According to Table 1, the four patch types were identified. The Shannon-Wiener diversity index (H'), the number of species in every patch (S) and evenness (J') were used to quantify the species diversity and richness in each patch. β diversity is used to compare the difference of floristic composition among different patch types (Duan et al. 2009).

$$H' = -\sum_{i=1}^{s} \left(P_i \ln P_i\right) \quad ...(1)$$

$$J' = H' / \ln S \quad ...(2)$$

$$CD = 1\text{-}2c/(a+b) \quad ...(3)$$

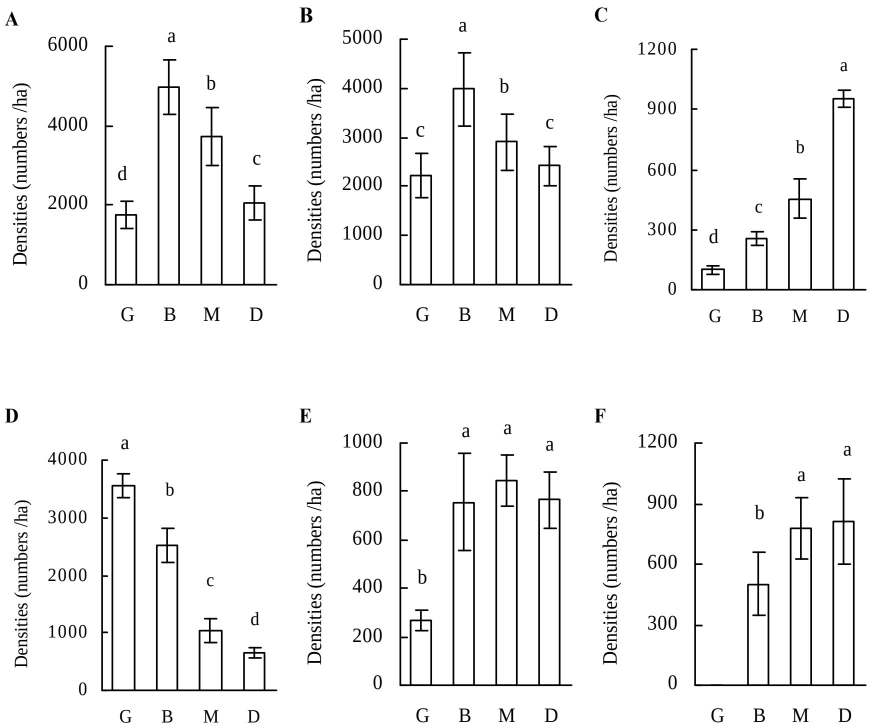
Where $P_i = N_i/N$, N_i is the important value of species i and N is the sum of the importance values of all species found in each layer of standing. CD is β diversity; a and b represent the number of species existing only in one patch; and c is that of species existing in both patches A and B.

Plant functional types were classified as tree, shrub, herb (including annual grasses and perennial grasses), vine and fern. The patch species were subdivided into six habitat groups (GS, BS, MS, DS, GES, INF), GS, BS, MS and DS are the species only occurred in gap phase, building phase, mature phase and degeneration phase, separately; GES is the generalist species (not biased); INF is infrequent species.

Statistical analysis was carried out using one-way ANOVA analysis in STATISTICA 7.0 at $P < 0.05$.

RESULTS

The specific community characteristics (standing volume, average basal area, the average DBH, average height, average volume of each individual) increased with patch development (G-B-M-D), and they were significant in four different patches (p <0.05) (Fig. 1). Most tree density with different sizes in the forest cycle showed significant differences (p<0.05), and trees of DBH ≥ 35cm only occurred in the M and D (Fig. 2). Most species (such as *Cyclobalanopsis glauca*, *Quercus glandulifera*, *Bothrocaryum controversum*,



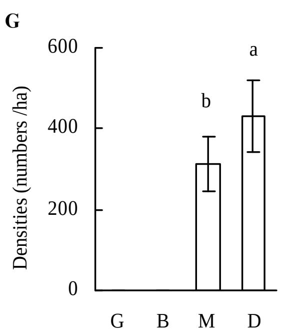


Fig. 2: The average densities (numbers of individuals/hm^2) of trees of different height and size (*DBH*) classes in different patch types in evergreen and deciduous broad-leaved mixed forest.

Note: A is all trees, B is 1.3<H<10, C is H≥10, D is *DBH*<10, E is 10 ≤ *DBH*<20, F is 20≤*DBH*<35, G is *DBH*≥35. Values with different letters indicate statistically significant differences at p<0.05 between different patch types (G, B, M and D).

Lindera glauca, *Photinia schneideriana*) were present in all four phases (G, B, M and D), and there were significant differences (p<0.05). *Celtis biondii* was found only in the G phase (Fig. 3). Some species (*Bothrocaryum controversum*, *Lindera glauca*, *Photinia schneideriana*, *Albizzia kalkora*) showed the highest frequency in the G, while some species (*Carpinus viminea*, *Pterostyrax corymbosus*, *Albizzia kalkora*) did not occur in the M. Six species life forms (vine, fern, perennial grasses, annuals grasses, shrub and tree) all occurred in four patch types, but fern and vine had the lowest frequency (Fig. 4). No MS occurred in G, fewer GS, BS and DS were found in M, while more INF occurred in all the four patches (Fig. 5). β diversity index of non-adjacent patch phases was higher than that of the two adjacent patch phases (Table 2). M had the least number of species (S), while G had the highest species. *D'* and *H'* reached the maximum in the G, declined from the B to M, and then increased in D (Fig. 6).

DISCUSSION

Different community characteristics in four patches (G, B, M and D) may be attributed to heterogeneous environmental factors (Latif & Blackburn 2010). In these heterogeneous environmental factors, light determining forest tree growth is one of the most important influential factors (Latif & Blackburn 2010). Some growth differences are found in tropical trees establishing in high or low light (Oguchi et al. 2006, Chávez & Macdonald 2010). For example, there are

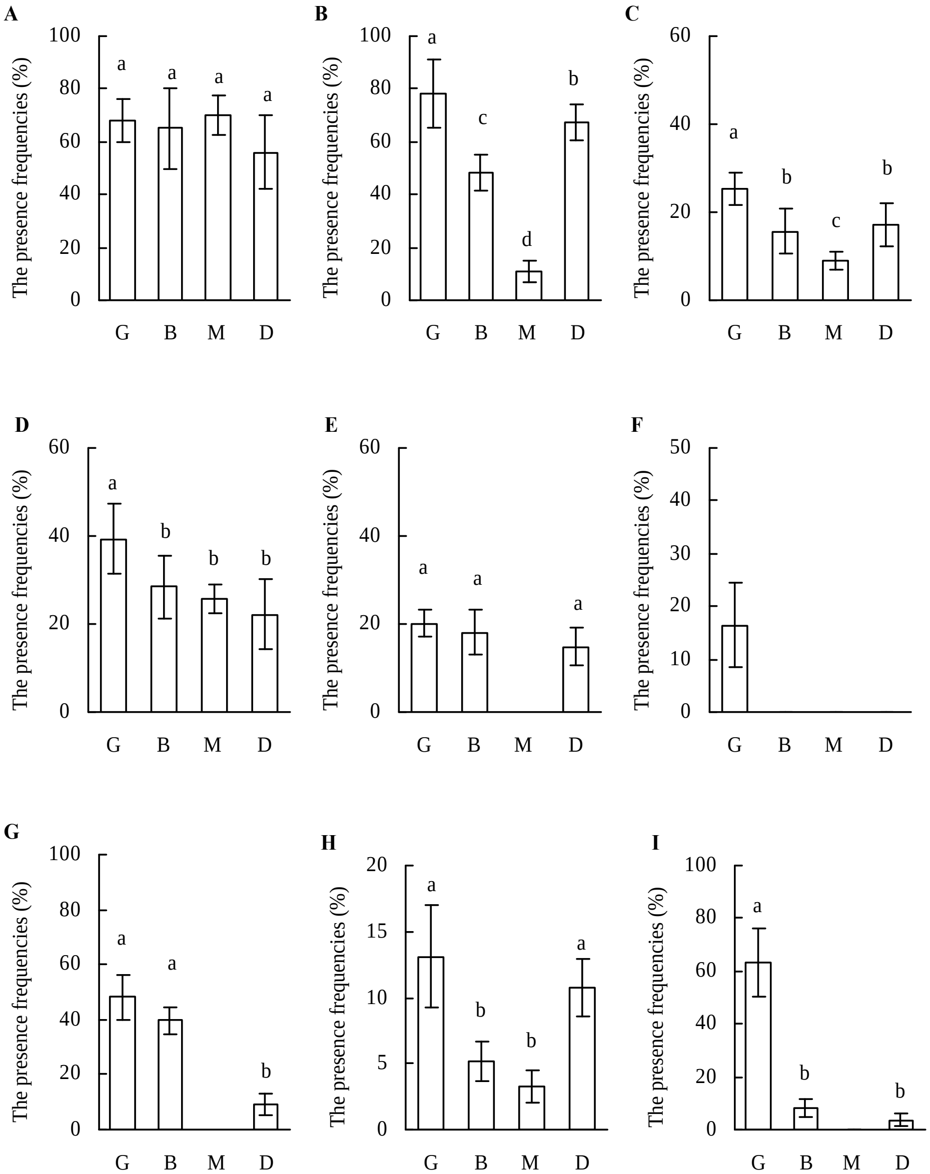


Fig. 3: The presence frequencies (%) of main woody plants and tree seedling in different patch types in evergreen and deciduous broad-leaved mixed forest.

Note: A is *Cyclobalanopsis glauca*, B is *Quercus glandulifera*, C is *Bothrocaryum controversum*, D is *Lindera glauca*, E is *Carpinus viminea*, F is *Celtis biondii*, G is *Pterostyrax corymbosus*, H is *Photinia schneideriana*, I is *Albizzia kalkora.* Values with different letters indicate statistically significant differences at $p<0.05$ between different patch types (G, B, M and D).

many chloroplasts on the surface of the mesophyll cells and the light-saturated rate of photosynthesis per unit leaf area (Pmax) increases (Oguchi et al. 2006, Aoyagi et al. 2013). The biological and ecological characteristics of different plants express at different levels four patches (G, B, M and D), which also cause the difference of species composition. Heterogeneity patches are important to select species with different sizes and functions (Liira et al. 2011). At the same time, these heterogeneous environmental factors provide the necessary ecological basis for different species or functional groups that have the different demand for ecological environment in their different life history stages (Shimatani & Kubota 2011). Interestingly, some species only appear in particular habitats, in other words, these species have specificity.

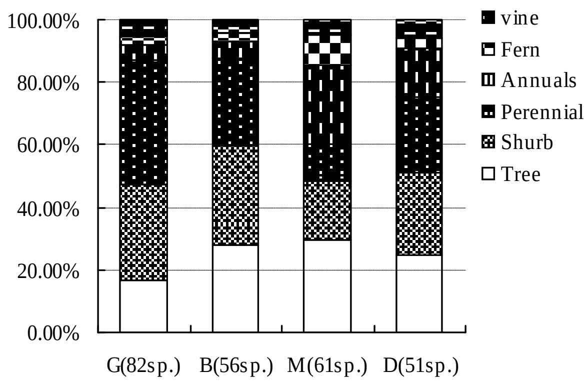


Fig. 4: Proportion of species life forms occur in different patch types in evergreen and deciduous broad-leaved mixed forest.

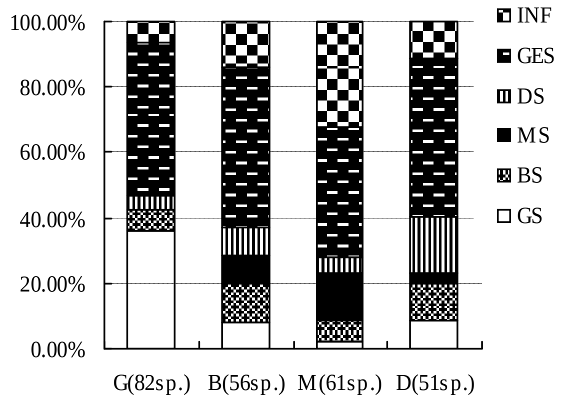


Fig. 5: Proportion of plant dispersal types in different patch types in evergreen and deciduous broad-leaved mixed forest.

The results that species diversity is highest in the gap phase may be attributed to result from higher resource heterogeneity, such as air temperature, light and soil moisture in gap phase, compared with the other patch phases. For example, Ritter & Einhorn (2005) have confirmed that air temperature, soil moisture and light regimes gradually decrease with gap development in a semi-natural beech-dominated forest. When one to a few canopy trees die, patch can form gap, and patch development creates ample resource heterogeneity (light and nutrients), at last the resource is partited, niche is differentiated, plant species can establish and/or reproduce. Whereas, they can not form without gap (Prévost & Raymond 2012). As predicted, the similarities of neighbouring patch types are higher than for non-neighbouring patch, for example, the similarity in G-B is higher than that in G-M. Our results imply that the patch dynamic progress is a step-change. The results may also be resulted from the micro-environmental factors similarities of neighbouring patch types, and our results are consistent with the results of Galanes & Thomlinson (2009), in which woody

Table 1: The standards of classifying patch types in evergreen and deciduous broad-leaved mixed forest.

	H_q (m)	HC_q (m)	Gap makers	Emergent trees
G	<9.1	< 9.1	Yes	No
B	<9.1	9.1~ 12.1	No	No
M	=9.1	=12.1	No	No
D	>9.1	> 12.1	No	Yes

Note: H_q: the average tree height in the quadrate (5 m × 5 m); HC_q: the average height of canopy trees in the quadrate (5 m × 5 m); Emergent trees: the trees were even exceeded the main canopy layer of the forest and they had sparse leaves, broken branches, bald necrotic spots or holes in the stems (Duan et al. 2013).

Table 2: β diversity index in different patch types in evergreen and deciduous broad-leaved mixed forest.

Patch	Tree layer			Shrub layer			Herb layer			total		
	B	M	D	B	M	D	B	M	D	B	M	D
G	0.32	0.45	0.26	0.09	0.14	0.11	0.45	0.68	0.38	0.43	0.56	0.32
B		0.54	0.14		0.21	0.08		0.51	0.21		0.49	0.16
M			0.35			0.24			0.42			0.45

plant species composition has more similarity in closer patches than farther apart patches in northeastern Puerto Rico.

Trees in different height classes or size classes in the forest community occupy different ecological niches and partite the heterogeneous environment, which can explain the coexistence mechanisms of the same species in different developmental phases and different species in the same developmental phases (Chazdon et al. 1999, Yu & Sun 2013). If niche partitioning (a deterministic factor) controls demographic events, such as the recruitment and survival of suppressed and current saplings, some species with different demandings will only appear in some specific patches. Plant growth and survival are not completely affected by some deterministic factors but can be neutral events, and mainly affected by stochastic events (Hubbell 1999, Prévost & Raymond 2012). Species with different regeneration characteristics, whose seedling may be built in a specific microenvironment, can share continuous canopy layer space in the adult stage, adding the biodiversity in the community. Manabe et al. (2009) have observed the same results when they reconstructed the gap forming and development processes for eight representative patches in an old growth evergreen broad-leaved forest in Japan during a 40-year period. Note that the size of the patch in our research is 5 m × 5 m, which may be a little rough. A more systematic criterion that can distinguish the patch types is needed and this can benefit to find the possible connections between species diversity and gap-developing processes.

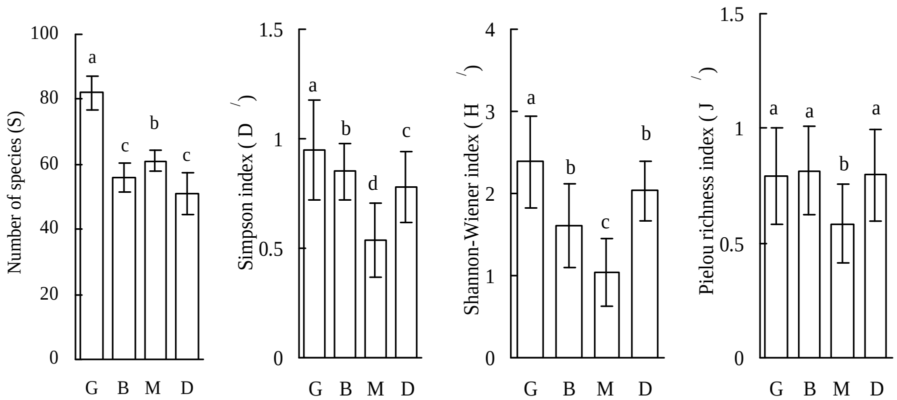


Fig. 6: Species diversity indices for species in different patch types in evergreen and deciduous broad-leaved mixed forest. Note: Values within the same column with different letters indicate statistically significant differences at $p<0.05$ between different patch types (G, B, M and D).

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REFERENCES

Aoyagi, R., Imai, N. and Kitayama, K. 2013. Ecological significance of the patches dominated by pioneer trees for the regeneration of dipterocarps in a Bornean logged-over secondary forest. Forest Ecol. Manag., 289: 378-384.

Canham, C.D., Denslow, J.S., Platt, W.J., Runkle, J.R., Spies, T.A. and White, P.S. 1990. Light regimes beneath closed canopies and treefall gaps in temperate and tropical forests. Can. J. Forest Res., 20: 620-631.

Chávez, V. and Macdonald, S.E. 2010. The influence of canopy patch mosaics on understory plant community composition in boreal mixedwood forest. Forest Ecol. Manag., 259: 1067-1075.

Chazdon, R.L., Colwell, R.K. and Denslow, J.S. 1999. Tropical tree richness and resource-based niches. Science, 285: 1459.

Duan, R.Y., Huang, M.Y. and Wang, X.A. 2013. Forest patch dynamics initiated by disturbance: Distribution pattern of *Larix chinensis* (bessen) patches along the altitudinal gradient in relation to light and temperature conditions (Qinling Mts. China). Polish J. Ecol., 61: 225-235.

Duan, R.Y., Wang, C. and Wang, X.A. 2009. Differences in plant species diversity between conifer (*Pinus tabulaeformis*) plantations and natural forests in middle of the Loess Plateau. Russ. J. Ecol., 40: 501-509.

Galanes, I.T. and Thomlinson, J.R. 2009. Relationships between spatial configuration of tropical forest patches and woody plant diversity in northeastern Puerto Rico. Plant Ecol., 201: 101-113.

Hubbell, S.P. 1999. Tropical tree richness and resource based niches. Science, 285: 1495.

Latif, Z.A. and Blackburn, G.A. 2010. The effects of gap size on some microclimate variables during late summer and autumn in a temperate broadleaved deciduous forest. Int. J. Biometeorol., 54: 119-129.

Lertzman, K.P., Sutherland, G.D., Inselberg, A. and Saunders, S.C. 1996. Canopy gaps and the landscape mosaic in a coastal temperate rain forest. Ecology, 77: 1254-1270.

Liira, J., Sepp, T. and Kohv, K. 2011. The ecology of tree regeneration in mature and old forests: Combined knowledge for sustainable forest management. J. For. Res., 16: 184-193.

Manabe, T., Shimatani, K., Kawarasaki, S., Aikawa, S.I. and Yamamoto, S.I. 2009. The patch mosaic of an old-growth warm-temperate forest: Patch-level descriptions of 40-year gap-forming processes and community structures. Ecol. Res., 24: 575-586.

Oguchi, R., Hikosaka, K., Hiura, T. and Hirose, T. 2006. Leaf anatomy and light acclimation in woody seedlings after gap formation in a cool-temperate deciduous forest. Oecologia, 149: 571-582.

Prévost, M. and Raymond, P. 2012. Effect of gap size, aspect and slope on available light and soil temperature after patch-selection cutting in yellow birch-conifer stands, Quebec, Canada. Forest Ecol. Manag., 274: 210-221.

Ritter, E. and Einhorn, K. S. 2005. Light temperature and soil moisture regimes following gap formation in a semi-natural beech-dominated forest in Denmark. Forest Ecol. Manag., 206: 15-33.

Shimatani, I.K. and Kubota, Y. 2011. The spatio-temporal forest patch dynamics inferred from the fine-scale synchronicity in growth chronology. J. Veg. Sci., 22: 334-345.

Yu;, M. and Sun, O. J. 2013. Effects of forest patch type and site on herb-layer vegetation in a temperate forest ecosystem. Forest Ecol. Manag., 300: 14-20.

Zang, R.G., Tao, J.P. and Li, C.Y. 2005. Within community patch dynamics in a tropical montane rain forest of Hainan Island, South China. Acta Oecol., 28: 39-48.

Zanne1, A.E. and Chapman, C.A. 2005. Diversity of woody species in forest, treefall gaps and edge in Kibale National Park, Uganda. Plant Ecol., 178: 121-139.