論　文

Contribution of regeneration sources in early succession stage of a subtropical evergreen broad-leaved forest after selective logging in Okinawa [*1]

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Wu, L., shinzato, T., Aramoto, M., Ishigaki, C., Kuto, T.: **Contribution of regeneration sources in early succession stage of a subtropical evergreen broad-leaved forest after selective logging in Okinawa J. For. Res. 59 : 75－81, 2006** The contribution of regeneration sources to secondary forest was studied in a subtropical evergreen broad-leaved forest after selective logging. It was observed that there were four regeneration sources of stems according to their origins: residual, residual-sprout, stump-sprout and seedling. Species composition in the secondary forest was similar to that in the primary forest. The residual-origin stem had nearly half of the total basal area of the secondary forest with an annual average mortality 2.3 % year $^{-1}$. Although the stump-sprout-origin stem occupied 6.8 % of total number of stems only, it contributed 22.9 % of the total basal area. The seedling-origin stem occupied the majority of the total number of stems, but only contributed a basal area of 23.0 %, suggesting stump-sprout regeneration is an important regeneration source, and that the seedling-origin stem had limited contribution to the forest. The residual-sprout-origin stem had the least contribution to the forest. Of all sources of stems, primary dominant species *Castanopsis sieboldii* was shown to be dominant in the secondary forest. It was considered that the secondary forest might gradually recover to a stand similar to that before selective logging.

Keywords: contribution of regeneration sources, subtropical evergreen broad-leaved forest, selective logging, secondary succession

Ⅰ. Introduction

Selective logging is often proposed as a low-impact alternative to clear-cutting and is the most widely employed approach for commercial timber production in humid tropics （Pelissier *et al*., 1998; Dickinson *et al*., 2000; Pereira *et al*., 2002; Okuda *et al*., 2003）. It allows not only sustainable timber production but also limit damage including changes in forest microclimate, erosion, soil compaction and so on. In subtropical regions, however, selective logging is not popular in practical （Inoue Y., 1968; Aramoto *et al*., 1977; Wu *et al*., 2003）. Although some studies have been made on the damage of residual trees and stand composition just after selective logging （Hirata *et al*., 1980; Shinzato *et al*., 1995）, and the rot of stand in the evergreen broad-leaved forest （Aramoto *et al*., 1981） in Okinawa, these reports are insufficient for understanding the selective logging techniques in this region. Further studies on selective logging in Okinawa seem to be warranted.

Okinawa, the unique subtropical region in Japan, consists of the southernmost islands of Japan, which is characterized by a maritime subtropical climate. In this area well-developed evergreen broad-leaved forest dominated by *Castanopsis sieboldii* remains. Unfortunately, this type of forest had ever been destroyed during the Second World War, and had been deformed by excessive cutting for the construction after the Second World War. In the recent decades, along with the development of tourism in Okinawa, environment problems have been emphasized （Ito 1995, 1997; Wu *et al*., 2003）. Therefore, the conservation of forest resources in Okinawa, have become an urgent task to keep the harmonization for both forest utilization and conservation. Natural regeneration has been regarded as an important forest regeneration measures in this region due to its ecological benefits （Kyushu Forest Bureau, 2000）.

In the early succession stage, several sources of regeneration stems may occur in a selective logged forest except for the unlogged residual tree stems. Firstly, the sprout stems may come out from the stump directly when a tree was logged （Shinzato *et al*., 2000）. Secondly, sprout stems may be from the residual unlogged tree. Except for existence of sprout stems, the seedling stems may be present abundantly in the selectively logged forest （Wu *et al*., 2001）. However, most of these stems

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may disappear due to space or nutrient competition. Which sources of stems dominate the secondary stand in the beginning stage? What is their contribution for different sources of stems to the secondary forest after selective logging? These kinds of knowledge are of crucial importance to the maintenance and restoration of Okinawa evergreen broad-leaved forest ecosystem. However, we know few about them, especially contributions of different sources of stems to the secondary forest in the early succession stage after selective logging in Okinawa

The objectives of this study were to investigate the contribution of regeneration sources to the secondary forest in early succession stage following selective logging in Okinawa.

Ⅱ. Material and Methods

1. Study area

The study area is located in the Yona Field, Subtropical Field Science Center, Faculty of Agriculture, University of the Ryukyus, in the northern part of Okinawa Island in Japan (26° 45′ 30″ N and 128° 05′ E). The region is characterized by a maritime subtropical climate and abundant rainfall throughout the year. Typhoons frequently occur from July to October, bringing high rainfall and strong winds to the island. Total annual precipitation averages about 2,750 mm, and the mean annual temperature is 21.8 ℃. The altitude of the study site ranges from 330 m to 350 m a.s.l. The total area for selective logging is 4,370 m^2.

2. Experimental design and data analysis

Eight plots (10 m × 10 m each) were established in a natural evergreen broad-leaved forest at a gently protuberant slope, northwest facing with a gradient of 15° in 1994. The plots were arrange as two rows (4 plots each) adjacently. Each plot was further divided into 25 quadrats (2m × 2m each) for convenience of investigation. Before the selective logging in 1994, a tree census was conducted. All trees with height equal to or higher than 1.2 m in the study plots were recorded including species name, tree height and DBH. The fixed number was tagged on the base part of the trees or stems in 1994 before selective logging. In February 1994, the all tree stems with DBH larger than 8.0 cm were felled at the base (20 cm height above the ground), being called selective logging in the paper. The total harvest intensity in terms of stems was 7.1 %, while *C. sieboldii* had the highest harvest intensity (50.3 %). The study site was then left undisturbed for 8 years until a tree census in December 2002.

The tree species and stem height were recorded for all trees exceeding 1.0 m in height, and for those exceeding 1.3 m in height, DBH was also measured. The stems were divided into 4 sources in terms of their regeneration origins (Fig. 1). The residual origin stems were the ones that resided before selective logging with DBH < 8.0 cm, the residual sprout origin stems were the ones that sprouted from the residual tree, the stump sprout origin stems were the ones that from the logged stump, while the seedling origin stems were the ones from seeds after selective logging.

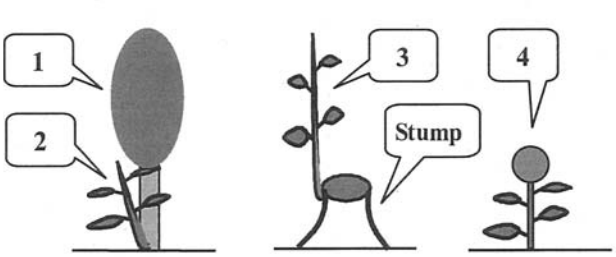

Fig.1. Stem sources divided by regeneration origins in the secondary forest. 1) Residual origin stem, 2) residual sprout origin stem, 3) stump sprout origin stem, 4) seedling origin stem

The woody trees (phanerophytes) in the survey were classified into four life forms: megaphanerophyte (MM) (arbor), mesophanerophyte (M) (mid-arbor), microphanerophyte (NM) (sub-arbor), and nanophanerophyte (N) (shrub) (Hatusima, 1975; Asato *et al*., 2004). The natural forest before selective logging is called primary forest in this paper, and the tree species presented in primary forest was called primary species. The species which did not present in primary forest but presented in secondary forest were called invading species.

In the present study, the data in eight plots were combined due to the similar topography of the plots. The species importance value (IV) was evaluated for each regeneration source according to Basnet (1992) as follow:

$IV = (RD+RBA) / 2 \times 100$

where RD is the relative density, calculated as number of stems of a given species in plots, divided by the total number of stems of all species within the same plots (%); RBA is the relative basal area, calculated on the basis of the basal area of a given and all species in the same plot. The dominant species were designated as those with importance value higher than 5.0 in this paper.

Assuming the loss of a constant fraction of the population each year for the residual stems after selective logging, the annual mortality rate (m) was estimated using the negative exponential decay model by the formula (Condit *et al*., 1995; Sheil *et al*., 1995):

$m = 100 \times (LnNo-LnNs) / t$

where No is the initial number of trees just after logging (1994) and Ns is the number of trees still alive in year t.

Ⅲ. Results

1. Species composition

Sixty five woody species were present in the study plots prior to selective logging. *C. sieboldii* dominated the forest with the highest importance value (IV=27.1). ***Distylium racemosum*** was

Table 1. Comparition of species compositon between primary and secondary forest by life form and origin

Life form	Primary forest	Secondary forest				
		Stump sprout	Seedling	Residual	Residual sprout	Total
MM	20	11	21	20	14	22
M	11	7	11	10	8	12
NM	24	4	29	24	17	32
N	10	0	15	10	7	16
Total	65	22	76	64	46	82

the next most important species (IV= 15.2). The other two important species were ***Ardisia quinquegona*** (IV=8.8) and ***Camellia japonica*** (IV=5.8). In addition, ***A. quinquegona*** had the stem density as high as 17.0 %, but contributed of basal area 0.6 % only to the forest.

A total of 82 woody species (>1.0m in height) were recorded in the eight-year-old secondary forest following selective logging in the 8 study plots, (Table 1). These could be classified into 31 families and 57 genera. The largest family represented was Rubiaceae (10 species), followed by Lauraceae (8) and Theaceae (7). Among these species, stump sprout origin stems contained 22 species, of which, most of them were MM species. Seedling origin stems had the highest species numbers (76) among the 4 sources of stems, of which, NM had the highest species (29) following by MM (21). MM and M species had almost the similar number of species, however, NM and N species increased obviously compared to the primary forest. Residual origin stems had 64 species with a similar species composition compared to the primary forest.

The secondary forest had a similar tree species composition compared to the primary forest eight years after selective logging. Most of primary species were present in the secondary forest; however, one species (***Turpinia ternate***) was lost without living residual stems. Due to invading of some NM and N species, the secondary forest (82 species) had more tree species number than that in the primary forest (65 species).

2. Residual origin stem

Just after selective logging, ***D. racemosum*** (IV=25.1) were the first dominant species in the residual origin stems in 1994 (Table 2), due to the highest harvest intensity of *C. sieboldii* (50.3 %), followed by other three species, ***A. quinquegona*** (10.5) , ***C.***

Table 2. Comparison of residual stem composition between the forest just after selective logging (1994) and eight years after selective logging (2002) for the species whose basal area higher than 1.25 × 10 $^{-1}$m^2 ha $^{-1*}$

Species	Life form	1994			2002			Changes		Mortality (%year $^{-1}$)
		Stem	Basal area	IV	Stem	Basal area	IV	Stem	Basal area	
Ardisia quinquegona	N	5,400	0.35	**10.5**	4,250	0.46	**10.2**	−1,150	0.11	2.7
Camellia japonica	NM	2,038	1.28	**8.4**	1,788	1.11	**7.1**	−250	−0.18	1.5
Camellia lutchuensis	NM	425	0.62	3.1	313	0.43	1.9	−113	−0.19	3.4
Castanopsis sieboldii	MM	925	0.34	2.9	738	1.52	**6.1**	−188	1.18	2.5
Cinnamomum pseudo-pedunculatum	M	400	0.14	1.2	363	0.31	1.7	−38	0.17	1.1
Daphniphyllum glaucescens	MM	238	0.39	1.9	188	0.65	2.4	−50	0.26	2.6
Dendropanax trifidus	NM	313	0.36	1.9	163	0.36	1.4	−150	0.00	7.3
Diospyros morrisiana	M	175	0.13	0.8	138	0.19	0.9	−38	0.07	2.7
Diplospora dubia	N	125	0.16	0.8	125	0.18	0.8	0	0.02	0.0
Distylium racemosum	MM	7,388	3.27	**25.1**	6,688	3.90	**25.7**	−700	0.64	1.1
Elaeocarpus japonicus	MM	513	0.64	3.3	350	0.58	2.5	−163	−0.05	4.2
Gardenia jasminoides	N	288	0.15	1.1	263	0.18	1.1	−25	0.03	1.0
Helicia cochinchinensis	MM	225	0.05	0.6	150	0.13	0.7	−75	0.07	4.5
Ilex goshiensis	M	150	0.12	0.7	113	0.15	0.7	−38	0.03	3.2
Ilex integra	NM	250	0.09	0.8	200	0.16	0.9	−50	0.07	2.5
Lithocarpus edulis	MM	63	0.01	0.1	63	0.14	0.6	0	0.13	0.0
Meliosma lepidota	NM	300	0.46	2.3	250	0.37	1.6	−50	−0.09	2.0
Meliosma simplicifolia	M	200	0.16	0.9	163	0.17	0.8	−38	0.01	2.3
Neolitsea aciculata	M	363	0.11	1.1	225	0.13	0.8	−138	0.01	5.3
Neolitsea sericea	M	688	0.48	3.0	575	0.52	2.8	−113	0.04	2.0
Persea thunbergii	MM	425	0.24	1.6	363	0.37	1.9	−63	0.13	1.8
Randia canthioides	NM	1,063	0.35	3.1	838	0.27	2.6	−225	−0.08	2.6
Rapanea neriifolia	NM	1,538	0.76	**5.5**	1,063	1.22	**5.9**	−475	0.46	4.1
Schefflera octophylla	M	175	0.22	1.2	125	0.24	1.0	−50	0.02	3.7
Schima wallichii ssp. *liukiuensis*	MM	100	0.23	1.1	88	0.47	1.6	−13	0.24	1.5
Syzygium buxifolium	MM	288	0.19	1.2	275	0.27	1.4	−13	0.08	0.5
Tutcheria virgata	M	700	0.26	2.2	550	0.41	2.4	−150	0.15	2.7
Viburnum japonicum	N	688	0.10	1.5	488	0.15	1.5	−200	0.05	3.8
Other species		4,138	1.27	11.9	3,225	1.49	11.2	−913	0.22	2.8
Total		29,575	12.93	100.0	24,113	16.52	100.0	−5,463	3.59	2.3

*:The dominant species are given in bold figures.

japonica (IV=8.4) and *Rapanea neriifolia* (IV=5.5). The dominant species in the primary forest, *C. sieboldii*, became non-dominant species (IV=2.9). The 4 dominant species in 1994 were still dominant in the secondary forest eight years after selective logging. Moreover, *C. sieboldii* rose into a dominant species (IV=6.1). Among these residual origin stems, *D. racemosum* had the highest importance value (IV=25.7) rather than *C. sieboldii* (IV=6.1) because of a large of residual stems of the former.

A total of 437 stems (5,463 stem ha^{-1}) in the study plots were found dead in an 8-year period with an annual average mortality rate of 2.3 % year^{-1}. There were 28 species with basal area higher than 1.25 × 10^{-1}m^{2}ha^{-1}, of which, two species, *Dendropanax trifidus* and *Neolitsea aciculata*, had mortality rates more than 5.0 % year^{-1}, which corresponded to twice of that for the average of all species. Another seven species, *Helicia cochinchinensis*, *Elaeocarpus japonicus*, *R. neriifolia*, *Schefflera octophylla*, *Viburnum japonicum*, *Camellia lutchuensis* and *Ilex goshiensis*, also had high mortality rates higher than 3.0 % year^{-1}. From the view of absolute dead number, there were 11 species, which had dead stems>10 stems (125 stem ha^{-1}) in plots. *A. quinquegona* had the highest decrease with 92 dead stems (1,150 stem ha^{-1}) in plots, following by *D. racemosum* (56 stems, *i.e.* 700 stem ha^{-1}), *R. neriifolia* (38stems, *i.e.* 475 stem ha^{-1}), *C. japonica* (20stems, *i.e.* 250 stem ha^{-1}) and so on. On the other hand, two species, *Lithocarpus edulis* and *Diplospora dubia*, had no dead stem found.

Although the stem decreased slightly in whole the plots, the basal area increased by 3.59 m^{2}ha^{-1}. For the dominant species, three species had increased basal area except for *C. japonica*. *C. sieboldii* showed the largest increase in basal area among all species (1.18 m^{2}ha^{-1}), indicating that *C. sieboldii* was a fast growing species in the forest.

3. Residual sprout origin stem

The residual sprout origin stems were composed of 46 species with stem density and basal area, 8,675 stems ha^{-1} and 1.51 m^2 ha^{-1}, respectively (Table 3). Of these species, most of stems were small-size, and 2 species (*C. sieboldii* and *Schima wallichii* ssp. *liukiuensis*) only had the basal area higher than 1.25 × 10^{-1} m^{2}ha^{-1}.

Table 3. Growth of residual orgin sprout stems with basal area higher than 1.25 × 10^{-1}m^2 ha^{-1}.

Species	Stem (ha^{-1})	Basal area (m^{2}ha^{-1})	IV
Castanopsis sieboldii	250	0.18	7.5
S. wallichii ssp .*liukiuensis*	88	0.16	5.9
Other 44 species	8,338	1.17	86.6
Total	8,675	1.51	100.0

4. Stump sprout origin stem

Stump sprout origin stems (Table 4) composed of 22 species, having stem density and basal area 6,113 stems ha^{-1} and 7.65 m^2 ha^{-1}, respectively. Among these stems, *C. sieboldii* had the majority of stems and basal areas, and had the highest importance value (IV=55.3), which was six-fold more than *Persea thunbergii*, the next highest species (IV=8.8), suggesting that the stump origin stems was mainly composed by *C. sieboldii*. The other two dominant species were S. wallichii ssp.*liukiuensis* (IV=6.0) and *S. octophylla* (IV=5.9). These four dominant species aforementioned contributed 70.0 importance values.

Table 4. Stem, basal area and importance value for main sprout origin stems with basal area higher than 1.25 × 10^{-1}m^2 ha^{-1}*.

Species	Stem (ha^{-1})	Basal area (m^{2}ha^{-1})	IV
Castanopsis sieboldii	3,363	4.24	**55.3**
Schima wallichii ssp .*liukiuensis*	138	0.75	**6.0**
Persea thunbergii	550	0.65	**8.8**
Schefflera octophylla	363	0.46	**5.9**
Lithocarpus edulis	238	0.42	4.7
Elaeocarpus sylvestris	63	0.27	2.3
Elaeocarpus japonicus	75	0.16	1.7
Distylium racemosum	338	0.16	3.8
Camellia japonica	100	0.15	1.8
Other 13 species	888	0.39	9.8
Total	6,113	7.65	100.0

* :The dominant species are given in **bold figures.**

5. Seedling origin stem

Table 5. Stem, basal area and importance value for the seedling-origin stems with basal area higher than 1.25 × 10^{-1}m^2 ha^{-1}*.

Origin	Species	Stems (ha^{-1})	Basal area (m^{2}ha^{-1})	IV
Primary	*Ardisia quinquegona*	8,350	0.39	**10.8**
	Callicarpa japonica	3,238	0.18	4.4
	Castanopsis sieboldii	5,388	1.23	**13.3**
	Daphniphyllum glaucescens	900	0.31	2.9
	Diospyros morrisiana	163	0.15	1.1
	Elaeocarpus japonicus	413	0.13	1.3
	Elaeocarpus sylvestris	1,200	0.13	2.0
	Neolitsea sericea	2,025	0.25	3.6
	Persea thunbergii	1,238	0.40	3.8
	Rhus succedanea	563	0.20	1.8
	S. wallichii ssp .*liukiuensis*	1,175	0.63	**5.3**
	Styrax japonicus	1,625	0.70	**6.1**
	Symplocos lucida	488	0.13	1.3
	Wendlandia formosana	1,638	0.38	4.1
	Other 44 species	17,200	1.63	27.5
	Subtotal	45,600	6.83	89.3
Invading	*Evodia meliaefolia*	313	0.14	1.2
	Glochidion acuminatum	2,775	0.45	**5.6**
	Viburnum japonicum	1,613	0.17	2.7
	Other 15 species	600	0.09	1.2
	Subtotal	5,300	0.84	10.7
Total	76	50,900	7.68	100.0

* : 58 species for primary species origin stems, 18 species for invading ones. The dominant species are given in bold figures.

In the logged secondary forest, the seedling origin stems were composed of 76 species (Table 5), of which, 58 species were primary species and 18 species were invading ones. The primary seedling species had a stem density of 45,600 stems ha^{-1}, far more than that of invading species (5,300 stems ha^{-1}). The most important species were *C. sieboldii*, *A. quinquegona*, *Styrax japonicus* and *S. wallichii* ssp. *liukiuensis* by turn in the logged secondary forest for the primary seedling origin species, while only one important species (*Glochidion acuminatum*) was found in the invading species. For importance value, the stems from primary species shared the value of 89.3, which was far more than that for invading species stems (10.7).

6. Structural characteristics

Eight years after selective logging, the secondary forest had a density of 89,800 stems ha^{-1}, which was two-fold more than that in the primaryl forest before selective logging (31,838 stems ha^{-1}), having basal area of 33.4 m^{2}ha^{-1}(Fig.2), much less than that in the primary forest(61.7 m^{2}ha^{-1}). Furthermore, the seedling origin stems shared the highest stem density of 50,900 stems ha^{-1}(56.7 %), followed by residual origin stems (36.5 %), which had stem density of 32,788 stems ha^{-1}. Stump sprout origin stems had the least stem density of 6,113 stems ha^{-1}(6.8 %). For basal area, residual origin stems had the highest value (16.5 m^{2}ha^{-1}), being 49.5 % of the total basal area. Stump sprout origin stems and seedling origin ones, however, had almost same basal areas, as 7.65 (22.9 %) and 7.68 m^{2}ha^{-1}(23.0 %) respectively, suggesting that the seedling origin stems had large number of stems but with many of small-size ones, in contrast, stump sprout origin stems had small percentage of the stems but many of them were big-size ones relatively.

The whole secondary forest was stratified into 6 layers according to height of stems as follows: layer Ⅰ $\geq$ 6.0 m, layer Ⅱ 5.0 m $\leq$ height < 6.0 m, layer Ⅲ 4.0 m $\leq$ height < 5.0 m, layer Ⅳ 3.0 m $\leq$ height< 4.0 m, layer Ⅴ 2.0 m $\leq$ height < 3.0 m and layer Ⅵ was with stem height < 2.0 m. The seedling and residual sprout origin stems were mainly distributed in lower layers at 1-3 m (Fig. 3). with a gradual decreasing of the number of stems towards the higher layers. The stump sprout and residual origin stems showed a unimodal distribution, which having the highest frequency in the intermediate layers with lower frequency in the smaller and larger layers. At the higher layers Ⅰ and Ⅱ, the stems were mainly contributed by stump sprout and residual origin ones, especially in the highest layer Ⅰ, only these two sources of stems were present. Nevertheless, the whole forest showed a gradual decreasing distribution from lower layer towards the larger layers (Fig. 4), but not a typical reverse-J shaped distribution.

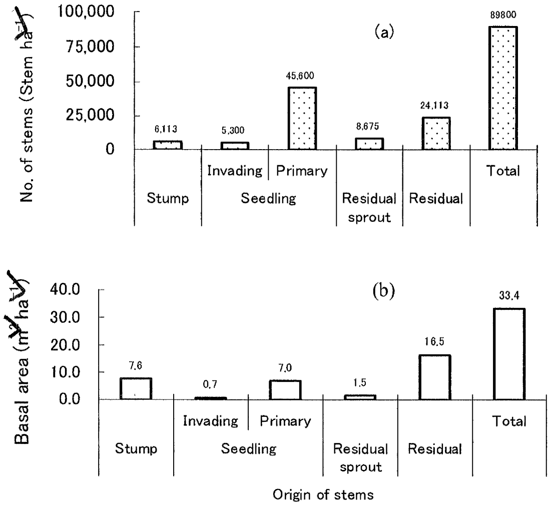

Fig.2. Number of stems (a) and basal area (b) for the all sources of stems.

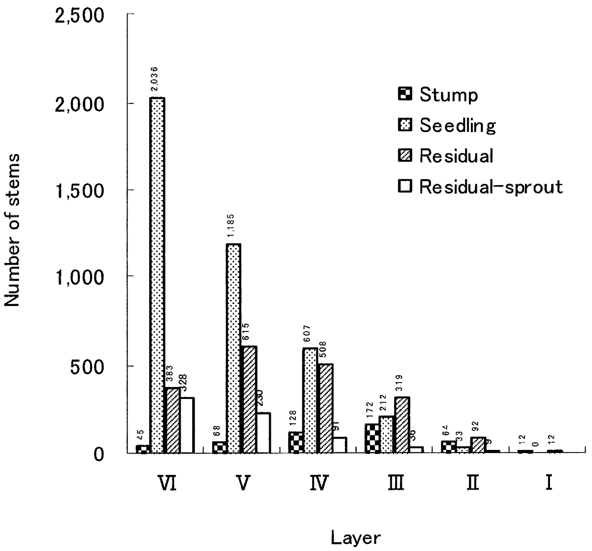

Fig.3. Distribution of stem number by height layer for the all sources of stems in plots.

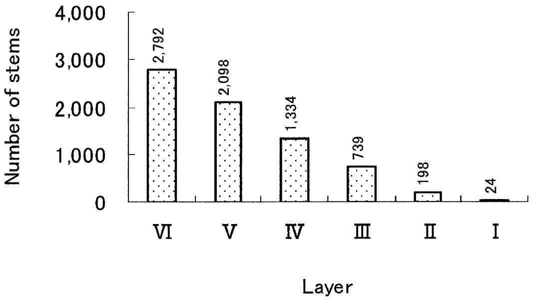

Fig.4. Distribution of stems by height layer for the all sources of stems.

Ⅳ. Discussion

The sprouting regeneration takes important role on maintenance of natural forests after natural or manmade disturbances. Through the pre-existing strong root systems to take up the nutrients from soil, the sprout stems grow fast and take prevailing position in composition of species compared with seedling stems (He *et al*., 2000; Miura and Yamamoto, 2003). Therefore, sprout regeneration is considered to be an important forest regeneration measure and obtained worldwide concerns at a global scale in recent decades (Harmer *et al*., 1997; Peterken, 1993; Stefan, 2002).

Shinzato *et al*. (2000) found that 79.8 % of the 1,893 stumps sprouted 5 years after clear-cutting in northern part of Okinawa Island, Japan. Wu *et al*. (2004) found the primary dominant species *C. sieboldii* dominated the secondary forest five years after clear-cutting in the northern Okinawa Island. Other researcher also found the similar result that species with strong sprouting capacity often come to dominate young secondary stands by vegetative regeneration (Noble and Slatyer, 1980; Tsuyuzaki and Haruki, 1996) in other regions. In the present study, stump sprout origin stems had basal area as high as 7.65 m^2 ha^{-1}, far more than that for the residual sprout origin stems (1.51 m^2ha^{-1}) ; moreover, most of canopy stems were from stump sprout origin stems, suggesting that the stump sprout origin stem is an important source of regeneration, and that the residual sprout stem makes less contribution to the selective logged secondary forest in the early stage.

Except for existence of stump sprout origin stems, abundant seedling stems occurred in the 8-yr-old secondary forest. In the present study, seedling origin stem had the highest stem density (50,900 stems ha^{-1}), which was 8-fold more than that of stump origin stem (6,113 stems ha^{-1}), and nearly 2-fold than that of residual stem (26,375 stems ha^{-1}). However, for the basal area, seedling shared only 23.0 % of the basal area in the forest. Moreover, the seedling sprout origin stems were mainly distributed in lower layers at 1-3 m (Fig. 3). The results suggested the seedling origin stems also had limited contribution to the secondary forest in the early stage compared to the stump sprout and residual origin stems. However, because of existence of abundant of seedling origin stems, they might take an important role in the future.

In the present study, *C. sieboldii* not only dominated absolutely in stump origin stems, but also dominated in residual, seedling and residual sprout origin stems, demonstrating that *C. sieboldii* is a fast growing species, and that it maintains populations by various ways in such a disturbed evergreen broad-leaved forest. The result may be a reason why *C. sieboldii* usually dominates in the natural evergreen broad-leaved forest in subtropical Okinawa. On the other hand, in the present study, *D. trifidus* had the annual mortality as high as 7.3 % $year^{-1}$, being nearly half of the residual origin stems (Table 2). Shinzato *et al*. (2000) reported *D. trifidus* had mortality as high as 90.5 % of a total of 21 stumps 5 years after clear-cutting in northern part of Okinawa Island. Thus, most attention should be paid to this species to restore a forest by natural regeneration.

After selective logging, huge gaps were created. In these gaps, great light intensity on the forest floor may promote the establishment of shade intolerant species. In the present study, several pioneer species were present abundantly, such as *G. acuminatum*, *Mallotus japonicus*, the former had a stem density of 2,275 stems ha^{-1}. Present of abundant of pioneer species suggesting that the 8-yr-old secondary forest was in the beginning stage of succession.

Ⅴ. Conclusion

The secondary forest after selective logging was contributed by the residual and stump sprout origin stems rather than seedling or residual sprout origin ones 8-yr-old after selective logging of an evergreen broad-leaved forest in subtropical Okinawa. The upper layers of the forest were mainly consisted by stump sprout and residual origin stems whereas the seedling and residual sprout origin ones shared mainly the lower layers. The increases of woody species with abundant of MM species as well as a great of M, NM and N species, suggested that the structure of the secondary forest to be complex, and with a distinct stratification. The secondary forest showed no signs of degeneration, but rather a progressive succession. From above results we predict that the secondary forest might gradually recover to a forest stand similar to that before selective logging. However, it should be pointed out that, this investigation is an early succession of the forest regeneration after all, further long-term investigation is necessary.

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