Original paper

Stand structure 5 years after clear-cutting for a natural subtropical evergreen broad-leaved forest in northern Okinawa, Japan [*1]

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Wu, L. and Shinzato, T. : **Stand structure 5 years after clear-cutting for a natural subtropical evergreen broad-leaved forest in northern Okinawa, Japan Kyushu J. For. Res. 57：104-109, 2004** Stand structure and regeneration of a natural evergreen broad-leaved forest with 62 tree species, 1,893 stumps in Okinawa was studied 5 years after clear-cutting. The result showed that 81 tree species with 8,121stems ≧ 1.0m in height occurred in regenerating stand including 60 primary species and 21 invading species in a 800m^2 plot. Among primary species, 60 species had sprout-origin stems whereas two species disappeared. The stem densities at plots were nearly similar for sprout- and seedling-origin stems, however, the former contributed vast majority of total basal area, and the latter had a large number of stems with very small basal areas. Consideration of total basal area *Castanopsis sieboldii* was exclusively dominant species in the study plot after cutting. However, from view of height distribution, *Schima wallichii* ssp. *liukiuensis* had the more stems in higher classes than *C. sieboldii*. Within seedling-origin stems, six dominant species showed a typical "L"-shaped distribution, whereas five sprout-origin species hit a peak at class with tree height 3-4m or with 2-3m. Megaphanerophyte from sprout-origin stems occupied both the highest stems and the highest basal areas, indicating that the sprout-origin stems may dominate the study plots in the future.
Key words：evergreen broad-leaved forest, natural regeneration, stand structure, sprout-origin stem, seedling-origin stem

Ⅰ. Introduction

Evergreen broad-leaved forest dominated by *C. sieboldii* is widely distributed in the northern part of the Okinawa Island, the only subtropical prefecture in Japan. This type of forest covers about 340 km^2, about 0.1% of total area of Japan, however, a total of 1,089 higher plant species, about 28% of them in Japan, are presented in the region（Shinjo *et al.*, 1988）. Therefore, to conserve this type of forest, natural regeneration has been recognized as an important ecological measure of forest sustainability in recent decades（Kyushu Forest Bureau, 2000）.

Several studies have been done on natural regeneration of evergreen broad-leaved forest in Okinawa. Hirata *et al.*（1979, 1990）studied the survival rate of stumps and mean sprout number per stump four to five months after selection cutting. Asato *et al.*（1978）reported the stand structure and growth of target species 3 years after cutting. Shinzato *et al.*（2000）studied the mortality and decay of stumps 5 years after clear-cutting. Wu *et al.*（2001a, b）studied the sprout position and growth of regenerating shoots from either sprout or seedling. However, few studies have focused on the regenerating forest characteristics consideration of both sprout- and seedling-origin stems.

After clear-cutting, abundant stems including stems from sprout and seedling may occur in the beginning stage of succession. However, most of them may die due to space competition. Which tree species dominate the stand in the beginning stage? Do they mainly come from stump sprout stems or from seedling one? Thus, detailed characterization of regenerating forest, especially succession process about origin of stems may be important to improve forest management. The purpose of this study is given an understanding of stand structure of regenerating forest, through comparison between sprout- and seedling-origin stems 5 years after clear-cutting for a natural subtropical evergreen broad-leaved forest in northern Okinawa, Japan.

Ⅱ. Study area and Methods

1. Study area

This study was conducted in the natural evergreen bread-leaved forest at Yona Field, Subtropical Field Science Center, Faculty of Agriculture, University of the Ryukyus, located in the northern part of Okinawa Island, Japan（26°45' 30″ N and 128° 05′ E）. The area is characterized by a maritime subtropical climate. Typhoons or tropical cyclones are frequent in the

Table 1. Tree composition in the study plots before cutting. The data in four plots were combined.

Species	Mean DBH (cm)	Mean height (m)	Density (stems/800m²)	Volume m³/800m²	Volume %
Castanopsis sieboldii	15.1	7.2	85	6.4	64.3
Schima wallichii ssp. *liukiuensis*	12.3	8.0	24	1.3	13.2
Elaeocarpus sylvestris	7.3	6.3	15	0.2	2.4
Schefflera octophylla	7.1	5.9	27	0.4	3.9
Camellia lutchuensis	3.8	4.0	54	0.2	1.7
Myrsine sequinii	2.2	3.1	101	0.1	0.9
Distylium racemosum	2.1	3.1	188	0.1	1.5
Ardisia quinquegona	1.0	2.2	509	0.1	0.7
others	2.6	3.3	890	1.1	11.4
Total			1,893	9.9	100.0

Table 2. Changes of tree species composition before and after clear-cutting by life form spectra

Life form spectra	Before cutting No	Before cutting %	After cutting Sprout-origin No	After cutting Sprout-origin %	After cutting Seedling-origin Primary	After cutting Seedling-origin Invading	After cutting Seedling-origin No	After cutting Seedling-origin %	Total of plots No	Total of plots %
MM	17	27.4	17	28.3	15	8	23	30.7	25	30.9
M	11	17.7	10	16.7	9	1	10	13.3	11	13.6
NM	26	41.9	25	41.7	22	8	30	40.0	33	40.7
N	8	12.9	8	13.3	8	4	12	16.0	12	14.8
Total	62	100.0	60	100.0	54	21	75	100.0	81	100.0

Difference was examined by analysis of variance (ANOVA) for life form spectra between before cutting and after cutting. No difference was found ($p > 0.05$).

summer months, bringing high rainfall and strong winds to the island. It never freezes in winter and the lowest temperature does not fall below 2.0 ℃. The mean annual precipitation measured was 2,680mm, the mean annual temperature was 21.6 ℃, the mean monthly maximum temperature was highest in August (32.1℃), and the mean monthly minimum temperature was lowest in February (10.8℃) in the past two decades. The altitude ranges from 300m to 330m a.s.l.

The study area was covered with natural forest. The vegetation was evergreen broad-leaved forest dominated by *C. sieboldii*. The parent bedrock is sandy shale, and the soil is classified as yellow soil. The thickness of soil horizon is more than 80cm, and the thickness of soil humus horizon is between 4 ～ 12 cm.

2．Methods

Four study plots (20m × 10m, in size) were established in the study area (0.32ha) in 1992. Each plot was divided into two subplots (10m × 10m, in size). In the study plots, all stems taller than 1.2 m were recorded including species name, height, diameter at breast height (DBH). The fixed number was tagged on the base of each stem. All trees in the study area were felled at the base about 20cm height above the ground in February 1993. After cutting, the study area was laid in nature without any man-made disturbance. Field investigation was performed in 1998 between May and July. All the living tree stems taller than 1.0 m were recorded including species name, height, DBH (for trees with height taller than 1.3m), stem-origin.

In this paper the data in four plots were combined and basal

area were accounted for stems taller than 1.3m. Difference was examined by analysis of variance (ANOVA) for life form spectra between before cutting and after cutting. ANOVA was also performed for basal areas among the study plots after cutting.

Life form spectra were divided into four types, megaphanerophyte(MM), mesophanerophyte(M), microphanerophyte (NM) and nanophanerophyte (N) according to Hatusima (1975).

Ⅲ．Results and discussion

1．Species composition

The composition of main tree species in study plots (800m² in area) before clear-cutting is shown in Table 1. In the study plots, 62 tree species, 1,893 stems with height ≧ 1.2m were identified. *C. sieboldii* dominated absolutely the forest, and hit the highest volume (64.3%). Five years after clear-cutting, a total of 81 tree species occurred with 8,121 stems ≧ 1.0m in height (Table 2). Within primary species, 60 species appeared with sprout-origin stems whereas two species disappeared without any living sprout stem. In seedling-origin stems, 75 species appeared including 54 primary species and 21 invading species.

There was no obviously difference found for species compositions by life form spectra before cutting and after cutting (ANOVA, $p > 0.05$). Within the study plots after cutting, MM, M, NM and N contributed 30.9%, 13.6%, 40.7% and 14.8% of total species, respectively, similar to those before cutting (28.3%, 17.7%, 41.9% and 12.9%, respectively), although the former had

Table 3. Basal area and number of stems for main species with basal area over 10.0 m$^2 \times 10^{-3}$ in the study plots 5 years after cutting*

| Species | Total of plots | | | | Sprout-origin | | | | Seedling-origin | | | |
| | Basal area | | No. of stems | | Basal area | | No. of stems | | Basal area | | No. of stems | |
	m$^2\times10^{-3}$	%	No	%	m$^2\times10^{-3}$	%	No	%	m$^2\times10^{-3}$	%	No	%
Castanopsis sieboldii	217.4	20.6	941	11.6	198.6	25.1	591	14.5	18.8	7.1	350	8.7
Elaeocarpus japonicus	142.5	13.5	222	2.7	121.6	15.4	138	3.4	20.9	7.9	84	2.1
Schima wallichii ssp. *liukiuensis*	106.9	10.1	205	2.5	95.4	12.1	114	2.8	11.5	4.3	91	2.3
Styrax japonicus	73.2	6.9	740	9.1	14.0	1.8	39	1.0	59.2	22.3	701	17.4
Glochidion acuminatum	60.7	5.7	925	11.4	0	0	0	0	60.7	22.8	925	22.9
Persea thunbergii	53.7	5.1	172	2.1	44.7	5.6	100	2.4	9.0	3.4	72	1.8
Elaeocarpus sylvestris	49.5	4.7	154	1.9	44.3	5.6	29	0.7	5.2	2.0	125	3.1
Schefflera octophylla	47.3	4.5	115	1.4	42.2	5.3	95	2.3	5.1	1.9	20	0.5
Rhus succedanea	31.0	2.9	55	0.7	24.6	3.1	21	0.5	6.4	2.4	34	0.8
Ardisia quinquegona	24.7	2.3	840	10.3	21.9	2.8	680	16.7	2.8	1.1	160	4.0
Diospyros morrisiana	23.0	2.2	42	0.5	17.2	2.2	27	0.7	5.8	2.2	15	0.4
Vibumum japonicum	19.4	1.8	203	2.5	15.9	2.0	142	3.5	3.5	1.3	61	1.5
Daphniphyllum glaucescens ssp. *teijsmannii*	16.8	1.6	99	1.2	11.4	1.4	21	0.5	5.4	2.0	78	1.9
Distylium racemosum	15.2	1.4	354	4.4	14.8	1.9	334	8.2	0.4	0.2	20	0.5
Neolitsea aciculata	12.5	1.2	113	1.4	10.6	1.3	57	1.4	1.9	0.7	56	1.4
Thtcheria virgata	11.7	1.1	131	1.6	11.4	1.4	115	2.8	0.3	0.1	16	0.4
Myrica rubra	11.7	1.1	35	0.4	10.2	1.3	20	0.5	1.5	0.6	15	0.4
Neolitsea sericea	10.6	1.0	99	1.2	9.2	1.2	47	1.2	1.4	0.5	52	1.3
Camellia lutchuensis	10.5	1.0	175	2.2	10.3	1.3	171	4.2	0.2	0.1	4	0.1
Others (62 species)	118.8	11.2	2501	30.8	73.0	9.2	1343	32.9	45.8	17.2	1158	28.7
Total	1057.1	100.0	8121	100.0	791.3	100.0	4084	100.0	265.8	100.0	4037	100.0

*Species are listed by total basal area

more tree species (81 species) than the latter (62 species).

2. Basal area and stem density

The basal areas and stem densities for main species (with basal area over 10.0m$^2\times10^{-3}$) 5 years after clear-cutting are shown in Table 3. Since there was no difference found for basal area among the study plots (ANOVA, *p* >0.05), the data in four plots were combined in this paper. Within sprout-origin stems, *Ardisia quinquegona, C. sieboldii* and *Distylium racemosum* comprised the three greatest stem densities by turn as 16.7%, 14.5% and 8.2%, respectively. However, except for *C. sieboldii* that attained the highest basal area in all species, the other two species contributed only the basal area 2.8% and 1.9%, respectively. *C. sieboldii*, *Elaeocarpus japonicus* and *S. wallichii* ssp. *liukiuensis*, comprised the three greatest tree species in basal area as 25.1%, 15.4% and 12.1%, respectively. This indicated that *A. quinquegona* and *D. racemosum* had a large number of stems with very small basal area at breast height in sprout-origin stems.

Among seedling-origin stems, *C. sieboldii* was not dominant species, attained basal area and stems 7.1% and 8.7%, respectively. Instead, *Glochidion acuminatum* and *Styrax japonicus* shared the greatest stem densities (22.9%, 17.4%, respectively), and the greatest basal area by turn (22.8%, 22.3%, respectively).

Consideration of total of study plots, *C. sieboldii* was exclusively dominant species, which contributed the highest total area and the highest stem density as 20.6%, 11.6%, respectively. The other five dominant species with total basal areas over 5.0% were *E. japonicus, S. wallichii* ssp. *liukiuensis*, *S. japonicus*, *G.. acuminatum* and *Persea thunbergii*. The aforementioned 6 species contributed the vast majority of the total basal area (61.9%) although they comprised only 39.4% of the total stems.

The stem densities at the study plots for sprout- and seedling-origin stems were nearly similar (4,084, 4,037 stems/plots, respectively), summed up 8,121 stems/ 800m^2. However, the basal areas were obviously different for the two kinds of stems. The sprout-origin stems contributed 74.9% of total basal area, which was nearly 3 times more than that in seedling-origin stems. The result indicated that sprout-origin stems contributed vast majority of total basal area, and seedling-origin stems had a large number of stems with very small DBH.

In addition, as a result of the clear-cutting on natural forest, huge gaps were created. In the huge gap, great light intensity on the forest floor promotes the establishment of shade intolerant species. It can be seen that after clear-cutting, *G. acuminatum* invaded the gaps and hence attained the largest stem density in seedling-origin stems. *G. acuminatum*, a kind of pioneer species, would decrease in the number of stems with time. Abundant exist of pioneer species showed that these regenerating forest was still in the beginning stage of succession

3. Height class

The study plot after cutting was stratified into five height classes according to height of stems. The distribution of tree species and stems by height class is shown in Fig. 1. Class Ⅰ was with tree height>5.0m; class Ⅱ 4.0m<height≤5.0m; class Ⅲ

3.0m<height≤4.0m; class Ⅳ 2.0m<height≤3.0m and class V 1.0m<height≤2.0m.

Class Ⅰ composed of three species including two sprout-origin species and one seedling-origin species. In this class 5 stems occurred, which shared 0.1% of all stems. Among them, 40% of stems were *S. wallichii* ssp. *liukiuensis*. Primary dominant species C. *sieboldii* did not appeared in this class.

Class Ⅱ was formed by 7 species, 5 sprout-origin species and 2 seedling-origin ones. There were 49 stems in this class, which comprised 1.1% of the all stems. Within this class the prevailing species was *S. wallichii* ssp. *liukiuensis*, which shared 34.7% of stems of the class; versus the primary dominant species *C. sieboldii* attained 8.0% of stems of the class.

Class Ⅲ was formed by 32 species including 27 sprout-origin species and 15 seedling-origin species.

Within this class there were 540 stems, which shared 10.3% of all stems. *C. sieboldii* was in remarkably dominant position with 153 stems, which shared 28.3% of all stems of the class. In this class abundant sprout stems were also found for species *S. wallichii* ssp. *liukiuensis*, *E. japonicus* and *S. japonicus*.

Class Ⅳ formed 64 species including 52 sprout- origin species and 54 seedling-origin species. In this class there were 2,207 stems, which shared 27.2% of all stems, which shared 27.2% of all stems. *C. sieboldii*, *S. japonicus* and *G.. acuminatum* were 3 prevailing species, had stem number 299,295 and 243, respectively.

Class V consisted of 73 tree species including 57 sprout- and 69 seedling-origin species. In this class there were 5,320 stems, shared the highest stem percentage of all sprout stems as 37.8%. In this class, *A. quinquegona*, *G.. acuminatum* and *C. sieboldii* were 3 prevailing species, with stems 769, 654 and 442, respectively.
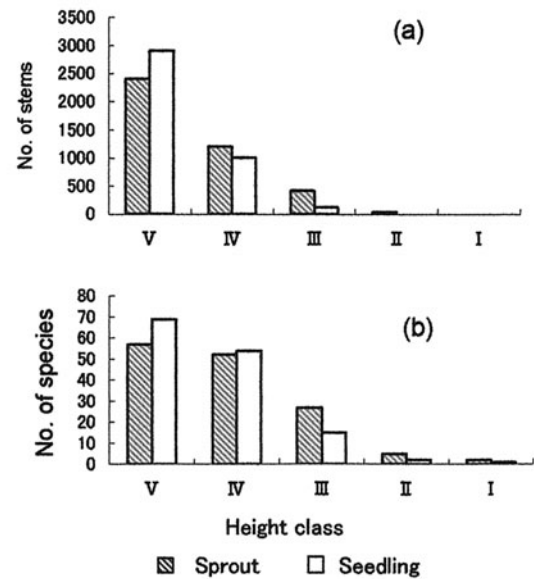

Fig－1. Number of stems （a）and number of species（b） for sprout- and seedling-origin stems by height class in the study plots

Fig. 1 (a) shows number distribution of stems for sprout- and seedling-origin stems, a typical "L"- type, which was formed by stems having the highest frequency in the small height class with a gradual decreases in the number of stems towards the larger classes. The similar distribution patterns were also found for number distribution of species by height class as shown in Fig. 1(b), a typical "L"-shaped distribution by height class.

4. Frequency distributions for six dominate species

This study focused on the six dominant species in basal area, *C. sieboldii*, *E. japonicus*, *S. wallichii* ssp. *liukiuensis*, *S. japonicus*, *G. acuminatum* and *P. thunbergii*. The height
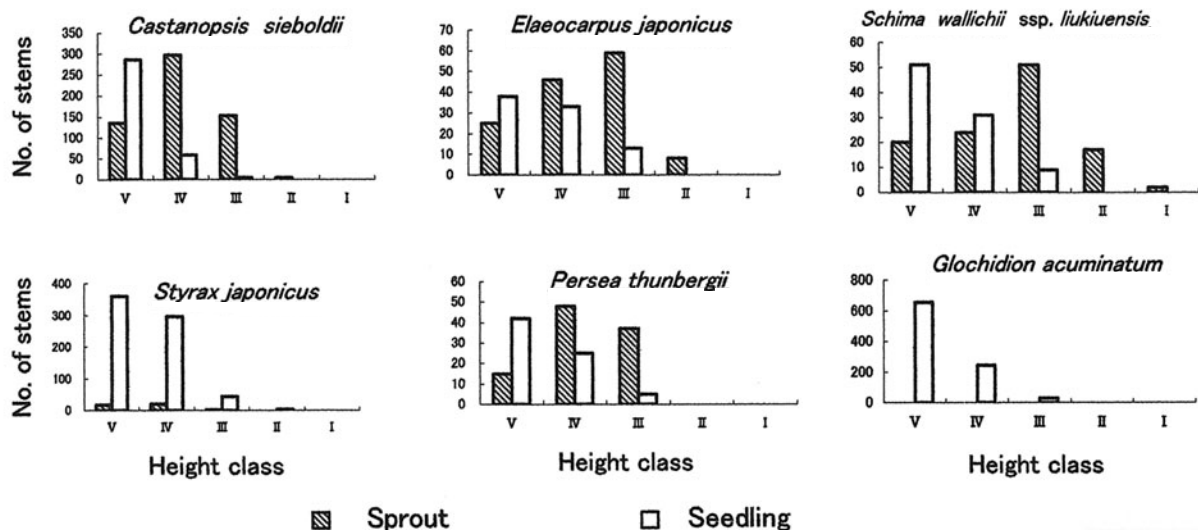

Fig－2. Height distribution of six dominate tree species for sprout- and seedling-origin stems in the study plots after cutting
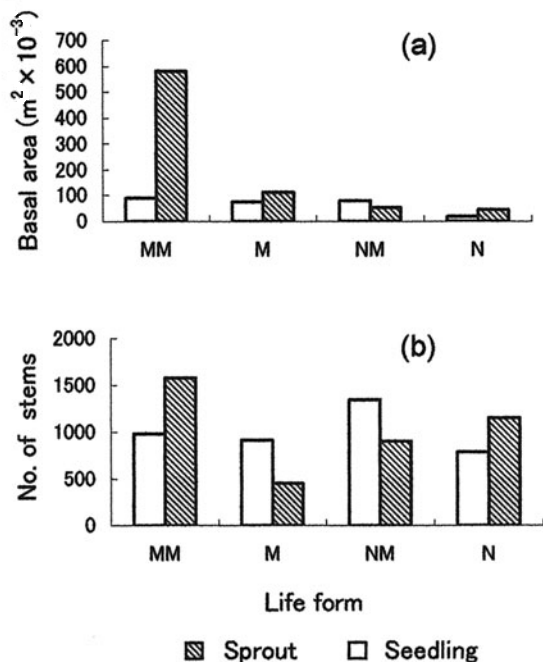
Fig－3. Total of basal area (a) and number of stems (b) by life
form spectra for both sprout- and seedling-origin stems
in the study plots

distributions for both sprout- and seedling-origin stems are
given in Fig. 2.

Within seedling-origin stems, all six dominant tree species
showed a similar height distribution, a typical "L"-shaped
pattern. However, for sprout-origin stems, the distribution
patterns were quite different to the seedling-origin stems. Two
species, *E. japonicus* and *S. wallichii* ssp. *liukiuensis* had
highest peaks at class Ⅲ, versus *C. sieboldii* and *P. thunbergii*,
had the highest peaks at class Ⅳ. Furthermore, compared to
sprout-origin stems, seedling-origin ones turned up with a peak
at class V; showing that seedling-origin stems consisted of the
lower stories while most sprout-origin stems comprised the
higher stories. Among stories Ⅰ to Ⅲ, sprout-origin stems were
3-10 times more than that in seedling-origin ones.

The reason why about 5 sprout-origin trees showed the non-
typical "L"-shaped distribution was considered the result of
space competition. At the first year after clear-cutting, abundant
stump sprouts occurred. A crowd of sprout shoots from one
stump or more in nearby may result in severe space
competition. Furthermore, most of them, especially the small
sprout stems died in the following years due to severe space
competition. Sprout- origin stems emerged generally with
abundant shoots on stumps. A crowd of sprout shoots from one
stump or more in nearby may result in severe space competition.
If space competition happened to the sprout-origin trees, why
did the same situation not happen to some seedling-origin trees?
The reason is probably from their spatial distribution. For
seedling-origin trees, they were normally sporadic-distributed in

the study plots no severe space competition was found among
them.

5．Life form spectra

The basal areas and stem densities by life form spectra for
sprout- and seedling-origin stems in the study plots are showed
in Fig. 3. Fig. 3 (a) shows that MM contributed 73.3% of basal
area for sprout-origin stems, which was far more than those for
M, NM and N (14.3, 6.8 and 5.6% respectively). For seedling-
origin stems, MM, M and NM had the similar values (33.9%,
28.7% and 30.1%, respectively), whereas N had the lowest value,
7.3%. Consideration of total basal area, MM contributed vast
majority of basal area (63.4%). MM from sprout-origin stems
shared the majority basal area in the study plots (54.9%).

Fig. 3 (b) shows that MM from sprout-origin stems shared
the highest stems (1,582 stems/800m²) among all life-form
spectra versus M had the lowest value (447stems/800m²). N
and NM had stems 1,152,903 stems/800m², respectively; were
not far less than that in MM; however, they shared only the
basal area 5.6%, 6.8%, respectively, indicating that N and NM
were of with abundant stems but less basal areas.

Within seedling-origin stems, MM, M and N comprised similar
values versus NM had the highest value as 1,349stems/800m².

Life form spectra imply similarities in the species' ecological
characteristics, and in particulars, the layer they occupied
within the overall forest structure. Now that these layer classes
were not based on the height of trees, but refer to groups of
species that are categorized as MM, M, NM and N. Thus, even
MM includes juvenile trees as well as large canopy trees. Thus,
life form spectra may be used to detect general trends of stand
structures in the response of the tree species to cutting in the
future. In the present study, MM contributed vast majority of
basal area and had the highest stems at the study plots in all life
form spectra. Furthermore, MM from sprout-origin stems,
occupied both the highest stems and the highest basal areas,
indicating that the sprout-origin stems may dominate the study
plots in the future.

Ⅳ. Conclusion

The present study demonstrated that five years after clear-
cutting, there was no difference found for tree species
compositions by life form spectra between the forests before
cutting and after cutting, indicating that the forest after cutting
may gradually recover to become similar to that of before
cutting. Abundant exist of pioneer species (*G. acuminatum*)
showed that the secondary succession at the study plots after
cutting was in the beginning stage.

In this study, the forest after cutting was divided into sprout-
and seedling-origin stems. We observed that the stem densities
at the study plots after cutting for sprout- and seedling-origin
stems were nearly similar, however, the basal areas were

obviously different for the two kinds of stems, the former contributed vast majority of total basal area, and the latter had a large number of stems with very small basal area.

It could be concluded that the space and nutrient competition among stems were still severe, since the density at the study plots after cutting was as high as 8,121 stems/ 800m², equal to 101,513 stems/ha, which was far more than that at the study plots before cutting. Most of stems will wither following years due to severe competition.

Consideration of total of study plots, *C. sieboldii* was exclusively dominant species in the study plots after cutting. But, from view of height distribution, *S. wallichii* ssp. *liukiuensis* had the more stems in higher classes than *C. sieboldii*, especially at class with tree height over 4m.

In the present study, we also observed the same height class distribution patterns, a typical "L" type, for both sprout- and seedling-origin stems. This coincided with other study in a natural broad-leaved forest in Okinawa (Xu, 2001). However, for the five dominant sprout-origin species, they hit a peak at class with tree height 3-4m or with 2-3m, a non-"L"-shaped distribution. The reason was considered the result of space competition.

Acknowledgments

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