Research note

Four-Year Monitoring of Thinning Effects on the Microclimate and Ground Vegetation in a Taiwania Plantation in the Liukuei Experimental Forest, Taiwan

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【Summary】

In this paper, we investigated 4-yr performance of the effects of the thinning strategies on the microclimate and ground vegetation development in a *Taiwania cryptomerioides* plantation in the Liukuei Experimental Forest in southern Taiwan. Thinning with 3 residual levels of basal area was carried out in 1999, and three 0.09-ha plots were set up to monitor each treatment.

The results showed that in terms of microclimate, differences in the relative light intensity measured synchronously among treatments were small before thinning. The relative light intensity increased after the thinning operations, with the greatest increase for heavy thinning (17%) followed by medium thinning (13%). Differences among treatments immediately occurred after thinning, but dropped dramatically in the second year and gradually decreased afterwards. As to air temperature, 4 yr after thinning, differences between the open area and forest stands were highly significant during the daytime, but no significant difference was detected among treatments for the entire day. At the same time, a very significant difference existed in relative humidity between the open space and forest stands for the entire day, but no significant difference was found during the night among treatments. Finally, the ground vegetation surveys indicated an increase in the absolute coverage rate 4 yr after thinning for all treatments and a higher absolute coverage rate in the thinned plots. Moreover, the relative coverage rate showed the concentration on a few dominant species. Because the relative percentages of the first 3 dominant species in all thinned plots had increased 4 yr after thinning, this caused a decrease in Shannon's diversity index value.

Key words: microclimate, relative humidity, ground vegetation, coverage rate.

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研究簡報

六龜試驗林台灣杉人工林疏伐四年後對微環境和地被植群影響之分析

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摘　要

本研究探討不同疏伐策略對六龜試驗林台灣杉人工林疏伐四年後對立地微環境、林木生長、林分結構和地被植物之影響。調查結果顯示疏伐處理前各處理區間之光度日變化差異較小，但疏伐處理後強度疏伐區相對光度增加最多成為17%，其次為中度疏伐區之13%，但此等提升之能量卻在疏伐第二年後便快速減少，對照區因未處理，其相對光度逐年呈緩慢減弱；疏伐處理前後，林內與林外在全天大氣溫度之變化有顯著之差異，但林內全天大氣溫度之變化在各處理間均差異不顯著；相對濕度亦呈相同之現象。此外，地被植物顯示，由於疏伐區之疏伐作業會產生使前三種優勢種更呈優勢之現象，導致疏伐4年後各疏伐區之Shannon氏指數均較未疏伐前為低，顯示疏伐作業會降低地被中草本植物之歧異度。

關鍵詞：微環境、相對濕度、地被植物、覆蓋度。

汪大雄、湯適謙、劉景國。2008。六龜試驗林台灣杉人工林疏伐四年後對微環境和地被植群影響之分析。台灣林業科學23(2):191-8。

Thinning is one of the major silvicultural tools applied to improve the condition of plantations. The most common management objective of commercial thinning is to maintain stand growth increments similar to those the stand would have achieved in an unthinned state, but concentrating wood production onto larger stems, and producing higher-quality sawlogs (Smith 1986). Besides the benefits to timber, nontimber benefit issues have attracted greater public attention recently, such as biodiversity, environmental, recreational, and microclimate aspects of forest sites, as well as carbon sequestration, and habits for wildlife and fungi in relation to thinning practices (Sheriff 1996, Chambers et al. 1999, Humphrey et al. 2000).

In addition to the effects on timber growth, thinning is known to affect the moisture (Della-Bianca and Dils 1960, Donner and Running 1986), foliar nutrients (Ginn et al. 1991), and light availability to residual trees as well as air temperature within a stand and on the forest floor (Della-Bianca and Dils 1960).

Taiwania (*Taiwania cryptomerioides*) is the major species in plantations at the Liukuei Experimental Forest. An inventory showed that by the end of 1991, approximately 51.6% of the plantation area was covered by Taiwania; therefore, its tending practice is of great importance (TFRI 1992). The purpose of this study, consequently, was to investigate the influence of alternative thinning strategies on the microclimate and ground vegetation in a Taiwania plantation 4 yr following commercial thinning in the Liukuei Experimental Forest.

This study was conducted in an even-aged Taiwania plantation in compartment no.

3 of the Liukuei Experimental Forest, Taiwan Forestry Research Institute. The plantation spaced 2×2 m was established in 1972 with an area of 78 ha at elevations ranging 1500~1700 m. The mean annual precipitation is 3800 mm, being concentrated in the period from May to September. The mean annual temperature is 17.5℃. In this plantation, a thinning practice from below with 3 residual levels of basal area (i.e., 40, 50, and 80 m^2 ha^{-1} for the control) was carried out in 1999. The area for each treatment was 3~5 ha. In each treatment, 3 square monitoring plots with an area of 0.09 ha each were set up at random. In the plot, factors associated with microclimate (light, temperature, and moisture) and ground vegetation coverage were measured immediately before and after the thinning practice.

In this study, microclimate refers to light, air temperature, and relative humidity. The measurement of light intensity included the intensity at midday (10:00~14:00) and the intensity for the entire day (0:00~24:00). In the midday survey, 9 gauge points evenly distributed in an area of 10×10 m^2 were set up in each plot. At each point, a pole, 1.3 m in height, served as a platform to hold a LI-190SA quantum sensor to collect light intensity data with a LI-250 light meter (LI-COR, USA). The light intensity data were collected twice annually for 2~3 consecutive days each in March and September. During the measurement period, the survey crews were divided into 3 groups to measure the relative light intensity (i.e., the proportion of solar radiation reaching a given location, relative to a location with no obstructions) synchronously in each plot for each treatment. Meanwhile, the light intensity in an open space outside the plantation was measured at the same time as well. On the measurement days, we measured the relative light intensity twice at each point. The first measurement was obtained by averaging data collected for 15 s, and then, we waited 1 min to repeat the same process to get the second measurement. The mean value of the 2 measurements for 9 gauge points was recorded for comparisons of relative light intensities caused by alternate thinning practice. For the entire day survey, a weather shelter was set up for each treatment and open space. A LI-1000 data logger connected to a LI-190SA quantum sensor at 1.3 m above the ground was installed inside the shelter. Each year, every day in 1-week sampling period in September, the recording cycle on the data logger was set to 30 min, and an average interval of 5 s was computed as a record. A threshold of 0 was set to avoid data collected at night.

For the light intensity surveyed on an entire-day basis, the average of light intensity observed at a given time during the survey period was calculated. Figure 1 displays the diurnal changes in light intensity over 24 h during the survey period before thinning (1999) and for 4 yr after thinning (2000~2003). It can be seen that the light intensity in the open space was much higher than that within the stand regardless of the thinning practice. Differences in light intensity among treatments were small before thinning. However, differences rapidly increased after thinning, then gradually dropped in 2001 but dramatically dropped in 2002. A similar pattern in the difference of the relative light intensity measured synchronously is also shown in Table 1. It reveals that the relative light intensity of the thinned plots was immediately rapidly amplified after thinning with the most notable magnitude in the heavily thinned area (reaching 17%), followed by the medium thinning area (reaching 13%). However, the increment of relative light intensity began to drop 2 yr after thinning. A two-way ANOVA test

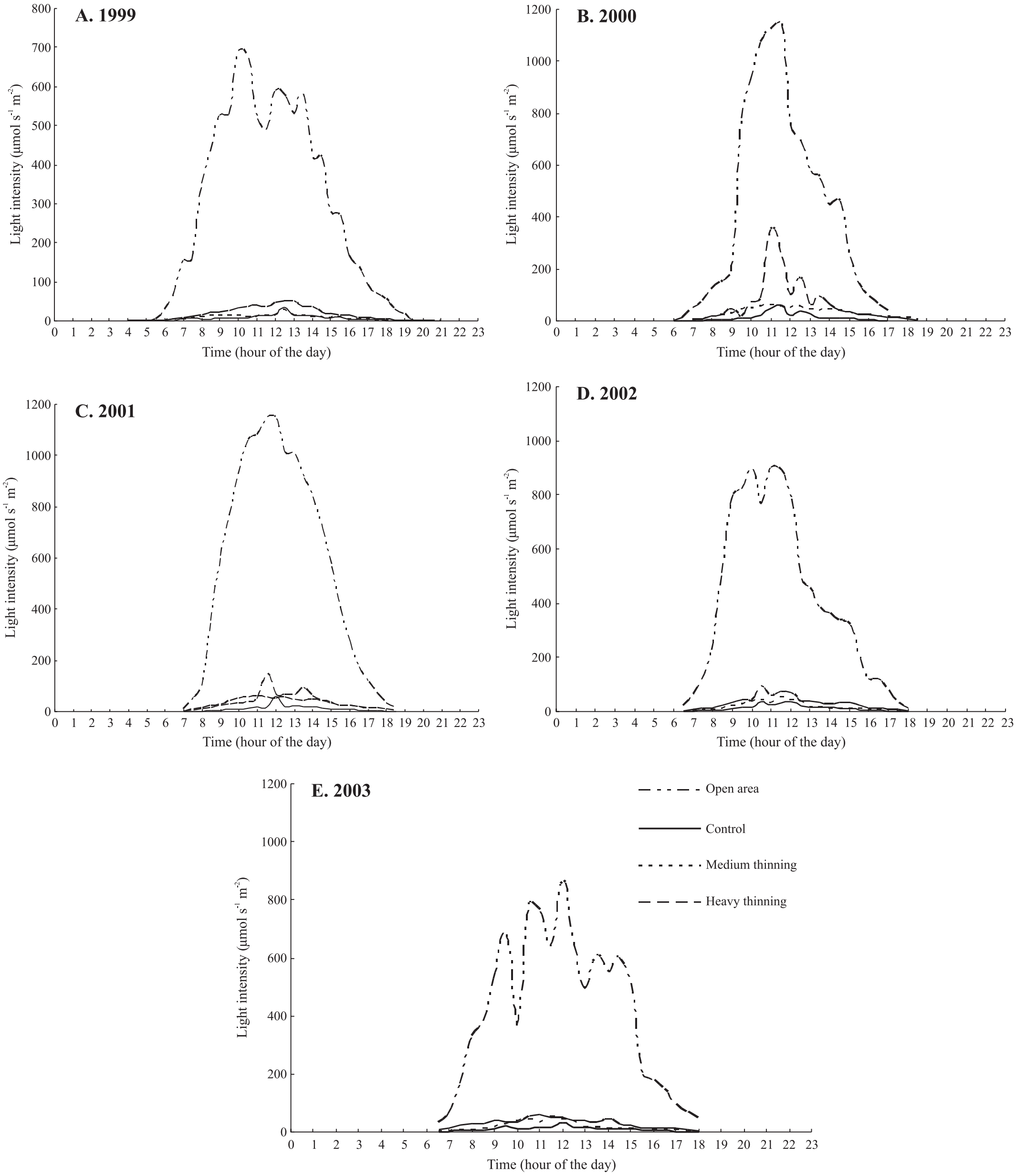

Fig. 1. Mean diurnal changes in light intensity during the survey period for alternative thinning regimes before thinning (A) and the years after thinning (B~E).

showed that significant differences existed among treatments (p = 0.015) and times (p = 0.048). Nevertheless, the significance of the difference among treatments became trivial 2 yr after thinning.

A weather shelter was set up to measure the air temperature and relative humidity for each treatment and open space. During the survey period, a Hobo H8 temperature and relative humidity sensor (Onset Computer Corp, USA) was installed inside the shelter at 1.3 m above the ground. The recording cycle

Table 1. Relative light intensity (%±standard deviation) on plots measured at midday with alternative treatments before thinning in 1999 and after thinning in 2000~2003 on Taiwania plantations (The value is the average of 2 measurements made in March and September of each year)

Year	Control	Medium thinning	Heavy thinning
1999	2.03±0.43	3.29±0.82	4.74±1.42
2000	1.96±0.78	13.00±2.63	17.00±3.06
2001	1.88±0.32	6.61±1.40	7.22±1.47
2002	1.63±0.26	4.65±1.08	5.64±1.11
2003	1.56±0.23	4.52±1.03	5.37±1.05

on the data logger was set to 30 min with a period of 24 h each day for 7 d in September.

Diurnal variations in air temperature within 24 h were measured in 1999 and 2003, and results are given in Fig. 2. During the period from 8:00 to 15:00, the air temperature in the open area was always higher than that within a stand regardless of the thinning operation in both 1999 and 2003. Compared to the control area, temperatures in the thinned plots not only rose at a higher rate in the morning but also declined at a higher rate in the afternoon (Fig. 2). This finding implies that the diurnal pattern of change in air temperature in the stands was affected by the thinning practice. Duncan's multiple-range test showed that in 2003, except for the period from 18:00 to 6:00, there was a very significant difference in average air temperature (α = 0.01) between the open space and the forest stands. No significant difference existed between thinned and unthinned stands for the entire day or in the period from 6:00 to 18:00 pm, 18:00 to 6:00. However, a significant difference was found between the heavily thinned stands and the other 2 thinning levels from 10:00 to 14:00 (Table 2).

From 8:00 to 15:00, a significant distinction in RH occurred between the open space and within the stands prior to the thinning exercise. The difference was still substantial after the thinning activity (Fig. 3). Duncan's multiple-range test showed that within stands no significant difference existed among treatments in 2003 except for the period from 6:00 to 18:00 (Table 3).

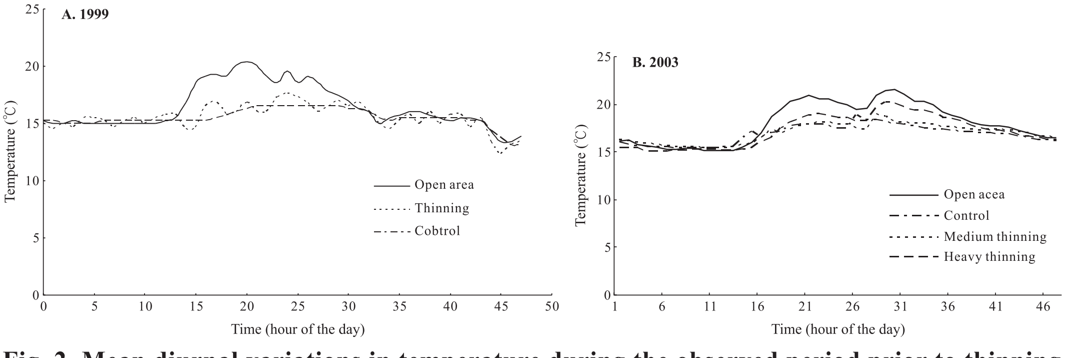

Fig. 2. Mean diurnal variations in temperature during the observed period prior to thinning in September 1999 (A) and 4 yr after thinning in September 2003 (B).

Table 2. Duncan's multiple-range test on air temperature (℃ ± standard deviation) on plots with alternative thinning regimes in 2003

Period	Open space	Control	Medium thinning	Heavy thinning
Entire day	$17.95^{a1)} \pm 2.15$	$16.81^{b} \pm 1.00$	$16.95^{b} \pm 0.99$	$17.17^{b} \pm 1.64$
06:00~18:00	$19.44^{a} \pm 1.79$	$17.52^{b} \pm 0.70$	$17.54^{b} \pm 0.85$	$18.22^{b} \pm 1.45$
18:00~06:00	$16.36^{a} \pm 1.04$	$16.06^{a} \pm 0.65$	$16.34^{a} \pm 0.76$	$16.08^{a} \pm 0.90$
10:00~14:00	$20.42^{a} \pm 0.67$	$18.03^{b} \pm 0.44$	$18.03^{b} \pm 0.50$	$18.92^{c} \pm 0.63$

1) Values in a row with the same lowercase letter do not significantly differ at the 1% significance level.

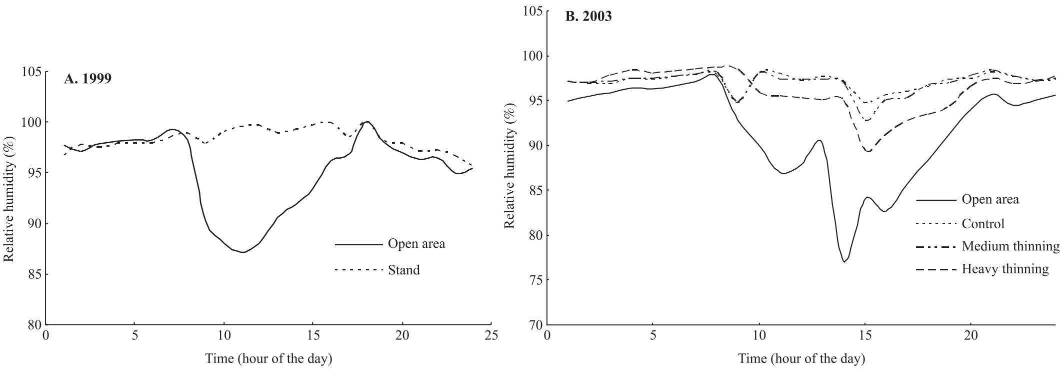

Fig. 3. Mean diurnal variations in relative humidity during the observed period prior to thinning in September 1999 (A) and 4 yr after thinning in September 2003 (B).

Table 3. Duncan's multiple-range test on relative humidity (% ± standard deviation) on plots with alternative thinning regimes in 2003

Period	Open space	Control	Medium thinning	Heavy thinning
Entire day	$92.00^{a1)} \pm 4.74$	$97.06^{b} \pm 1.18$	$96.90^{b} \pm 1.54$	$95.91^{b} \pm 2.60$
06:00~18:00	$89.93^{a} \pm 5.07$	$96.77^{b} \pm 1.53$	$96.42^{b} \pm 1.83$	$94.56^{c} \pm 3.01$
18:00~06:00	$95.24^{a} \pm 1.05$	$97.38^{b} \pm 0.48$	$97.43^{b} \pm 1.04$	$97.31^{b} \pm 0.72$
10:00~14:00	$86.53^{a} \pm 4.08$	$96.47^{b} \pm 0.34$	$95.75^{b} \pm 2.30$	$93.67^{b} \pm 2.43$

1) Values in a row with the same lowercase letter do not significantly differ at the 1% significance level.

The ground vegetation surveys were conducted using the cross-line method. A 30-m line transect across a plot was set up horizontally to record species and their coverage lengths along the line. Absolute and relative ground vegetation coverage rates were calculated based on equations 1 and 2, respectively:

Absolute coverage = Σ (the distance of the ith species / cross-line distance) × 100 (1)

Relative coverage = Σ (the absolute coverage of the ith species / the total absolute coverage) × 100 (2)

In addition, Shannon diversity index was calculated as well (Magurran 1988):

Shannon diversity index $H = -\Sigma (n_i / N) \log (n_i / N)$ (3)

where n_i is the number of observations of species i, and N is the total number of observations.

Herbaceous plants were the principal component of the ground vegetation considered in this study. While the biomass of herbaceous cover is typically low relative to the total forest biomass, the energy and nutrients in the herbaceous stratum may determine the success or failure of the regeneration of dominant tree species, therefore, examining populations in the herbaceous layer is key to understanding the regeneration process of all species (Bormann and Liken 1979, Maguire and Forman 1983).

The ground vegetation survey showed that before thinning, control plots exhibited little vegetation coverage because of the absence of precommercial thinning in 1991. For plots in the treatment area, the ground vegetation had greater coverage due to the previous precommercial thinning practice (Wang et al. 2003).

Table 4 shows the differences in ground vegetation coverage and diversity indices among the alternative thinning regimes. There was an increase in the absolute ground vegetation coverage rates over time for all plots. Among treatments, the absolute coverage in thinned plots was higher than that in control plots. This can be explained by the increase in light intensity caused by the thinning operation. Moreover, the high values of the relative coverage rates for the first 3 dominant species showed the concentration by a few dominant species for all treatments both before and after thinning. The increased values of the relative coverage rates over time in the thinned plots imply the promotion of dominance caused by thinning manipulation.

From a biodiversity point of view, before the thinning operation, similar values of the diversity index measured by the Shannon index in the control and treatment areas indicated a homogenous diversity of species and evenness in all plots (Wang et al. 2003). However, as the dominance of the first 3 dominant species before thinning for all thinned plots increased 4 yr after thinning, the thinning

Table 4. Ground vegetation characteristics among alternative thinning regimes

Treatment	Year	1999	2000	2001	2002	2003
Control	Absolute coverage (%)	22.28	39.18	39.71	43.02	45.56
	Relative coverage (%)[1)]	83.88	65.72	67.45	70.03	72.78
	Shannon diversity index	0.59	0.75	0.77	0.73	0.71
Medium thinning	Absolute coverage (%)	66.22	88.26	90.56	94.08	96.07
	Relative coverage (%)[1)]	85.74	79.55	82.03	83.45	89.10
	Shannon diversity index	0.48	0.62	0.61	0.57	0.43
Heavy thinning	Absolute coverage (%)	58.79	79.25	79.78	79.02	80.84
	Relative coverage (%)[1)]	79.66	80.84	78.07	82.05	84.34
	Shannon diversity index	0.69	0.69	0.68	0.65	0.62

[1)] The relative percentage covered by the first 3 dominant species. The first 3 dominant species for the control were *Elatostema lineolatum* Wight var. *majus* Wedd., *Arachniodes pseudo-aristata* (Tagawa) Ohwi, and *Lasianthus microphyllus* Elmer. The first 3 dominant species for medium thinning were *Elatostema lineolatum* Wight var. *majus* Wedd., *Diplazium dilatata* Bl, and *Carex baccans* Nees. The first 3 dominant species for heavy thinning were *Elatostema lineolatum* Wight var. *majus* Wedd., *Diplazium dilatata* Bl., and *Smilax china* Linn.

operation actually reduced Shannon diversity index values in the thinned areas. In other words, this study showed that the biodiversity of herbaceous plants among the ground vegetations was reduced 4 yr after the thinning operation.

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LITERATURE CITED

Bormann FH, Liken GE. 1979. Pattern and process in a forested ecosystem. New York: Springer-Verlag. 253 p.

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

Della-Bianca 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(4):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.

Maguire DA, Forman RT. 1983. Herb cover effects on tree seedling patterns in a mature hemlock-hardwood forest. Ecology 64(6):1367-80.

Magurran AE. 1988. Ecological diversity and its measurement. New Jersey: Princeton University Press. 179 p.

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.

TFRI 1992. Forest management plan on Liu-Kuei Experimental Forests. Taipei, Taiwan: Taiwan Forestry Research Institute (TFRI). 80 p.

Wang DH, Chiu CM, Hsieh HC, Tang SL, Tang SC, Liu CK. 2003. Investigation on stand structure and microsite condition on Taiwania plantation prior to the secondary thinning practices in Liu-kuei Experimental Forest. Q J Chin For 36(1):1-16. [in Chinese with English summary].