Research note

Baseline Survey and the Immediate Thinning Impact on the Stand Composition of Woody Plants and Overstory Structure of a Sugi Plantation (*Cryptomeria japonica*) in the Zenlen Area

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【Summary】

The practice of forest thinning can influence the functions and structure of forest ecosystems. To investigate the effects of alternative thinning strategies on the stand structure and tree composition of a sugi (*Cryptomeria japonica)* plantation, this study was conducted on national forests in the Nandai Working Circle Area. In a 35-yr-old plantation, the baseline stand status was surveyed to determine the inventory of timber resources in the study area on 12 plots with a size of 1 ha each. Among them, a randomized block design was adopted for 3 treatments with 4 replications for each treatment in 1 ha. A gap thinning rule was used to remove trees with 3 levels of thinning intensity in terms of removing 0, 25, and 50% area of sugi trees in a plot. In each plot, all woody plants with a diameter at breast height (dbh) of > 1.0 cm were tallied, tagged, identified to species, the position was recorded, and dbh was measured. Baseline survey results showed that due to variations in growth among trees in the past, inconsistencies in tree densities were evident among plots. While the basal area shared by understory woody plants was quite small in the plantation (i.e., < 5%), the enhancement of biodiversity was obvious. In terms of Shannon diversity index, the biological diversity of all woody plants increased after thinning, but there was little change in overstory trees. Vertical evenness of the overstory tree canopy was reduced after thinning and there was a not noticeable left-truncated Weibull dbh distribution after thinning.

Key words: plantation structure, biodiversity index, understory plants, gap thinning.

Wang DH, Chung CH, Hsieh HC, Tang SC, Chen TH. 2011. Baseline survey and the immediate thinning impact on the stand composition of woody plants and overstory structure of a sugi plantation (*Cryptomeria japonica*) in the zenlen area. Taiwan J For Sci 26(3):295-303.

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Received January 2011, Accepted May 2011. 2011年1月送審 2011年5月通過。

研究簡報

人倫地區柳杉疏伐前後林分木本植物組成和結構之調查

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摘 要

人工林疏伐及其後之經營措施對森林生態系之功能及結構有著重要影響。本研究在林務局南投林區管理處人倫地區1972~1973年造林之柳杉人工造林地內，設置12個面積各為1公頃之方形樣區，實施伐採25、50%面積和不疏伐之孔隙疏伐作業(gap thinning)，進行上層林木(柳杉)之每木調查以探討疏伐處理對林分上層林木之結構和生長之影響。疏伐前每木調查資料顯示林分株數之異質性。林分組成中雖然下層木質林木之斷面積總合佔林分總斷面積之比例甚低(< 5%)，但在生物多樣性方面則貢獻甚多。以Shannon多樣性指標言之，疏伐會立即增加現有所有木本植物之生物多樣性但不改變上層林木生物多樣性。雖然各區疏伐前之垂直均勻指標有些差異，但其值均大於0.5，顯示出有分佈不錯之垂直結構之均勻程度。疏伐作業會造成垂直均勻指標值之降低；在孔隙疏伐後林木胸徑Weibull分佈並無發生明顯朝左截斷(left-truncated)之現象。

關鍵詞：林分結構、生物多樣性、下層林木、孔隙疏伐。

汪大雄、鍾智昕、謝漢欽、湯適謙、陳財輝。2011。人倫地區柳杉疏伐前後林分木本植物組成和結構之調查。台灣林業科學26(3):295-303。

In plantations, the effects of juvenile spacing do not last long because of competition in the roots and crowns of younger trees beginning at the onset of closure. Crowded trees compete for light, water, and nutrients, resulting in the slow growth or even death of some trees (Oliver and Larson 1996). Moreover, some weak trees also become vulnerable to insects and disease. To avoid overcrowding and competition, trees are often thinned to increase the growing space available to the remaining trees. Enhancing growth of final crop trees by removing some trees, therefore, has long been recognized and practiced as commercial thinning (Abbott and Loneragan 1983).

The traditional objective of thinning was to create more space for residual trees, thereby producing higher-quality sawlogs (Smith 1986). Besides the timber value added, issues of nontimber benefits such as biodiversity, environment, recreation, and microclimate of forest sites, land cover, carbon sequestration, and habitats for wildlife were noticed by the public recently and are also related to thinning practices (Sheriff 1996, Chambers et al. 1999).

Thinning allows forest managers to choose trees to which additional growth is allocated and to harvest growth that would otherwise be lost due to mortality (Della-Binanca and Dils 1960, Smith 1986). Thinning was found to affect moisture (Donner and Running 1986), plant physiology, foliar nutrients (Ginn et al. 1991), and light availability of residual trees as well as air temperatures within a stand and on the forest floor (Della-Binanca and Dils 1960).

Forest structure is of interest to many disciplines and is often discussed in the context of ecosystem management. Spies (1998) pointed out that forest structure encompasses many meanings and can be described in many ways. At the stand level, measurements of trees size, age, foliage, biomass, and spatial distribution in overstory and ground vegetation layers are commonly viewed as components of stand structure. The structure of tree crowns, for example, is a characteristic of stand structure that influences the growth of both trees and understory vegetation (Latham et al. 1998). Changes in structural attributes of stands also affect stand functions such as photosynthesis, respiration (Waring and Schlesinger 1985), tree growth (O'Hara 1988), suitability of a stand for wildlife (Morrison et al. 1992), and understory plant diversity (Latham et al. 1998). Therefore, structural diversity has become an important facet within forestry, especially for countries (e.g., those of the Central European Region) with a rather low level of tree species diversity (Neumann and Stalinger 2001).

Stand composition and architecture play important roles in determining habitat and species diversity. Increasing horizontal and vertical heterogeneity of a stand structure often leads to a higher number of species and contributes to higher stand stability (Latham et al. 1998). Thinning practices can modify the stand structure and therefore have important potential roles in determining stand diversity and ecological stability (Pretzsch 1997, Spies 1998, Humphrey et al. 2000).

Sugi (*Cryptomeria japonica*) plantations are the 2nd largest man-made forest in Taiwan. The inventory of the 3rd forest resources survey in Taiwan showed that the area of sugi plantation reached 39,100 ha within a total area of 295,500 ha of national man-made forests around Taiwan, with a growing stock of about 9.33 x 10^6 m^3. Therefore, sugi plantations are the most-common forest type of mid-elevation areas of Taiwan (TFB 1995). Usually, in the past, sugi plantations were planted as monocultures for the main purpose of timber production. Nowadays, to be consistent with forest ecosystem management, determining how to apply thinning practices to existing sugi plantations to enhance the heterogeneity of the stand composition and structure to meet the goals of biodiversity conservation, land productivity promotion, and stability of the ecosystem has become an important issue for sustainable forest management. The purposes of this study, therefore, were to collect baseline data and investigate the immediate influence of alternative thinning strategies on stand composition and structure of a sugi plantation in the Zenlen area of the Nantou Forest District in Taiwan.

The experimental site in this study was located in compartments 74 and 75 of the Nandai National Working Circle of the Taiwan Forestry Bureau. The sugi plantation was planted in 1971~1972 with an area of 78 ha at elevations ranging 1500~1700 m. The mean annual precipitation is 3800 mm most of which falls in May to September. The mean annual temperature is 17.5℃.

A randomized block design was adopted for 3 treatments with 4 replications for each treatment. Each plot was 1.0 ha. The buffer zone among plots was about 10~15 m wide. The total area of the sugi plantation for this experiment was about 25~30 ha. In each plot, all woody plants with a diameter at breast height (dbh) of > 1.0 cm were tallied, tagged, and identified to species, their orientations were noted, and dbh was measured. In addition to tallying data for 1.0 ha, 2 subplots with an area of 0.16 ha each were set up on each plot. In each subplot, the tree height of each sugi tree was measured to develop a sugi tree height curve. Moreover, the height to crown base and crown width of each sugi tree in each subplot were also measured. In addition to the overstory species (sugi and China fir), a variety of broadleaf species occur in the understory woody vegetation (Table 1).

Gap thinning was used as the thinning practice. The thinning design was laid out as that in the case of thinning intensity of removing 25% of area, for each quadrant of size 20 x 20 m, the thinning point was positioned in the lower-right corner of one-fourth quadrant (i.e., the cutting area was 10 x 10 m), and all sugi trees located in the cutting area at the thinning point were felled. In the thinning intensity of removing 50% of area case, sugi trees located in 2 quarter quadrant of 20 x 20 m connected northwest to southeast diagonally were fully harvested.

The vertical and horizontal aspects of the stand structure were assessed. Five canopy layers with tree heights of < 13, 13~15, 15~17, 17~19, and > 19 m were used to calculate the vertical evenness. The Weibull function was used to estimate the dbh distribution among tress because of its advantages of great flexibility and easy computation (Clutter and Bennett 1965, Kynch and Moser 1986).

Due to the difficulty in measuring the tree height in large-scale forest inventories, a height-diameter curve is often used to estimate the tree height for a tree given dbh size. This study observed that previously published height models (Yang 1975, Lo and Feng 1985) would either underestimate or overestimate most of the tree heights measured (Fig. 1). Therefore, it is essential to fit the height-diameter curve by using data collected in this study. Several height models were used and compared based on mean square error (mse) criteria. The goodness of fit showed the superiority of model 8 (Table 2). The tree total volume was calculated based on an equation developed by Lo and Feng (1985).

Tallied data from 1 ha revealed the heterogeneity of the stand density of overstory trees on the plot. The stand density of overstory trees ranged 893~1285 trees ha^{-1}, and the average dbh was 24.1~27.8 cm among plots (Table 3). Competition among trees and other factors may account for the heterogeneity in plantations. Computation of the species composition in basal area showed the overwhelming dominance of overstory trees [sugi and China fir (*Cunninghmia lanceolata*)] in the stand. Moreover, as expected, sugi accounted for a far greater quantity than China fir in the overstory layer (Table 1). Because the basal area of sugi was > 80% of the total basal area in the overstory layer in each plot, the plantation was still considered a pure sugi plantation.

Biological diversity and conservation are 2 great issues that need to be considered in plantation management. While a variety of dominant understory woody plants existed among plots, in general, *Eurya loquaiana* was the most dominant species of understory woody plant in the area (Fig. 2). In each plot, the Shannon diversity index for all tallied trees was calculated, and results are given in Table 1. While the basal area shared by understory woody plants was quite small in the plantation (i.e., < 5%), the enhancement of biodiversity characteristics was quite obvious. For example, the Shannon index was much higher if the biodiversity of the understory woody plants was considered as an entire entity.

The impacts of thinning on biological diversity on woody plants after thinning are shown in Table 1. Based on the Shannon diversity index calculated with the number of trees, the biological diversity of all woody plants increased after thinning but with a little change in overstory trees. In other words, thinning operations benefited conservation from a biodiversity context.

Table 1. Composition of the basal area of woody trees and the biodiversity index before and after thinning of the plots

plot		Basal area (%) before thinning			Before thinning			After thinning		
		Sugi	China fir	Understory woody plants	S	N	Shannon	S	N	Shannon
	ALL	74.00	24.09	1.91	55	1542	2.28	55	1306	2.46
1	A				53	649	2.81	53	649	2.81
	B				2	893	0.62	2	657	0.62
	ALL	93.52	5.33	1.15	52	2309	1.74	52	2102	1.79
4	A				50	1370	1.55	50	1370	1.55
	B				2	939	0.24	2	732	0.27
	ALL	98.23	0.09	1.68	59	2931	1.55	59	2642	1.62
7	A				57	1646	1.53	57	1646	1.53
	B				2	1285	0.01	2	996	0.01
	ALL	97.26	0.54	2.19	35	3363	2.49	35	3111	2.58
11	A				33	2289	2.62	33	2289	2.62
	B				2	1074	0.01	2	822	0.01
	ALL	97.31	1.81	0.88	35	1894	1.42	35	1416	1.57
2	A				33	950	1.31	33	950	1.31
	B				2	944	0.10	2	466	0.10
	ALL	95.58	0.16	4.26	90	2304	2.09	90	1866	2.27
5	A				88	1412	2.20	88	1412	2.20
	B				2	892	0.07	2	454	0.06
	ALL	97.31	0.00	2.69	61	2721	2.41	61	2215	2.66
8	A				60	1701	2.72	60	1701	2.72
	B				1	1020	0.00	1	514	0.00
	ALL	96.82	0.23	2.95	65	3395	2.50	65	2792	2.73
9	A				63	2211	2.73	63	2211	2.73
	B				2	1184	0	2	581	0
	ALL	98.46	0.00	1.54	60	2552	2.26	60	2552	2.26
3	A				59	1497	1.87	59	1497	1.87
	B				1	1055	0	1	1055	0
	ALL	97.34	0.00	2.66	62	2688	3.11	62	2688	3.11
6	A				61	1574	1.98	61	1574	1.98
	B				1	1114	0	1	1114	0
	ALL	95.78	0.00	4.22	67	4006	1.11	67	4006	1.11
10	A				66	3033	0.75	66	3033	0.75
	B				1	973	0	1	973	0
	ALL	81.18	17.37	1.45	37	1607	1.91	36	1607	1.91
12	A				35	711	2.28	34	711	2.28
	B				2	896	0.48	2	896	0.48

All, biodiversity index for all woody plants with a diameter at breast height (dbh) of > 1.0 cm; A, biodiversity index for understory woody plants with a dbh of > 1.0 cm; B, biodiversity index for overstory plants only; S, number of species; N, number of trees.
Plot 1, 4, 7, and 11 had a thinning intensity of 25%; plots 2, 5, 8, and 9 had a thinning intensity of 50%; and plots 3, 6, 10, and 12 were the control plots.

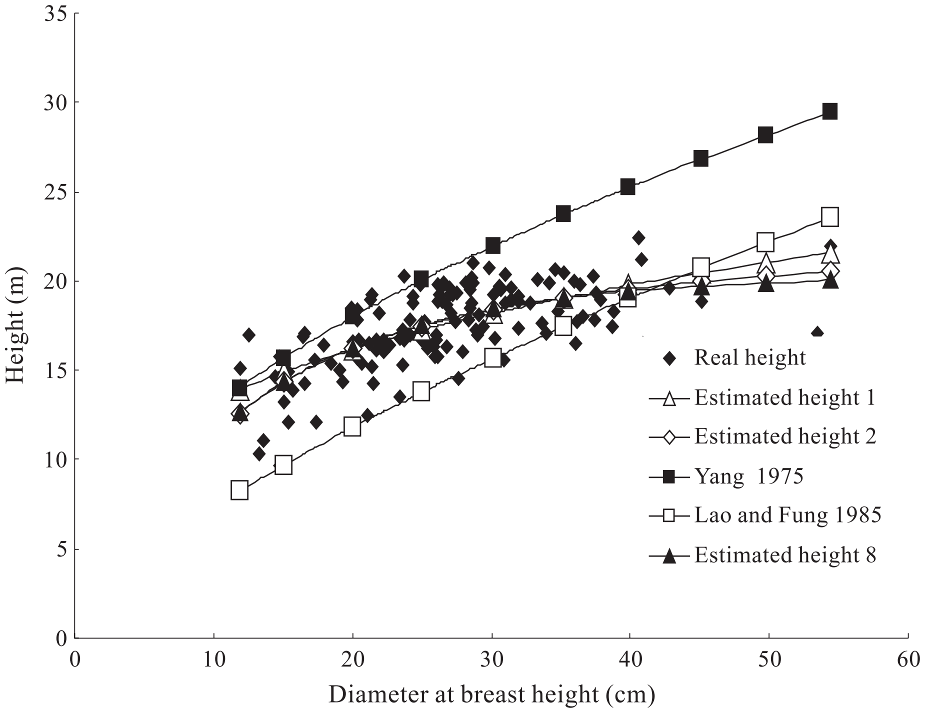

Fig. 1. Height-diameter curve of sugi plantations.

Table 2. Height-diameter model of sugi

Model	Parameter a	Parameter b	Parameter c	MSE	R^2
1. H = exp(a + blnD)	1.9136	0.2902		2.9698	0.991
2. H = exp(a + b/D)	3.1572	-7.4171		2.7802	0.991
3. H = a + bD^c	-1836.9	1837.6		2.8912	0.462
4. H = D/(a + bD)	0.4313	0.0402		2.7882	0.991
5. H = a + bD + cD^2	4.3148	0.7746	-0.00982	2.9843	0.614
6. H = a + blnD	0.5781	5.1963		2.8906	0.464
7. H = aD^b + 1.3	5.8272	0.3127		2.9768	0.989
8. H = a(1-exp(bD)) + 1.3	19.0349	-0.0764		2.7367	0.989
9. H = a(1-exp(bD)^c) + 1.3	18.6527	0.0923	1.2976	2.7575	0.989

MSE, mean square error.

Changes in the tree diameter distribution immediately after thinning operation are shown as Figs. 3 and 4. In general, in the thinning from below, the diameter distribution was notably left-truncated after thinning because trees of a small size or suppressed trees were removed. However, under systematic gap thinning, all overstory trees in the thinning quadrant area were removed regardless of tree size; therefore, no or only a little truncation of the tree diameter distribution after thinning was observed in this study. This finding was valid regardless of the thinning intensity adopted in this study.

Table 3. Characteristics of stand attributes for overstory trees surveyed on a 1-ha basis in the study area

Plot	Density (no. of stems)	DBH (cm)[1)]	Height (m)[1)]	Basal area (m^2 ha^{-1})	Volume (m^3 ha^{-1})
1	893	27.0±7.3	17.48±1.99	54.77	461.45
2	944	27.6±7.5	17.62±1.70	60.63	512.10
3	1055	26.0±6.3	17.37±1.45	58.39	488.86
4	939	27.8±6.9	17.72±1.63	60.57	511.86
5	895	25.2±6.9	17.15±1.85	47.88	400.10
6	1114	26.5±6.6	17.49±1.56	65.32	548.84
7	1285	24.1±6.3	16.98±1.61	62.79	520.77
8	1019	25.6±5.8	17.37±1.41	55.24	461.92
9	1184	24.2±6.4	16.98±1.59	58.32	484.17
10	964	27.5±7.1	17.64±1.57	61.01	514.90
11	1074	24.3±6.3	17.00±1.70	52.92	439.60
12	896	26.3±7.2	17.38±1.66	52.28	439.05

1) Mean±standard deviation.

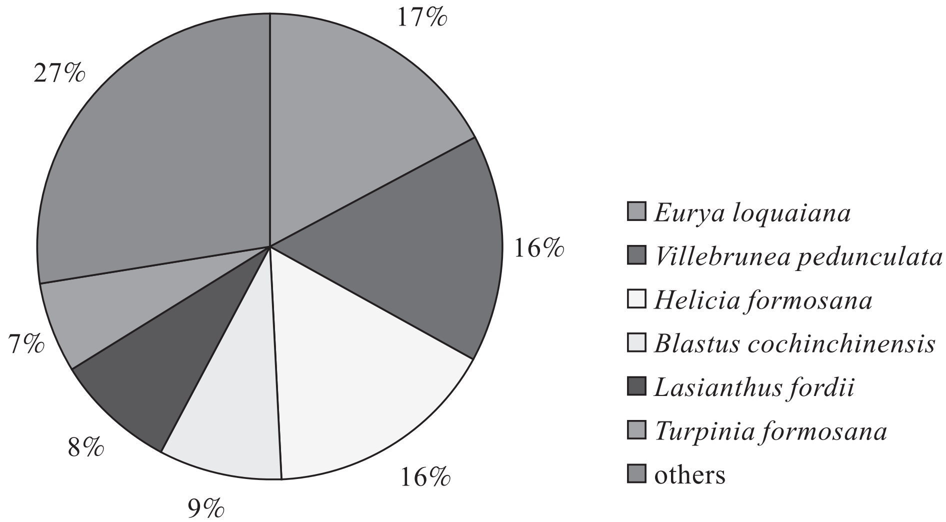

Fig. 2. Composition of species of understory woody plants in the sugi plantation.

The vertical evenness index showed that while little difference was found among plots, the evenness index value was > 0.5 for all plots before thinning. The vertical evenness of the canopy was slightly reduced immediately after thinning. This finding was also valid regardless of the thinning intensity adopted in this study (Fig. 5).

Thinning is a prerequisite activity to tend plantations. This preliminary study showed the baseline stand woody plant composition and structure of a sugi plantation before thinning, and the effect on the stand tree diameter structure immediately after thinning. However, data of more years of monitoring are required to investigate the long-term effects

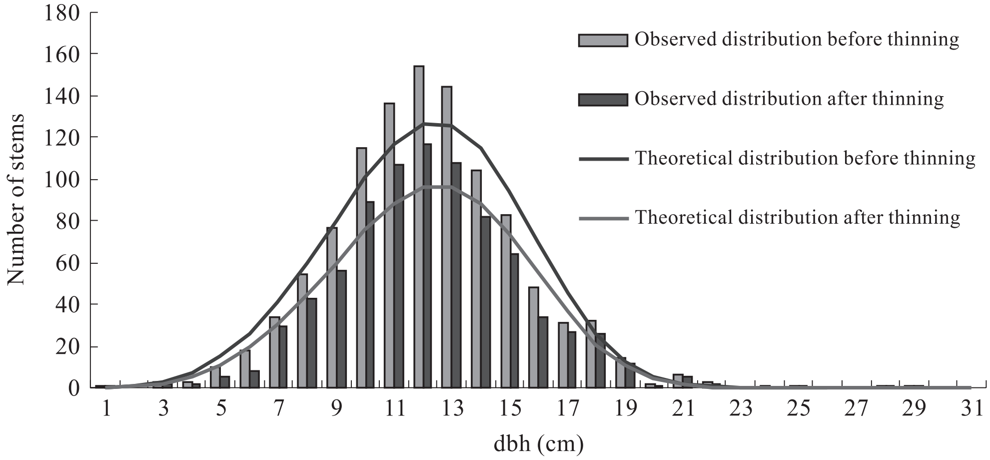

Fig. 3. Diameter at breast height (dbh) distribution for plot 11 with a 25% thinning intensity.

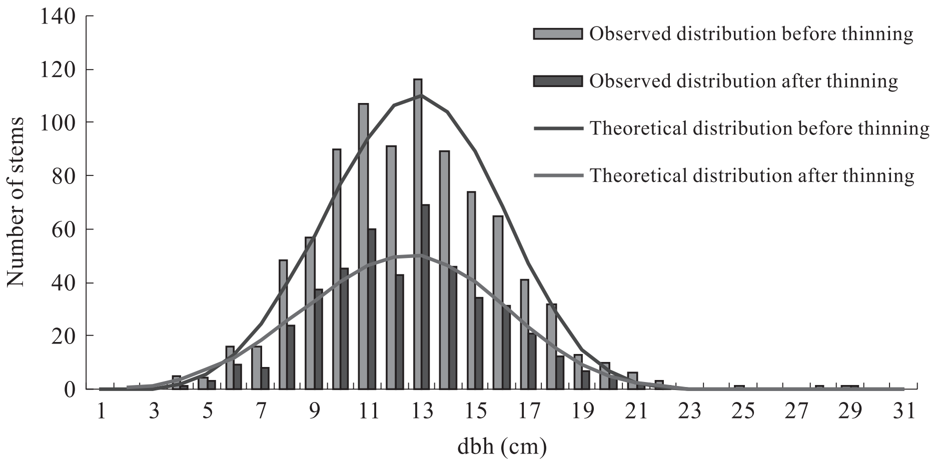

Fig. 4. Diameter at breast height (dbh) distribution for plot 5 with a 50% thinning intensity.

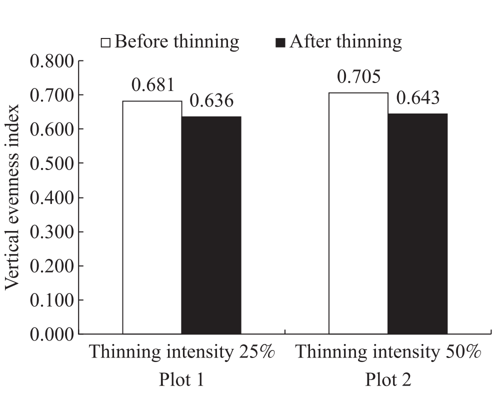

Fig. 5. Vertical evenness index of the canopy before and after thinning.

of thinning on items monitored in this study.

ACKNOWLEDGEMENTS

The authors thank the National Science Council, Taiwan, Republic of China, for financial support of this project (NSC96-2621-Z-054-001). Moreover, assistance with the field survey by colleagues at the Lienwhachi Research Center, Taiwan Forestry Research Institute and students from the Department of Life Science, Tong-hai Univ. are appreciated as well.

LITERATURE CITED

Abbott L, Loneragan O. 1983. Response of jarrah (*Eucalyptua marginata*) regrowth to thinning. Aust For Res 13:217-9.

Chambers CL, McComb WC, Tappeiner JC. 1999. Breeding bird response to three silvicultural treatments in the Oregon Coast Range. Ecol Appl 9:171-85.

Clutter JL, Bennett FA. 1965. Diameter distribution in old-field slash pine plantations. Georgia Forest Research Council Report. no. 13. 9 p.

Della-Binanca L, Dils RE. 1960. Some effects of stand density in a red pine plantation on soil moisture, soil temperature and radial growth. J For 58:373-7.

Donner BL, Running SW. 1986. Water stress response after thinning *Pinus contorta* stands in Montana. For Sci 32:614-25.

Ginn SE, Seiler JR, Cazell, BH, Kreh RE. 1991. Physiological and growth responses of eight-year-old loblolly pine stands to thinning. For Sci 37:1030-40.

Humphrey JW, Newton AC, Peace AJ, Holden E. 2000. The importance of conifer plantations in northern Britain as a habitat for native fungi. Biol Conserv 96:241-52.

Kynch TB, Moser JW Jr. 1986. A generalized framework for projecting forest yield and stand structure using diameter distributions. For Sci 32:697-706.

Latham PA, Zuuring HR, Coble DW. 1998. A method for quantifying vertical forest structure. For Ecol Manage 104:157-70.

Lo SL, Fong FL. 1985. Stand structure and yield of stand-conversed *Cryptomeria* plantation in Taiwan. Bull Exp For National Chung Hsing Univ. 6:73-91.

Morrison ML, Marcot BG, Mannan RW. 1992. Wildlife-habitat relationships. Madison, WI: Univ. of Wisconsin Press. 343 p.

Neumann M, Stalinger F. 2001. The significance of different indices for stand structure and diversity in forest. For Ecol Manage 145:91-106.

O'Hara, KL. 1988. Stand structure and growing space efficiency following thinning in an even-aged Douglas-fir stand. Can J For Res 18:859-66.

Oliver CD, Larson BC. 1996. Forest stand dynamics. New York: Wiley. 520 p.

Pretzsch H. 1997. Analysis and modeling of spatial stand structures, methodological considerations based on mixed beech-larch stands in Lower Saxony. For Ecol Manage 97:232-53.

Sheriff DW. 1996. Responses of carbon gain and growth of *Pinus radiata* stands to thinning and fertilizing. Tree Physiol 16:527-36.

Smith DM. 1986. The practice of silvilculture. New York: Wiley. 527 p.

Spies TA. 1998. Forest structure: a key to the ecosystem. Northwest Sci 72:34-9.

TFB 1995. The third forest resources and land use inventory in Taiwan. Taipei, Taiwan: Taiwan Forestry Bureau (TFB). 258 p.

Waring RH, Schlesinger WH. 1985. Forest ecosystems: concepts and management. Orlando FL: Academic Press. 340 p.

Yang CY. 1975. The studies of growth and yield on sugi plantation in experimental forest of National Taiwan University. Taipei, Taiwan: Experimental Forest of National Taiwan Univ. 136 p.