Jour. Korean For. Soc. Vol. 96, No. 2, pp. 151~159 (2007)

JOURNAL OF KOREAN
FOREST SOCIETY

The Effects of Silvopastoral Practice on Changes of Understory Vegetation in a Japanese Larch (*Larix kaempferi*) Plantation

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Abstract : This study was conducted to investigate the effects of thinning on changes in stand characteristics and understory vegetation in a silvopasture practiced Japanese larch plantation in the Research Forest of Kangwon National University, Korea. Three different thinning intensities (64%, 35%, and control) were applied. Before and after thinning, the understory plant species increased its number from 48 (7 tree species, 7 shrubs species, 28 herbaceous species, and 6 woody climbers) to 100 (11 tree species, 15 shrub species, 67 herbaceous species, and 7 woody climbers). Thinning made plants invade easily on the forest floor, and plot A (325 stems/ha) had much higher number of undersory species than those of plot B (575 stems/ha) and control plot (1,150 stems/ha). In three years after thinning, understory aboveground biomass (kg/ha) of herbs were 523 for control, 1,230 for plot B, and 1,288 for plot A. The canopy coverage had remarkable influence on the understory biomass production, resulting in relatively small amount of herbage production on control plot. The differences were statistically significant between thinned plots and unthinned plot, but there were no significant differences among the thinned plots ($p<0.05$).

Key words : *agroforestry,* Larix kaempferi, *silvopastoral system, stand characteristics, thinning, undersotry biomass, understory vegetation*

Introduction

One of the major species planted in degraded forest areas in the 1960s and 1970s was *L. kaempferi* (LAMB.) CARR. (Japanese larch) to rehabilitate deforested areas by the Korean Government. This species was introduced from Japan early 1900s and has been extensively planted throughout the region because they have rapid early growth rates (Kim *et al.*, 1995). Korean white pine and Japanese larch were planted, mostly in the central parts of the country during the period. However, these species were planted on a large scale without careful consideration of site characteristics. This led to widespread failure of its plantations and little economic value from the forest (Lee *et al.*, 2004).

Total plantation area of *L. kaempferi* was 636,410 hectare, which was 35.1% of total plantation area (1,810,761 hectare) in South Korea. In case of Gangwon Province, it was 127,745 hectare of total plantation area (220,696 hectare) and the ratio was approximately 20.1% (Korea Forest Service, 2005).

Thinning is commonly applied at an age of 15~20 years for this species (Son *et al.*, 2004). Thinning increases stem diameters (Harrington and Reukema, 1983; MacLean and Morgan, 1983; Ker, 1987; McCormack and Lemin, 1998; Brissette and Frank, 1999; Brissette *et al.*, 1999; Pothier, 2002; Sullivan *et al.*, 2002), and crown size (McCormark and Lemin, 1988; Brissette and Frank, 1999; Brissette *et al.*, 1999; Lindgren and Sullivan, 2001; Sullivan *et al.*, 2001), but decreases mortality of crop trees (Ker, 1987; Brissette and Frank, 1999; Brissette *et al.*, 1999). The purpose of thinning is to increase growth on high-value trees and there are some reports on the effects of thinning on environmental conditions related to tree growth (Son *et al*, 1999, 2004a, 2004b).

In the Research Forest of Kangwon National University, the current silvicultural practice consists of tending in young stands and from one to three successive commercial thinnings from below using the thinning guidelines, for several decades. Intensified silvicultural treatments are still required in order to increase timber quality. On the other hand, well-timed silvicultural treatments are probably the most desirable issue in young stands. The main reason for delayed thinning is the low profitability of first thinning owing to small stem size, low timber

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yield per hectare and high thinning cost (Kangwon National University, 1999).

In general, agroforestry practices can be classified into five systems; alley cropping, silvopasture (silvopastoral systems), windbreaks, riparian buffer strips, and forest farming (Merwin, 1997). Silvopasture is an agroforestry practice that intentionally intergrates trees, forage crops, and livestock into a structural practices of planned interactions (Garrett *et al.*, 2004), important types of agroforestry to be applied in Korea (Kang *et al.*, 2002).

Fujimori (2003) suggested that Sustainable Forest Management (SFM) must consider other land uses, including agroforestry, and changes in land use to or from forested land. One of the challenges facing the forestry profession today is how to encourage landowners to invest in management when financial returns are futuristic at best.

There are numerous studies investigated production and growth for this species (Yim *et al.*, 1981ab; Yim *et al.*, 1982, Son *et al.*, 2004). However, Korean forestry has seldom practiced so called agroforestry in a *L. kaempferi* stand. Therefore the potentiality of that is expected to be very high. With this point of view, the objectives of this study were 1) to examine changes in stand characteristics such as, DBH, height, basal area, and volume by thinning intensity levels in silvopasture practiced a *L. kaempferi* plantation, and 2) to investigate changes in species composition and biomass of understory vegetation after thinning.

Material and Methods

1. Study area

The study was conducted in the Research Forest of Kangwon National University (KNU), located extending Chuncheon city and Hongchon county, Gangwon Province, Korea (37° 47'N, 127° 50'E) (Figure 1).

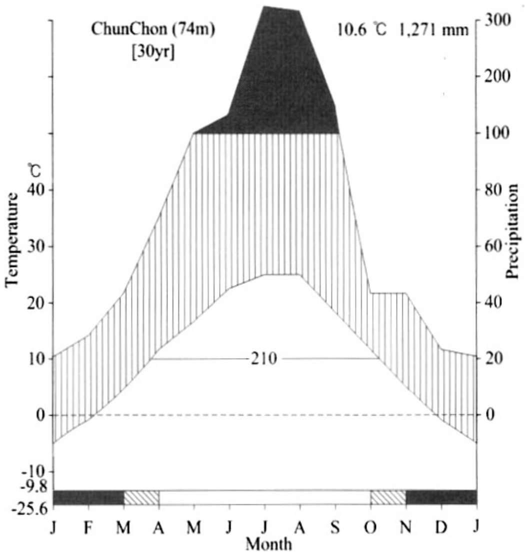

Figure 2. Climate diagram of the study area.

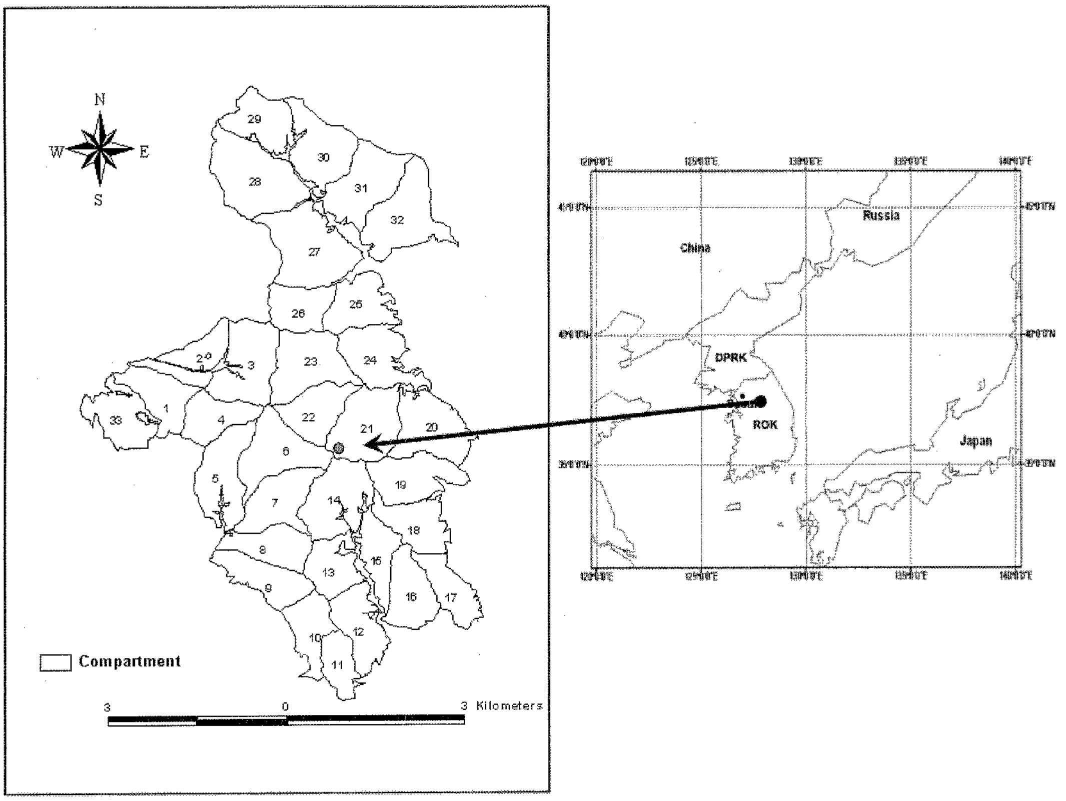

Figure 1. The location map of the study area.

Table 1. Site conditions of the study area.

	Plot A (325 stems/ha)	Plot B (575 stems/ha)	Control (1,150 stems/ha)
Aspect	SW	SW	SW
Slope gradient (°)	15	24	19
Altitude (m)	690~700	700~710	710~720
Area (ha)	0.08	0.08	0.04

The mean annual air temperature is 10.6°C. Mean annual precipitation is 1,271mm and approximately 71.1% of that falls during the summer season (June to September) (Korea Meteorological Administration, 2002) (Figure 2). The aspect, slope, altitude of study plots were contributed on the southwest direction, 15~24°, and 690~720m of the sea level, respectively (Table 1).

2. Material sampling, thinning, and forage sowing

Two 0.08ha (40 m×20 m) permanent plots were delineated in the plantation and randomly assigned both a heavy and light thinning level. In the winter of 2002, heavy thinning from below reduced stand density to 325 stems per hectare (plot A), and light thinning from below reduced density to 575 stems per hectare (plot B) (Table 2). Thus, heavy thinning removed 64% (29.7 cm^2 →10.7 cm^2) of the basal area (BA), whereas light thinning removed 35% (29.7 cm^2→19.2 cm^2) of the BA (Table 2). One 0.04ha (20 m×20 m) control plot was selected to compare the changes in stand characteristics after thinning treatment and was not thinned and left untreated (the control plot).

Selected a variety of cool-season grasses and legumes to establish silvopastoral field in May 2003, we sowed a mixed cool season forage such as Orchardgrass (*Dactylis glomerata* L.) which is known as shade tolerant species (Burton, 1973; Lewis *et al*., 1983), Timothy (*Phleum pratense* L.), Perennial ryegrass (*Lolium perenne* L.), Tall fescue (*Festuca arundinacea* L.), Kentucky blue grass (*Poa pratensis* L.), and Ladino clover (*Trifolium repens* L.) with 9, 3.6, 7.2, 7.2, 3.6, and 5.4 kg/ha, respectively.

3. Data collection and analyses

The field study was conducted at a 25-year-old Japanese larch plantation established in the Research Forest of KNU. During summer season from 2002 to 2005, vegetation investigations such species variation were conducted in each plot. All trees (≥6 cm DBH) in the plots were tagged and measured before and after thinning treatment for height and DBH. Before thinning measurement of trees, the measurement was conducted in the spring of 2002, the summer of 2004, 2005 for diameter, and height were measured after thinning. The volumes of individual trees present in the last measurements were examined together with the volumes of trees removed in the thinning (KFS, 2001). To investigate of understory species invaded from adjacent stands, the method of Braun-Blanque (1964) was used and the life form of undersotry species was classified by Raunkiaer (1934).

At four sample points of each plot, the changes in relative light intensity were measured from 2002 to 2005 in summer season. Twelve points with 10 m spacing were laid out systematically across the center of study plot, identified by permanent PVC stakes for measurement of relative light intensity. Direct measurements of transmitted light intensity were made at each permanent point using a digital illumination meter (Lux foo-candle, Taiwan), while the full light was measured in an adjacent open area. The ceptometer was measured at 30 seconds intervals for 5 minute at each point and measurements were made under clear sky conditions from 11 a.m to 2 p.m (Stohlgren *et al*., 1998).

Including forage, biomass of understory vascular plants (i.e., shrubs, herbs, seedlings and saplings) was measured by cutting fifteen randomly located 1 m×1 m quadrats within each sown plot in the course of the growing season in the years from 2004 to 2005. The sampling dates were selected according to growing period through the year. All forage and natural herbaceous plants within the 1.0 m^2 area were cut out to measure an average weight. All herbage samples were weighed in laboratory and dried at 70°C for 64 hour by

Table 2. Stand characteristics of the *L. kaempferi* plantation.

	Before thinning (2002)	After thinning					
		Year 1 (2003)			Year 3 (2005)		
		Plot A	Plot B	Control	Plot A	Plot B	Control
Density (stems/ha)*	1,019	325	575	1,150	325	575	1,100
Average DBH (cm)	18.9	20.1	20.0	18.5	24.6	22.0	19.6
Average Height (m)	17.4	18.9	17.0	17.1	21.0	19.1	18.8
Basal Area (m^2/ha)	29.7	10.7	19.2	32.5	15.7	19.4	35.1
Volume (m^2/ha)	248.9	96.3	158.4	270.1	150.6	174.2	320.1

*The plantation was originally established on about a 1.8 m×1.8 m spacing, 3,000 stems ha^{-1}.

the drier (LABTECH), and re-weighed after oven-drying for determination of dry matter yield/ha and biomass (Zoi *et al.*, 1995).

The differences in biomass of understory vegetation among thinning treatments were determined by analysis of variance (ANOVA). Duncan's multiple range test was used for multiple comparisons (SAS 9.1).

Results and Discussion

1. Stand characteristics

Average DBH, height, BA, and volume before thinning were 18.9 cm, 17.4 m, 29.7 m^2, and 248.9 m^2 per hectare, respectively. In 2003, the first year after thinning, stand density, BA, and volume of thinned plots were sharply decreased, while average DBH and height were increased. Immediately after thinning treatment, the basal area was reduced from 29.7 to 10.7 and 19.2 m^2 per hectare in the plot A and B treatments, respectively, which corresponds to an exploitation of 64 and 35% of the initial basal area.

The average diameter increment of thinned plots clearly increased compared to the unthinned plot. In the third year after thinning, tree diameter was recorded 5.0 cm more in plot A and 2.4 cm more in plot B than that of control plot (Table 2). This results agree with other thinning studies, where trees generally grew the largest in the most heavily thinned treatments (Johnstone, 1981; Leak and Solomon, 1997; Smith *et al.*, 1997; Medhurst *et al.*, 2001; Suzanne *et al.*, 2004).

2. Changes in understory vegetation

The total number of plant species found in this study prior to thinning treatments were 48: 7 tree species, 7 shrub species, 28 herbaceous species, and 6 woody climbers species. However, significant changes of the number of species occurred after thinning treatments. Immediately after the thinning, September of 2004, the total number of plant species increased up to 100 species: 11 tree species, 15 shrub species, 67 herbaceous species, and 7 woody climbers species (Table 3 and 4). This is a little different from the result of Son *et al* (2004) that a total of 82 species including 10 trees, 29 shrub species, and 43 herb species on the ground in a Japanese larch plantation after thinning treatments.

The proportion of life form spectrum in plot A after thinning was Geophyte (22.7%)-Hemicryptophytes (17.3%) -Nanophanerophytes (16.0%)-Megaphanerophytes, Therophytes (13.3%)-Microphanerophytes, Chamaephytes (8.0%) -Hydatophytes (1.4%) (Table 6). In comparison of life form spectra between plot A and control after thinning, the ratio of He (*Astilbe rubura* Hook. f. & Thomson var. *rubura*., *Cirsium japonicum* var. *maackii* (Maxim.) Matsum, and *Viola rossii* $\mathrm{H_{EMSL}}$. and so on), Th (*Impatiens textori* var. *textori*, *Persicaria nepalensis* (Meisn.) H. Gross and *Persicaria perfoliata* H. $\mathrm{G_{ROSS}}$ and so on), and

Table 3. Changes in the number of understory species by thinning treatments.

	Before thinning (Sep. 2002)	After thinning & forage sowing					
		Plot A(325 stems/ha)		Plot B (575 stems/ha)		Control (1,150 stems/ha)	
		Sep. 2004	Aug. 2005	Sep. 2004	Aug. 2005	Sep. 2004	Aug. 2005
Trees	7	10	10	8	11	8	11
Shrubs	7	9	12	13	15	8	9
Herbs	28	48	50	45	38	25	22
Woody climbers	6	5	3	3	3	4	1
Total	48	72	75	69	67	45	43

Table 4. Life form spectra of understory plant species recorded before and after thinning treatment in study site.

Treatment			Life form[1]								Total
			Me	Mi	Na	Ch	He	Ge	Th	Hy	
Before thinning (Sep. 2002)		No. of species	8	5	6	6	8	9	6	0	48
		ratio (%)	16.7	10.4	12.5	12.5	16.7	18.7	12.5	0	100
After thinning	Plot A (325 stems/ha)	No. of species	10	6	12	6	13	17	10	1	75
		ratio (%)	13.3	8.0	16.0	8.0	17.3	22.7	13.3	1.4	100
	Plot B (575 stems/ha)	No. of species	12	6	12	6	11	13	7	0	67
		ratio (%)	17.9	8.9	17.9	8.9	16.4	19.5	10.5	0	100
	Control (1,150 stems/ha)	No. of species	10	6	7	4	5	10	1	0	43
		ratio (%)	23.3	13.9	16.3	9.3	11.6	23.3	2.3	0	100

[1] Me(Megaphanerophytes) Mi(Microphanerophytes), Na(Nanophanerophytes), Ch(Chamaephyte), He(Hemicryptophyte), Ge(Geophyte), Th (Therophyte), Hy (Hydatophytes).

Hy (*Commelina communis* L.) were increased, while those of Me (*Cornus controversa* $\mathrm{H_{EMSL}}$., *Kalopanax septemlobus* (Thunb. ex Murray) Koidz., and *Pinus koraiensis* S. et Z. and so on), Mi (*Actinidia polygama* $\mathrm{M_{AX}}$, *Aralia cordata* var. *conunentalis* (Kitag.) Y.C.Chu, and *Zanthoxylum schinifolium* S. et Z. and so on), and Ch (*Oxalis corniculata* L., *Potentilla freyniana* $\mathrm{B_{ORNM}}$, *Trifolium repens* L. and so on) were decreased as residual stand density was increased (Table 4).

The total number of plant species was somewhat reduced to 93 in the third year after thinning: 16 tree species, 15 shrub species, 58 herbaceous species, and 4 woody climbers species (Table 3 and 4). The total number of woody climber decreased while the total number of trees, shrubs, herbs increased than those of before thinning. This is in accordance with the result of Son *et al* (2004) that the number of herbs significantly increased in a Japanese larch plantation 4 years after thinning treatment. Therefore, light availability was the dominant factor affecting herbaceous responses in a thinning study (Harrigton and Edwards, 1999) (Figure 3).

Changes in relative light intensity by thinning treatment are shown in Figure 3. The relative light intensity was highest in May of 2005 with 54.7% in plot A, 32.8% in plot B, and 13.3% in control plot and light transmission through the tree canopy of plot A was 32.5 ~54.7% of an adjacent open area, 29.5~32.8% in plot B plot, and 8.4~13.3% in control plot (Figure 3).

The transmittance increased as basal area was reduced. The relationship between transmittance and proportion of basal area removed could be used as guidance for managers wishing to manipulate the light environment beneath a closed-canopy several stand types, for example to encourage natural regeneration and agroforestry practices.

Results suggest that thinning has accelerated the rate of understory cover by greatly increasing the number of understory species. Plot A had much higher number of understory species than those of plot B and control (Table 3). The results of this study is also in accordance with the results of others studies (Bakker, 1989; Kull and Zobel, 1991) that the practices of both cutting and removing vegetation often lead to increased plant establishment and diversity.

3. Biomass of undersory vegetation

It is well-known that the biomass of understory is inversely correlated with the density of the overstory (Zavitkovski, 1976; Cannell and Grace, 1993; Brown and Parker, 1994; Lieffers and Stadt, 1994; Richard and Messier, 1996), so was this study. Understory aboveground biomass (kg/ha) of herbs (including forage) was 540 for control, 1,060 for plot B, and 1,033 for plot A in September of 2004. In May of 2005, 398 for control, 833 for plot B, and 895 for plot A. In July of 2005, 800 for control, 1,400 for plot B, and 1,650 for plot A. In August of 2005, 523 for control, 1,230 for plot B, and 1,288 for plot A (Figure 4).

Garrett *et al* (2004) have assessed that the productivity of forage in a silvopastoral practice in the temperate zone of North America is dependent upon tree and forage species in addition to canopy structure and climatic conditions (rainfall amount and seasonality). In this study, the yield pattern of forage was in accordance with the result of Garrett *et al* (2004) due to the heavy precipitation was occurred during the summer season (June to September). Based on the above results, the differences were statistically significant between thinned plots and unthinned plot, but there were no significant differences among the thinned plots ($p<0.05$). Tree canopy had influence on pasture production and considerably

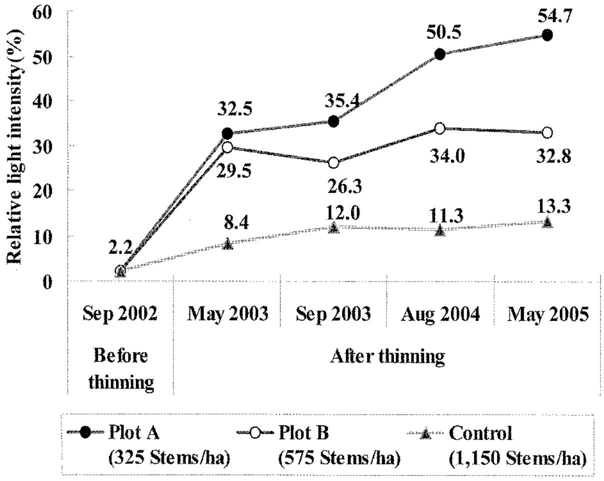

Figure 3. Changes in relative light intensity at each treatments.

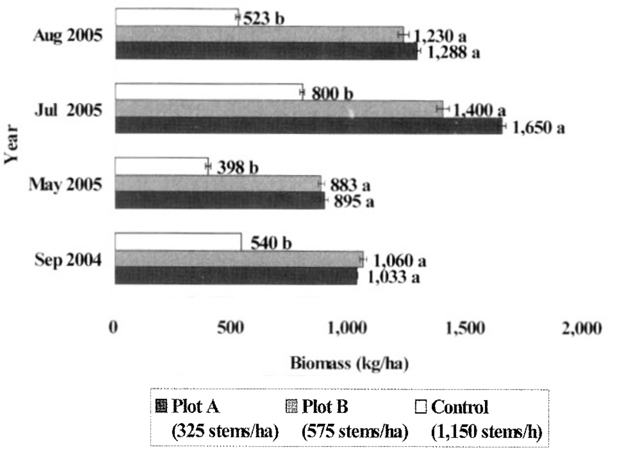

Figure 4. Biomass in each treatment plots after thinning. Same letters indicate no significant difference among thinning treatments (p<0.05).

small amount of herbage production occurred in control plot compared with the thinned plots (Figure 4).

Conventional stand thinning generally leads to positive responses in biomass of understory vegetation (Crouch, 1986; Hungerford, 1987; Klinka *et al.*, 1996; Thomas *et al.*, 1999; Sullivan *et al.*, 2001). Thus, there is an opportunity to increase stand-level diversity in thinned stands in terms of understory vegetation.

Lee and Lee (1989) reported that the highest dry mater production was obtained in May (2,040 kg/ha) in previous study. Otherwise, maximum biomass production in this study occurred in July of 2005 for all plots, which corresponded to the month when temperatures and radiation levels were the highest and precipitation was close to the moderate level. Minimum biomass production occurred in spring (May of 2005) (Figure 4). The results of this study are also similar to the results of Silva-Pando *et al* (2002).

The authors found that a significant effect of tree canopy on biomass production, the lowest herbage production occurring under the highest tree canopy cover. Papanastasis *et al* (1995) reported significantly higher herbage production under *P. pinaster* stands with 300 trees per hectare than in medium and high-density stands with 600 and 1,200 trees per hectare, respectively. As a result, we can conclude that thinning intensity affects yields of understory biomass, by producing different microclimatic conditions which influence biomass production.

Son *et al* (2004) reported that understory aboveground biomass (kg/ha) of herbs for low layers under the Japanese larch plantation after thinning treatments was 186 for control, 327 for T10 (10% thinning, 2,000 stems ha^{-1} after thinning), 528 for T20 (20% thinning, 1,750 stems ha^{-1} after thinning), and 716 for T40 (40% thinning, 1,200 stems ha^{-1} after thinning), respectively. However, this results are somewhat different from above study in terms of sowing forage species and thinning intensity (Figure 4).

As trees grow, their demand upon site resources increases and forage production declines accordingly. This is due to the corresponding decrease in the amount of light reaching the forest floor (Hawke, 1989; Lewis, 1989; Sharrow, 1991; Sibbald *et al.*, 1994), and trends in forage yields are reflected in livestock carrying capacity.

Tree size, density, and pattern all influence understory forage production. Typically, trees have little impact upon understory forage production until their combined canopy cover exceeds 35% (Krueger, 1981). Forage yields then tend to drop off quickly as canopy cover and tree basal area increase. Since forage yields decrease as conifer canopies close, altering canopy closure patterns by reducing planting densities of trees and changing their spatial arrangement can substantially increase forage production in mid to late rotation of agroforestry stands (Clason and Sharrow, 2000). Therefore, additional thinning is indispensible to improve forage yields in a few years later and thinning can result in increased herbage production (Anderson and Batini, 1983; McConnel and Smith, 1965).

Several previous studies reported that the amount of sunlight at the forest floor was the primary influencing factor for understory production (Bisbee *et al.*, 2001; Harrington and Edwards, 1999; Martinez Pasture *et al.*, 2002). More sunlight input at plot A and B appeared to increase understory vegetation production in this study. The results of this study were also in accordance with the results of Son *et al* (2004). This indicated that the understory vegetation grew faster with more light, apparently because the soil moisture conditions had also improved (McConell and Smith, 1965; Anderson and Batini, 1983; Braziotis, 1993).

Current study suggested that the effects of thinning on light conditions at the forest floor, species richness and diversity and production of understory vegetation continued seven years after the treatment (Son *et al.*, 2004). However, more studies are needed to clarify the long term effects of thinning on light condition and understory vegetation in the region (Battles *et al.*, 2001; He and Barclay, 2000; Ito *et al.*, 2003; Son *et al.*, 2004).

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(Received August 31, 2006; Accepted February 20, 2006)