Research paper

Vegetation Composition and Structure in the Ecotone between Deciduous and Evergreen Broad-leaved Forests in an Upstream Region of Nantzuhsiensi, South-Central Taiwan

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【Summary】

The Nansi forest dynamic plot, 8.37 ha, was set up during January 2005 to February 2006 in the upstream region of the Nantzuhsien River in south-central Taiwan. This study was conducted on the mid-western ridge of the Nansi plot in a transitional zone between an *Alnus formosana* deciduous forest and an evergreen broad-leaved forest to understand differences in species composition and vegetation structure in the ecotone between these 2 forests. We studied a total of 2.56 ha (256 quadrats) on the mid-western ridge of the Nansi plot, which we divided into 5 sections, including 1 section of deciduous forest and 4 ecotone sections (0~10, 10~20, 20~30, and 30~40 m away from the edge into the evergreen broad-leaved forest). Tree density and basal area were calculated based on the quadrat (10×10 m^2) of each section. Both the total density and mean basal area were highest in the section of 10~20 m. Fifty percent of the total recorded 52 species were found in the deciduous forest, and 96% were found in the evergreen broad-leaved forest. *Alnus formosana* was dominant in the deciduous forest, whereas *Castanopsis carlesii*, *Litsea acuminata*, and *Eurya leptophylla* were dominant in the broad-leaved forest. The density and mean basal area of *A. formosana* decreased along the gradient from the deciduous forest to the evergreen broad-leaved forest, and disappeared in the section of 20~30 m. These factors reflected the depth of edge influence (DEI) presenting 20 m into the interior of the evergreen broad-leaved forest. In the deciduous forest section, there were many small trees of evergreen broad-leaved species, e.g., *L. acuminata*, *Machilus japonica*, *Cyclobalanopsis stenophylloides*, *Neolitsea sericea*, *Pasania kawakamii*, *M. zuihoensis*, *Gordonia axillaris*, and *L. akoensis*. Thus, this *A. formosana* deciduous forest is likely

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Received August 2009, Accepted February 2010. 2009年8月送審 2010年2月通過。

to be gradually replaced by these evergreen broad-leaved tree species, and its vegetation structure and species composition are likely to change in the future.

Key words: ecotone, deciduous forest, evergreen broad-leaved forest, depth of edge influence, Nansi forest dynamic plot.

Yang KC, Lin JK, Wang YH, Hsieh CF, Kuan LH. 2010. Vegetation composition and structure in the ecotone between deciduous and evergreen broad-leaved forests in an upstream region of Nantzuhsiensi, south-central Taiwan. Taiwan J For Sci 25(1):41-52.

研究報告

台灣中南部楠梓仙溪上游集水區落葉林與常綠闊葉林交會帶的植被組成與結構

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摘　要

台灣中南部楠梓仙溪上游集水區內，於2005年1月至2006年2月間設立一處8.37公頃的森林動態樣區(楠溪樣區)。為了瞭解落葉林與常綠闊葉林交會帶的物種組成與結構，本研究選定楠溪樣區中西側稜脊上的台灣赤楊落葉林及鄰近的常綠闊葉林進行分析，研究範圍共計2.56公頃(256個10×10平方公尺的樣方)，區分5個區塊，包含落葉林與兩林相邊界至常綠闊葉林林內的交會帶(0~10公尺、10~20公尺、20~30公尺與30~40公尺等)區塊。本研究估算各區塊中，每個樣方內木本物種的密度與底面積。總密度與總平均底面積在距離落葉林10~20公尺的常綠闊葉林區塊內達到最高。研究結果共記錄了52種木本植物，其中有50%出現在落葉樹林中，而有96%的種類則出現在常綠闊葉林中。台灣赤楊是本落葉林中優勢的物種，在常綠闊葉林則以長尾栲、長葉木薑子與薄葉柃木為優勢。台灣赤楊的密度與平均底面積在落葉林區塊中數量最高，越往常綠闊葉林內數量逐漸下降，至距離落葉林20~30公尺的常綠闊葉林區塊內則完全消失。這些結果反應邊際影響深度(DEI)為從兩種森林邊緣至常綠闊葉林內部20公尺。在落葉林中存在許多常綠闊葉樹的小樹，如長葉木薑子、假長葉楠、狹葉櫟、白新木薑子、大葉石櫟、青葉楠、大頭茶與屏東木薑子等物種。這些闊葉樹種將可能逐漸取代台灣赤楊落葉林，而改變落葉林的結構與物種組成。

關鍵詞：生態交會帶、落葉樹林、常綠闊葉樹林、邊際影響深度、楠溪森林動態樣區。

楊國禎、林笈克、王豫煌、謝長富、管立豪。2010。台灣中南部楠梓仙溪上游集水區落葉林與常綠闊葉林交會帶的植被組成與結構。台灣林業科學25(1):41-52。

INTRODUCTION

Ecotones, the interface between different ecosystem types, are important landscape elements. Forest edges are defined as interfacing between forested and nonforested ecosystems or between 2 forests of contrasting composition or structure (Harper et al. 2005). In many forested regions, forest fragmentation has produced a landscape in which forest edges are a dominant feature, and most forested tracts are subject to extensive edge influences

(Chen et al. 1993). The edge zone (ecotone) may provide a refuge and/or buffer zone for plants and animals (Forman and Godron 1986). For forest plants, many studies focused on the edge influence on the forest structure and species composition, using stem density and basal area as parameters (Gysel 1951, Wales 1972, Williams-Linera 1990). Recently, some research examined the 'depth of edge influence' (DEI). For example, according to the species composition and tree densities, the DEI was approximately 5 and 45 m on the northern and southern orientations of sugar maple-beech forests (Palik and Murphy 1990). The DEI was detected to be about 25 m in Monterey pine forests of Chile according to the diameter at breast height (DBH) (Cancino 2005). In terms of vegetation diversity, the DEI was 4~26 m on the forest side and 10~31 m on the agricultural field side (Li et al. 2007).

In Taiwan, large amount of *Alnus formosana* usually appears after disturbances, e.g., landslides or forest fires (Hsieh et al. 1989, Chen 1995, Gu et al. 2005), in the mountains at mid-elevations. After a deciduous forest of *A. formosana* has developed in disturbed areas near evergreen broad-leaved forests, there are usually clear edges between the 2 types of forests. *Alnus formosana* will gradually be replaced by evergreen broad-leaved tree species if no further disturbances occur (Hsieh et al. 1989). In the Nansi forest dynamic plot, an *A. formosana* forest existed on mid-western and southwestern ridges of the plot (Yang et al. 2008). Grass (*Miscanthus sinensis* f. *glaber*) covers all of the understory of the *A. formosana* forest, but has disappeared in the nearby evergreen broad-leaved forest, forming an edge between these 2 forest types. This study site provides a good opportunity to study the edge influences between the *A. formosana* deciduous forest and evergreen broad-leaved forest. In this paper we analyze the difference in species composition and vegetation structure along the gradient from the deciduous to the evergreen broad-leaved forest in order to detect the DEI.

MATERIALS AND METHODS

Study area

The Nansi forest dynamic plot, at 8.37 ha, near 9.5~10.0 km of the Nantzuhsiensi forest road, centered approximately at 23°27' 40.7"N and 120°54'22.2"E, is located in the western part of Yushan National Park, south-central Taiwan (Fig. 1). The topography of this plot contains valleys, gentle slopes, and ridges. One stream runs through the plot from the northwest to south year round, and another one rises in the east and runs to the southwest (Fig. 2). Both streams converge to the south outside of the plot. Elevations of this plot range 1955~2064 m. Mean monthly temperatures range 7.2℃ in January to 14.5℃ in July, and the mean annual rainfall is 2007 mm (Yang et al. 2008).

The Nansi forest dynamic plot contained 837 quadrats, each 10×10 m^2 in area, and all free-standing woody plants with DBH of stems ≥ 1 cm were tagged, measured, mapped, and identified between January 2005 and February 2006. Four plant communities of the Nansi plot were classified by two-way indicator species analysis (TWINSPAN), including the *Machilus japonica* type, *M. japonica-Castanopsis carlesii* type, *Schima superba-Cas. carlesii* type, and *A. formosana* type (Yang et al. 2008).

Methods

This study was mainly conducted on the mid-western ridge of the Nansi forest dynamic plot in the transitional zone between an *A. formosana* deciduous forest and

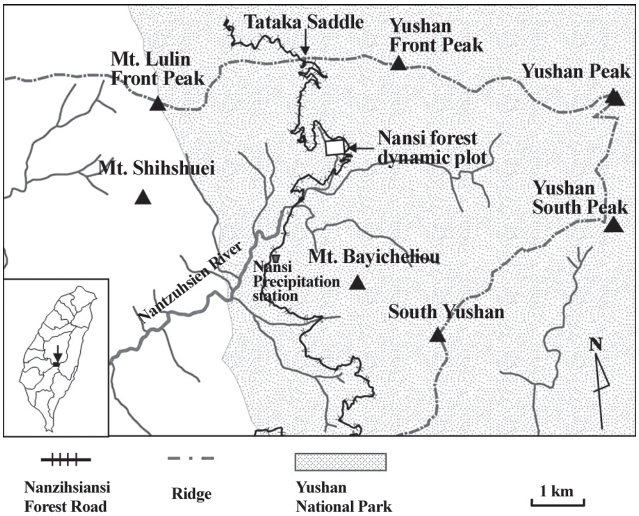

Fig. 1. Location of the Nansi forest dynamic plot.

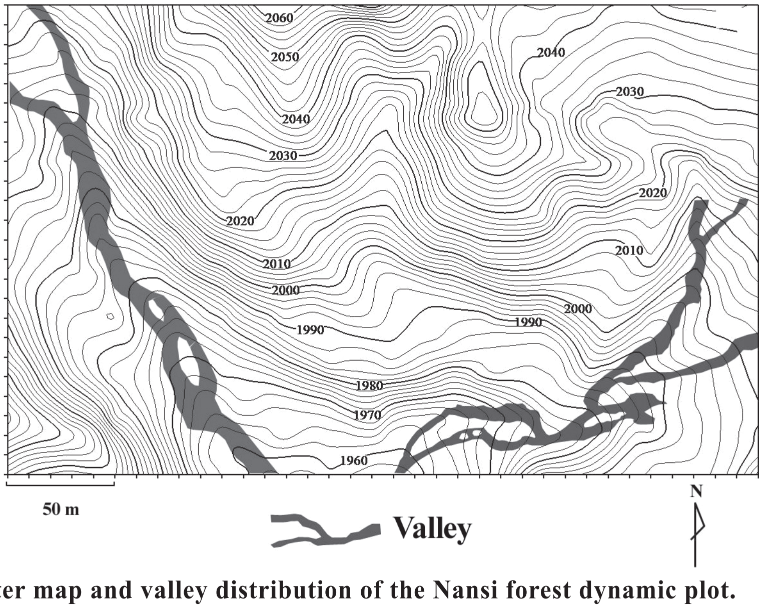

Fig. 2. Counter map and valley distribution of the Nansi forest dynamic plot.

a nearby evergreen broad-leaved forest. The 10×10 m^2 quadrat was the sampling unit of this plot. Plant communities were classified according to Yang et al. (2008). There are 4 forest types on this ridge, but mainly were the *A. formosana* type and *M. japonica*-*Cas. carlesii* type (Fig. 3). In this study, we defined 'edge' as a boundary line between 2 forests with contrasting compositions or structures (Harper et al. 2005). Therefore, the edge on the mid-western ridge of the Nansi plot was the boundary line along the outline of the *A. formosana* forest type which divides the forests into the deciduous and evergreen broad-leaved forests (Fig. 3). The deciduous forest sections were regarded as exterior

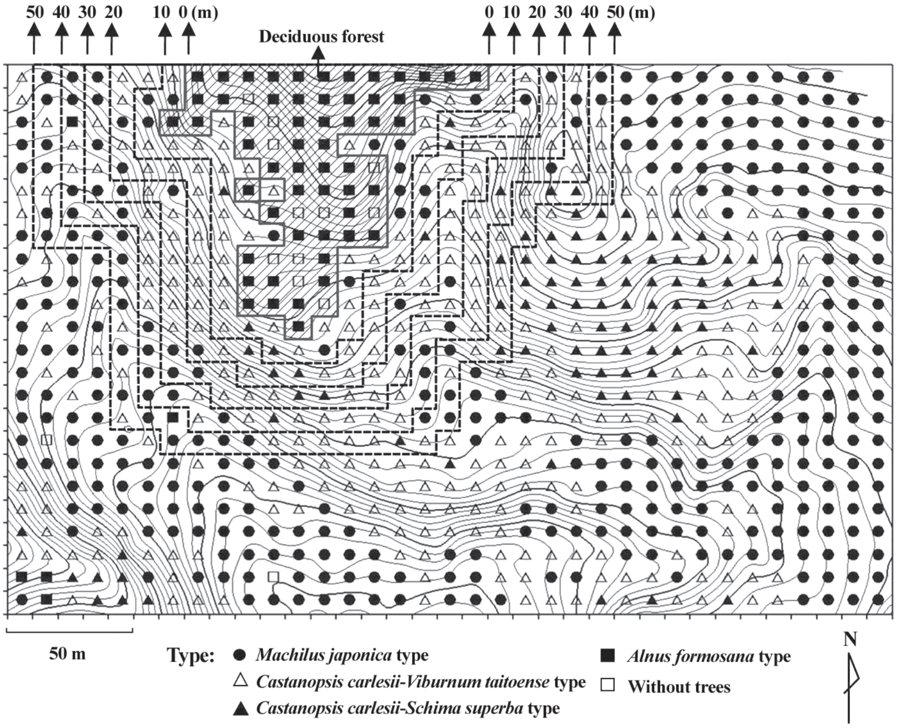

Fig. 3. Distribution patterns of plant communities in the Nansi plot and the sampling regions from the deciduous forest to the evergreen broad-leaved forest. The gradient sampling sections depended on the section of *Alnus formosana* type as a center and each interval of 10 m, by the unit of 10×10 m^2 quadrats, gradually expanding outward.

areas, including 55 quadrats of *A. formosana* type and 11 quadrats without trees (Table 1). Plant community compositions differed between sections of the deciduous forest and evergreen broad-leaved forest (Table 1). In the evergreen broad-leaved forest, the plant community of *M. japonica-Cas. carlesii* type (type II) was dominant in the sections of 0~10, 10~20, 20~30 and 30~40 m, but not in the section of 40~50 m, where the dominant plant community was the *M. japonica* type (type I) (Table 1). In the evergreen broad-leaved forest, this alteration of dominant plant community types was due to topographical variations (Yang et al. 2008). Therefore, we sampled a total 2.56 ha inside the Nansi plot (8.37 ha) as the study region where 5 sections were all included (Fig. 3), and analyzed the DEI in these sections. For species composition and vegetation structure, the density (individuals ha^{-1}) and mean basal area (m^2 ha^{-1}) were calculated for each species in the deciduous forest and the evergreen broad-leaved forest, and also in each section. Differences in density and mean basal area per quadrat among the 5 sections were evaluated by the Kruskal-Wallis test and then by the Behrens-Fisher test for multiple comparisons (Munzel and Hothorn 2001).

RESULTS

Woody floristic composition and structure

In total, 52 species, belonging to 42 genera and 24 families, were recorded in 2.56-ha study region of the Nansi plot. One half of all recorded species were found in the deciduous

Table 1. Quadrat numbers of each plant community in the deciduous forest section and from the edge to the evergreen broad-leaved forest at different distance sections

Plant community	Deciduous forest	Evergreen forest				
		0~10 m	10~20 m	20~30 m	30~40 m	40~50 m
I	0	13 (27.1%)	6 (13.6%)	13 (27.7%)	18 (35.3%)	25 (45.5%)
II	0	32 (66.7%)	32 (72.7%)	32 (68.1%)	30 (58.8%)	22 (40.0%)
III	0	3 (6.3%)	6 (13.6%)	2 (4.3%)	2 (3.9%)	7 (12.7%)
IV	55 (83.3%)	0	0	0	1 (2.0%)	1 (1.8%)
No trees	11 (16.7%)	0	0	0	0	0
Total	66	48	44	47	51	55

I: *Machilus japonica* type; II: *M. japonica-Castanopsis carlesii* type; III: *Cas. carlesii-Schima superba* type; IV: *Alnus formosana* type.

forest, and 96% were found in the evergreen broad-leaved forest (Table 2). There were 26 species, such as *Cas. carlesii*, *Osmanthus matsumuranus*, and *Viburnum taitoense*, that only appeared in the evergreen broad-leaved forest, whereas 2 species, *Tetrapanax papyriferus* and *Eurya gnaphalocarpa*, only occurred in the deciduous forest (Table 2). In total, 5538 individuals (2163 individuals ha^{-1}) and 133.58 m^2 (52.18 m^2 ha^{-1}) of basal area were contributed by both the deciduous and broad-leaved forests. The dominant tree species in the deciduous forest was *A. formosana* with the highest density and mean basal area. In terms of mean basal area and density, *Cas. carlesii* and *Litsea acuminata* were respectively the dominant tree species, and *Eurya leptophylla* was the dominant shrub species in the evergreen broad-leaved forest (Table 2). The density of the top 17 species with a high

Table 2. Species composition in the study region of Nansi forest dynamic plot: density (individuals ha^{-1}) and mean basal area (m^2 ha^{-1}) in the deciduous forest and evergreen broad-leaved forest

Species	Density		Mean basal area	
	Deciduous forest	Evergreen forest	Deciduous forest	Evergreen forest
Litsea acuminata	65.2	577.4	0.440	4.022
Eurya leptophylla	122.7	487.4	0.249	0.430
Machilus japonica	7.6	278.9	0.015	2.465
Eurya loquaiana	21.2	217.4	0.083	0.320
Castanopsis carlesii	0	220.5	0	22.873
Cyclobalanopsis stenophylloides	3.0	118.9	0.091	8.330
Alnus formosana	231.8	19.5	33.714	4.735
Neolitsea sericea	7.6	97.4	0.091	1.253
Callicarpa formosana	103.0	57.9	1.545	0.292
Pasania kawakamii	10.6	72.1	0.451	3.260
Machilus zuihoensis	3.0	46.3	0.012	1.327
Gordonia axillaris	15.2	41.6	0.271	0.773
Pourthiaea beauverdiana* var. *notabilis	19.7	38.9	0.627	0.417

(con't)

Species	Density		Mean basal area	
	Deciduous forest	Evergreen forest	Deciduous forest	Evergreen forest
Osmanthus matsumuranus	0	42.1	0	0.611
Vaccinium randaiense	9.1	33.2	0.185	0.240
Litsea akoensis	7.6	31.1	0.063	0.120
Viburnum taitoense	0	33.7	0	0.044
Rhododendron latoucheae	0	32.6	0	0.093
Michelia compressa	0	30	0	0.256
Eriobotrya deflexa	0	28.9	0	0.175
Cinnamomum insulari-montanum	0	24.7	0	1.248
Pittosporum illicioides	0	15.8	0	0.028
Viburnum luzonicum	1.5	14.7	0.001	0.020
Deutzia pulchra	31.8	2.6	0.269	0.038
Symplocos konishii	0	13.2	0	0.036
Clerodendrum trichotomum	28.8	2.6	0.255	0.025
Xylosma congesta	0	8.4	0	0.013
Schima superba	0	7.9	0	0.523
Mahonia oiwakensis	7.6	5.3	0.016	0.002
Elaeocarpus sylvestris	0	7.4	0	0.063
Sinopanax formosana	0	6.8	0	0.038
Acer insulare	7.6	3.2	0.737	0.293
Ilex ficoidea	0	5.8	0	0.053
Cephalotaxus wilsoniana	0	5.8	0	0.002
Tetradium meliaefolia	3.0	3.7	0.266	1.092
Malus doumeri	3.0	3.2	0.227	0.006
Debregeasia edulis	10.6	0.5	0.067	0.002
Rhododendron oldhamii	3.0	3.2	0.010	0.003
Quercus tatakaensis	0	3.2	0	0.259
Acer albopurpurascens	0	2.6	0	0.260
Rhododendron rubropilosum	3.0	1.6	0.006	0.002
Ardisia cornudentata ssp. *morrisonensis*	0	2.6	0	0.001
Beilschmiedia erythrophloia	0	2.1	0	0.030
Tetrapanax papyriferus	6.1	0	0.035	0
Acer serrulatum	0	1.6	0	0.234
Eurya gnaphalocarpa	4.5	0	0.096	0
Oreocnide pedunculata	0	1.1	0	0.012
Ligustrum matudae	0	1.1	0	0.001
Ulmus uyematsui	0	0.5	0	0.136
Lyonia ovalifolia	0	0.5	0	0.016
Deutzia taiwanensis	0	0.5	0	0.001
Itea parviflora	0	0.5	0	0
Total	737.9	2658.4	39.820	56.472

The species in bold font are deciduous species.

relative dominance represented more than 90% of total individuals, and the other 35 species were relatively sparse in this region.

Variation of densities in the distance sequence

Except for *Callicarpa formosana* and *Pourthiaea beauverdiana* var. *notabilis*, the densities of the other 15 relatively dominant species were not the same across the 5 sections (Table 3). The total density significantly increased ($p < 0.05$) from the deciduous forest to the section of 0~10 m in the evergreen broad-leaved forest, and this significant increasing pattern was also shown by the density of 10 of the top 17 relative dominant species, while *A. formosana* significantly decreased (Table 3). *Litsea acuminata*, the dominant tree species, and *L. akoensis* had the highest densities in the sections of 10~20 and 0~10 m, and the lowest densities in the deciduous forest section. Both shrub species, *Eurya leptophylla* and *E. loquaiana*, had greater densities in the 4 sections of the evergreen broad-leaved forest ($p < 0.05$) than in the deciduous forest section (Table 3). In the evergreen broad-leaved forest, densities of *E. leptophylla* in the sections of 0~10 and 10~20 m, and *E. loquaiana* in the sections of 10~20 and 20~30 m were also higher ($p < 0.05$) than both in the section of 30~40 m. Variations of the densities of *M. japonica*, *Cas. carlesii*, *Cyclobalanopsis stenophylloides*, *Neolitsea*

Table 3. Gradient variation of density (individuals ha^{-1}) of woody species from the deciduous forest to the evergreen broad-leaved forest (only the top 17 species with the highest density are listed)

Species	Deciduous forest (n = 66)	Evergreen forest (m) 0~10 (n = 48)	10~20 (n = 44)	20~30 (n = 47)	30~40 (n = 51)
Tree					
Litsea acuminata	65.2±137.6^{a}	552.1±600.7^{bc}	**881.8**±813.1^{b}	480.9±373.4^{bc}	427.5±323.2^{c}
Machilus japonica	7.6±26.7^{a}	64.6±122.9^{b}	254.6±244.4^{c}	**423.4**±375.5^{c}	368.6±294.3^{c}
Castanopsis carlesii	0^{a}	87.5±119.6^{b}	263.6±297.4^{c}	263.8±264.9^{c}	**268.6**±321.0^{c}
Cyclobalanopsis stenophylloides	3.0±17.3^{a}	47.9±65.2^{b}	118.2±155.9^{bc}	**187.2**±213.3^{c}	123.5±138.0^{c}
Alnus formosana	**231.8**±230.8^{a}	56.3±112.8^{b}	20.5±46.2^{bc}	0^{d}	2.0±14.0^{cd}
Neolitsea sericea	7.6±26.7^{a}	75.0±121.2^{b}	**136.4**±158.6^{b}	93.6±115.0^{b}	88.2±110.7^{b}
Callicarpa formosana$^{n.s.}$	**103.0**±188.9	83.3±117.3	47.7±84.9	53.2±92.9	47.1±90.2
Pasania kawakamii	10.6±35.6^{a}	43.8±64.9^{b}	79.6±95.4^{b}	74.5±98.8^{b}	**90.2**±118.8^{b}
Machilus zuihoensis	3.0±17.3^{a}	50.0±92.3^{b}	**52.3**±87.6^{b}	36.2±60.5^{b}	47.1±54.2^{b}
Gordonia axillaris	15.2±53.3^{a}	33.3±63.0^{ab}	**52.3**±90.2^{b}	36.2±73.5^{ab}	45.1±85.6^{ab}
Pourthiaea beauverdiana var. *notabilis*$^{n.s.}$	19.7±47.1	**47.9**±77.2	38.6±72.2	31.9±69.5	37.3±77.4
Osmanthus matsumuranus	0^{a}	6.3±32.0^{a}	40.9±72.6^{b}	**63.8**±109.2^{b}	56.9±102.5^{b}
Litsea akoensis	7.6±26.7^{a}	**135.4**±75.8^{b}	38.6±68.9^{a}	23.4±47.6^{a}	27.5±53.2^{a}
Shrub					
Eurya leptophylla	122.7±254.7^{a}	**777.1**±862.3^{b}	500.0±557.4^{b}	421.3±426.8^{bc}	264.7±362.7^{c}
Eurya loquaiana	21.2±62.1^{a}	227.1±266.4^{bc}	**347.7**±443.8^{b}	285.1±218.7^{b}	125.5±244.0^{c}
Vaccinium randaiense	9.1±33.9^{ab}	50.0±116.7^{a}	**63.6**±184.4^{a}	19.2±53.7^{ab}	3.9±19.6^{b}
Viburnum taitoense	0^{a}	6.3±32.0^{ab}	43.2±104.3^{bc}	34.0±84.1^{bc}	**51.0**±131.7^{c}
Total	737.9±672.3^{a}	2400.0±1673.5^{b}	**3252.3**±1855.2^{b}	2731.9±1526.7^{b}	2321.6±1216.1^{b}

Numbers in bold font indicate the highest mean density.

$^{n.s.}$: not significant by the Kruskal-Wallis test.

$^{a, b, c, d}$: groups indicated by the Behrens-Fisher test.

sericea, *Pasania kawakamii*, *M. zuihoensis*, *Gordonia axillaris*, *O. matsumuranus*, and the total species presented similar patterns, such that they were lowest in the deciduous forest section and increased significantly in the 0~10- or 10~20-m sections, then did not significantly vary inside the evergreen broad-leaved forest (Table 3). There were many species with higher or the highest density in the section of 10~20 m in the evergreen broad-leaved forest, which resulted the highest total density in this section. *Alnus formosana* presented a different pattern of variation in density, such that it was highest in the deciduous forest and then significantly decreased until 20~30 m inside the evergreen broad-leaved forest.

Variations of mean basal area in the distance sequence

In terms of the mean basal area, 14 of 17 relatively dominant species and the sum of total species significantly differed across the 5 sections, except for *Cal. formosana*, *Pou. beauverdiana* var. *notabilis*, and *L. akoensis* (Table 4). The mean basal area for most of the relatively dominant species from the edge of deciduous forest to the interior section of the evergreen broad-leaved forest presented an increasing pattern (Table 4). Ten of 17 relatively dominant species significantly increased ($p < 0.05$) in mean basal area from the section of the deciduous forest to 0~10 m, while *A. formosana* significantly decreased

Table 4. Gradient variation of the mean basal area (m^2 ha^{-1}) of woody species from the deciduous forest to the evergreen broad-leaved forest (only the top 17 species with the highest density are listed)

Species	Deciduous forest (n = 66)	Evergreen forest (m) 0~10 (n = 48)	10~20 (n = 44)	20~30 (n = 47)	30~40 (n = 51)
Tree					
Litsea acuminata	0.440±1.149^{a}	2.995±5.445^{b}	2.934±4.067^{b}	4.684±6.712^{b}	**5.318**±9.293^{b}
Machilus japonica	0.015±0.087^{a}	0.484±1.391^{b}	1.682±2.659^{c}	**4.417**±9.947^{c}	3.204±5.878^{c}
Castanopsis carlesii	0^{a}	8.538±21.843^{b}	**35.878**±44.681^{c}	29.544±48.649^{c}	18.996±32.542^{bc}
Cyclobalanopsis stenophylloides	0.091±0.726^{a}	1.864±6.724^{b}	6.395±17.500^{bc}	9.320±18.319^{c}	**15.171**±31.668^{c}
Alnus formosana	**33.714**±32.062^{a}	7.069±12.738^{b}	12.076±39.613^{bc}	0^{c}	0.568±4.057^{c}
Neolitsea sericea	0.091±0.546^{a}	0.211±0.450^{b}	0.889±2.354^{b}	1.484±4.274^{b}	**2.334**±6.830^{b}
Callicarpa formosana n.s.	**1.545**±3.612	0.660±1.064	0.178±0.493	0.113±0.319	0.210±0.617
Pasania kawakamii	0.451±2.677^{a}	1.777±9.364^{b}	**4.973**±11.359^{b}	3.611±9.607^{b}	2.855±8.609^{b}
Machilus zuihoensis	0.012±0.094^{a}	0.333±0.762^{b}	0.176±0.486^{b}	2.250±6.471^{b}	**2.405**±6.439^{b}
Gordonia axillaris	0.271±1.700^{a}	0.421±1.393^{ab}	1.303±5.231^{b}	**1.357**±7.086^{ab}	0.110±0.496^{ab}
Pourthiaea beauverdiana var. *notabilis* n.s.	0.627±2.197	**1.058**±2.980	0.297±1.040	0.153±0.539	0.160±0.792
Osmanthus matsumuranus	0^{a}	0.220±1.436^{a}	**1.096**±4.377^{b}	0.382±1.117^{b}	0.771±3.532^{b}
Litsea akoensis n.s.	0.063±0.271	0.147±0.499	**0.169**±0.785	0.128±0.749	0.044±0.133
Shrub					
Eurya leptophylla	0.249±0.554^{a}	**0.855**±0.957^{b}	0.414±0.487^{bc}	0.276±0.342^{c}	0.185±0.390^{a}
Eurya loquaiana	0.083±0.312^{a}	0.403±0.578^{bc}	**0.438**±0.526^{b}	0.256±0.332^{bc}	0.200±0.390^{c}
Vaccinium randaiense	0.185±0.774^{a}	**0.429**±1.382^{b}	0.327±0.938^{b}	0.181±0.882^{ab}	0.043±0.260^{a}
Viburnum taitoense	0^{a}	0.001±0.006^{ab}	0.033±0.084^{bc}	0.040±0.101^{bc}	**0.096**±0.415^{c}
Total	39.820±34.585^{ab}	32.358±32.813^{a}	**73.317**±63.365^{c}	61.335±54.155^{bc}	60.153±51.025^{bc}

Numbers in bold font indicate the highest mean basal area.

n.s.: not significant by the Kruskal-Wallis test.

a, b, c, d: groups indicated by the Behrens-Fisher test.

(Table 4). The total mean basal area for all species also significantly increased at the distances of 0~10 and 10~20 m, and then slightly decreased afterward. *Castanopsis carlesii*, the species with the greatest basal area in this study area, and *P. kawakamii*, *O. matsumuranus*, *L. akoensis*, and *E. loquaiana* also had the greatest mean basal area in the section of 10~20 m. *Litsea acuminata*, *Cyc. stenophylloides*, *N. sericea*, *M. zuihoensis* and the shrub *V. taitoense* had the greatest mean basal area in the section of 30~40 m inside the evergreen broad-leaved forest. The mean basal area of *A. formosana* significantly decreased from the deciduous forest to the broad-leaved forest before the section of 20~30 m (Table 4).

DISCUSSION

The species composition and structure between the *A. formosana* deciduous forest and the nearby evergreen broad-leaved forest differed in terms of density and mean basal area (Table 2). The highest density and mean basal area were found in the section of 10~20 m. This is similar to some tropical and temperate-zone forests, that showed higher stem densities and basal areas within 20 m from the edge (Palik and Murphy 1990, Williams-Linera 1990, Matlack 1994). Carolina (1995) pointed out that this is a kind of 'direct biological edge effect' that changes in the physical environment caused by edges directly affecting the forest structure. Both the total density and basal area were highest in the section of 10~20 m. This indicates that the DEI extended 20 m into the interior of the evergreen broad-leaved forest. Different species can reflect different DEI in a forest (Fraver 1994). For example, one of the dominant species, *L. acuminata*, revealed a peak in the section of 10~20 m, but it was at 0~10 m for *E. leptophylla*.

Castanopsis carlesii and *L. acuminata* were the most dominant species in the canopy and subcanopy layer in the entire Nansi plot (Yang et al. 2008), and also in the evergreen broad-leaved forest of this study in terms of the density and mean basal area (Table 2). *Castanopsis carlesii* had higher densities in the sections of 10~20, 20~30, and 30~40 m, but its mean basal area gradually dropped from the 10~20-m section into the interior sections of 20~30 and 30~40 m in the evergreen broad-leaved forest. This means that there were many saplings of *Cas. carlesii* far from the edge. Another Fagaceae species, *P. kawakamii*, also had a similar pattern. In comparison, *L. acuminata* had higher densities in the sections of 0~10 and 10~20 m than in 20~30 and 30~40 m (Table 3), but its mean basal area displayed a reverse pattern (Table 4). This means that *L. acuminata* had more saplings near the edge. Two other Lauraceae species, *N. sericea* and *L. akoensis*, also presented a similar pattern. *Litsea acuminata* is abundant and regenerates well in mid-elevation evergreen forests (Chen 2006). Another study also showed that this species can regenerate in small gaps of a single fallen tree (Hong 1989). Gap formation increases the light available for understory plants in forests (Oguchi et al. 2006). A similar condition occurs at the edge where there is a relatively high level of light which stimulates the germination and growth of plant species (Wales 1972, Lopez de Casenave et al. 1995). *Litsea acuminata* also had a much higher density than did other evergreen broad-leaved tree species in the deciduous forest section (Table 3). Its abundance and regenerative characteristics indicate that *L. acuminata* may be an evergreen broad-leaved tree species but with pioneer traits which can colonize under the *A. formosana* deciduous forest.

The dominant shrub species, *E. lepto-*

phylla, had the greatest density in the section of 0~10 m, while *E. loquaiana* peaked in the section of 10~20 m (Table 3). In an old-growth, temperate, evergreen broad-leaved forest in southwestern Japan, the spatial distribution of *E. japonica* individuals was largely correlated with tree-fall gaps (Manabe and Yamamoto 1997). Gaps and edges are similar to each other in that they offer more available light than the continuous forest canopy. Thus the 3 species have similar affinities to high light conditions. *Eurya leptophylla* had the greatest density among evergreen broad-leaved species in the section of the deciduous forest (Table 3). It seems that *E. leptophylla* is a pioneer evergreen broad-leaved shrub species under the *A. formosana* deciduous forest.

The *A. formosana* forest on the mid-western ridge of the Nansi plot is very close to the Nantzuhsiensi forest road. *Alnus formosana* usually appears after a disturbance (Chen 1995), thus the appearance of this *A. formosana* forest was likely caused by disturbances when the forest road was paved about 40~50 yr ago (Chen 2001). The fact that *A. formosana* occurred in the sections of 0~10 and 10~20 m and then disappeared in the 20~30-m section (Table 3) reflects that the disturbance appeared not only in the deciduous forest section, but also into the 0~10- and 10~20-m sections in the past. *Alnus formosana* disappeared in the section of 20~30 m, but the occurrence of a few *A. formosana* (n = 2) in the 30~40-m section may be attributed to disturbance caused by a stream on the western side of the study region (Figs. 2, 3), which is a different pattern from those *A. formosana* that occurred on the ridge due to road paving activities. In this section, *A. formosana* frequently appeared in the canopy layer, while it was not common in the shrub layer (Yang et al. 2008), indicating the poor regeneration feature of this species. The characteristics of *A. formosana* are that it is an early successional species, cannot regenerate well, and tends to be replaced by other evergreen broad-leaved tree species if no further disturbances occur (Hsieh et al. 1989). This replacement was present in the sections of 0~10 and 10~20 m where many evergreen broad-leaved species already existed (Table 3). Especially in 0~10-m section, there were a higher density (Table 3) and less mean total basal area (Table 4) reflecting many regenerating small trees. In the deciduous forest sections, there were many small trees of evergreen broad-leaved species, e.g., *L. acuminata*, *M. japonica*, *Cyc. stenophylloides*, *N. sericea*, *P. kawakamii*, *M. zuihoensis*, *G. axillaris*, and *L. akoensis*. These indicated that the *A. formosana* deciduous forest could eventually be replaced by evergreen broad-leaved species. How will the species composition and vegetation structure change along this deciduous-edge-evergreen broad-leaved forest zone in the future? Long-term observations are required to determine the dynamic of the forests in this plot.

ACKNOWLEDGMENTS

We appreciate the field assistance by numerous volunteers. We also greatly appreciate the staff of the Yushan National Park and Chiayi Forest District Office for their continuous support, and for permission to use the Nantzuhsiensi Station. Financial support was provided by the Forestry Bureau (grants 94-00-2-02 and 95-01).

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