Bull. Faculty of Liberal Arts, Nagasaki Univ.,(Natural Science), 36(1), 19–30 (July 1995)

Studies in the Evergreen Broad-Leaved Forest of Tatera Forest Reserve, Tsushima, Japan.

VII. Comparative analysis of the structure and composition of primary and secondary stands

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(Received May 2, 1995)

Abstract

In the Tatera Forest Reserve, tracts of secondary forests are contiguous to the primary forest. The secondary forest is young and regenerating after deforestation for production of charcoal. Our comparative study in the primary and secondary forests revealed that the canopy gap is present in the primary forest but absent in the secondary one, that *Castanopsis cuspidata* var. *sieboldii* is the dominant canopy tree species in both of the forests, and that *Distylium racemosum*, the second dominant in the canopy of the primary forest, is the major species having abundant regenerating saplings in the both forests. Those facts imply that the secondary forest will surely reach the same status as the primary forest and merge in the latter without difference in structure and composition, unless man disturbs or interferes the secondary forest tract for many years in the future. One of the conclusions in the present study emphasizes the importance of the secondary forest for the preservation of primeval forest.

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Introduction

The primary, or primeval, evergreen broad-leaved forest is rare on gentle slope in Japan, since such habitat has ever been exploited for agricultural purpose for centuries. The Tatera Forest Reserve, however, is the exception (Itow, 1991 ; Yamamoto, 1992). The forest in the reserve is primeval in condition, 25-30 m in height and 50-100 cm in diameter of trunk. The reserve is surrounded by secondary, or second-growth, forest, which is found on the same topography contiguous to the reserve and is composed of nearly the same species with the primary forest of the reserve. Such a situation is also rare in Japan and provides a good field for comparative study of the primary and secondary forests.

In the series of studies in the Tatera Forest Reserve, Tsushima, our previous paper of the reserve (Yamamoto and Itow, 1994) described the actual state of canopy gaps and gap regeneration of major tree species in the primary forest. In the present paper, we aim to clarify the difference and similarity in species composition and structure between the primary and secondary forests and to evaluate the importance of the secondary forest for conserving the reserve and in preserving the undisturbed forest ecosystem.

Study area and Methods

Study area

Tatera Forest Reserve is located in the center of the South Island of Tsushima, at 34° 25' N and 129° 20' E, between the Japanese Archipelago and the Korean Peninsula. The reserve, ca. 100ha, is situated on the north-facing slope of Mt. Tatera, ranging from 120m to 560m above sea level. The topography is flat and gentle in the low and middle altitudes, and rather steep at high altitudes. The well-developed evergreen broad-leaved forest is dominated by *Castanopsis cuspidata* var. *sieboldii* or *Distylium racemosum* at low altitudes, and by *Quercus acuta* at high altitudes. The reserve has been free from human interference for centuries (Itow, 1991). See Itow (1989) and Itow et al. (1992) for environmental features and outline of the vegetation of the reserve. Secondary forests, which surround the reserve, seem to be young regenerating forests abandoned after deforestation for production of charcoal.

Two study stands in the primary forest and a study stand in the secondary forest were sampled on the lower part (100-140 m a. s. l.) of north-facing gentle (inclination ; 0 – 10°) slope. Two study stands in primary condition are equivalent to Stands 1 and 2 in the previous paper (Yamamoto and Itow, 1994). In this paper, these two stands were treated as a primary stand after lumping together. General height of canopy layer of the primary stand was 20-30 m and that of the secondary stand was about 20 m. Canopy gaps were not formed in the secondary stand.

Methods

Next four regeneration categories were defined and used in this study : (1) 'canopy trees' were defined as trees which reach the canopy layer (usually with more than 30 cm of dbh (diameter at breast height) in the primary stand) ; (2) 'gapmakers' were defined as trees more than 30 cm dbh creating a gap ; (3) 'suppressed saplings' and (4) 'gap successors' were defined as the tallest sapling (taller than 1.3 m height, including non-canopy tree species) beneath the crown of each canopy tree and in a gap, respectively. In the case of canopy and sub-canopy trees, therefore, suppressed saplings mean their advance regenerations (Bormann and Likens, 1979) beneath a closed canopy. Gap successors mean the most probable next occupant in the canopy or the sub-canopy layers of the gap, and include both the advance regenerations and the new individuals (Bormann and Likens, 1979).

In both primary and secondary stands, along transect lines, species name and dbh of canopy trees were recorded by the point-centered quarter method (Cottam and Curtis, 1956), which has been considered the most efficient of the available distance methods (Mueller-Dombois and Ellenberg, 1974). Dbh of all trunks was measured when canopy trees were individuals with multi-trunks at breast height. According to the rules of the point-centered quarter method, not less than 20 points were selected at random along transect lines in both stands. The starting point of the initial transect line was located randomly in each study stand. The direction of transect lines was altered when the top of lines met any microtopographic changes (e. g. creek or small cliff). Beneath the crown of each canopy tree recorded, the species name, dbh, and whether they are sprouts or not for suppressed saplings were also recorded. Relative densities of canopy trees and suppressed saplings were calculated from the point-centered data. For the calculation of relative density, individual density was used.

The ground area under a canopy opening was defined as a 'gap'.

Therefore, my definition is different from expanded gaps by and is equivalent to canopy gaps by the definitions of Runkle (1981) ; gaps are taken to become indistinguishable from the background overstory when regeneration within the gap has reached a height of more than about 10 m. All gaps whose rough center was contained within either side of a 10 m distance perpendicular to the transect lines were described. For each gap, species name and dbh of gapmakers were recorded. Estimated values were used for the dbh of partly decomposed or broken-trunk (at breast height) gapmakers, although these were few such cases. The species name, dbh, and whether they are sprouts or not for gap successors were also noted. Density of gapmakers in the primary stand was calculated from their numbers in the total surveyed area of the stand.

Total surveyed area was calculated by the product of width of belt transects (i.e. 20 m) and the length of the transect lines. Based on the total number of gapmakers and gap successors in total surveyed area of the primary stand, relative densities of gapmakers and gap successors in each tree species were calculated. Field survey was done in October of 1989, of 1991 and of 1992.

Results

Relative density of tree species occurred

Seventeen tree species occurred in the canopy layer of primary and secondary stands (Table 1). In the primary stand, first dominant species in the canopy layer was *Castanopsis cuspidata* ; *Distylium racemosum* and *Quercus salicina* followed. *Castanopsis cuspidata* that is the first dominant species occurred in canopy trees, gapmakers and gap successors ; the relative densities were higher in canopy trees and gapmakers. However, the species did not occur or occurred very few in suppressed saplings. Next dominant species, *Distylium racemosum*, occurred in every regeneration category with higher relative densities except for gapmakers. Third dominant species, *Quercus salicina*, occurred in canopy trees and gapmakers with relatively higher relative densities, but it lacked completely suppressed saplings and gap successors. *Cleyera japonica* occurred in suppressed saplings and gap successors with higher relative densities, while the relative densities in canopy trees and gapmakers were very low.

Table 1. Relative densities (%) of tree species of each regeneration category (CT, canopy tree ; GM, gapmaker ; SS, suppressed sapling ; GS gap successor) in primary and secondary stands in the Tatera Forest Reserve.

Species	Primary stand				Secondary stand	
	CT	GM	SS	GS	CT	SS
Camellia japonica		2.2	9.9	7.1	0.5	5.5
Carpinus tschonoskii	0.8					
Castanopsis cuspidata	42.2	48.3	0.4	8.6	74.5	6.0
Cinnamomum insularimontanum			1.1	4.3		
Cleyera japonica	0.8	6.7	28.4	15.5		3.0
Daphniphyllum macropodum				1.6		4.5
Dendropanax trifidus	2.3	3.8	10.2	4.3		21.0
Distylium racemosum	33.1	5.9	35.7	37.8	5.0	23.0
Eurya japonica			0.8	1.6		1.5
Evodia meliaefolia					0.5	
Fagara ailanthoides	0.4		1.0		1.0	
Idesia polycarpa	0.4				1.0	
Illicium anisatum			0.4			
Ilex integra	0.8		1.1	1.0		3.0
Ilex rotunda		0.7				
Kalopanax pictus					0.5	
Ligustrum japonicum			0.4			3.0
Litsea acuminata				0.8		
Litsea lancifolia				1.0		
Michelia compressa					1.0	
Morus australis				1.0		
Neolitsea aciculata	0.4		1.2	2.0		1.0
Neolitsea sericea			0.8	1.6		1.0
Persea japonica	0.9	0.8	0.8	1.0		
Persea thunbergii	0.8			1.0	1.5	1.5
Pinus densiflora					2.0	
Podocarpus macrophyllus	0.4	1.5	3.6	2.0		
Prunus jamasakura	0.5				2.5	0.5
Quercus acuta	1.2				4.5	4.0
Quercus salicina	14.2	23.0			1.0	1.0
Quercus serrata					1.0	
Rhus succedanea	0.5				0.5	
Symplocos lucida			2.9	3.3	2.5	8.0
Symplocos prunifolia			0.8	3.1	1.0	7.0
Ternstroemia gymnanthera	0.8	0.8	1.6			3.0

In the secondary stand (Plate 1), the canopy layer was absolutely dominated by *C. cuspidata* (Table 1) ; many stems of *C. cuspidata* were sprouts from cut stumps (Plate 2). There were no other tree species with > 5%

of relative densities in the canopy layer. *Pinus densiflora*, a typical pioneer tree species, and *Quercus serrata*, a deciduous oak, occurred in the canopy. However, *D. racemosum* and *Dendropanax trifidus* occurred in suppressed saplings with relatively higher values, although the relative densities of *C. cuspidata* and *C. japonica* were low.

Size structures of *Castanopsis cuspidata* and *Distylium racemosum*

Two typical dominant species such as *C. cuspidata* and *D. racemosum* differed with their size structures. The maximum dbh of the canopy tree of *C. cuspidata* was larger than that of *D. racemosum* in the primary stand (Table 2). In the primary stand, dbh distribution of stems for the canopy

Table 2. Dbh (cm) of stems of *Castanopsis cuspidata* and *Distylium racemosum* in the primary and secondary stands in the Tatera Forest Reserve.

	Primary stand		Secondary stand	
	Canopy tree	Suppressed sapling	Canopy tree	Suppressed sapling
Castanopsis cuspidata				
Mean	92.9	17.5[1)]	27.8	12.2
Standard deviation	29.8		8.7	2.7
Minimum	38.5		12.1	8.3
Maximum	184.0		55.9	17.4
Skewness	0.648		0.411	0.311
Distylium racemosum				
Mean	56.1	17.0	39.0	6.4
Standard deviation	16.1	8.0	15.7	3.0
Minimum	30.6	5.9	14.9	1.9
Maximum	141.3	39.8	65.3	17.7
Skewness	2.238	0.929	−0.804	3.909

1) Only one stem appeared.

trees of *C. cuspidata* was bell-shaped, while that for those of *D. racemosum* was inverse J-shaped (Fig. 1). In the secondary stand, dbh distribution of stems for the canopy trees of *C. cuspidata* was bell-shaped, while that for those of *D. racemosum* was not clear for its shape (Fig. 2). Of suppressed saplings in the secondary stands, *C. cuspidata* lacked its stems with < 6 cm of dbh, although *D. racemosum* had its stems in all classes < 18 cm of dbh.

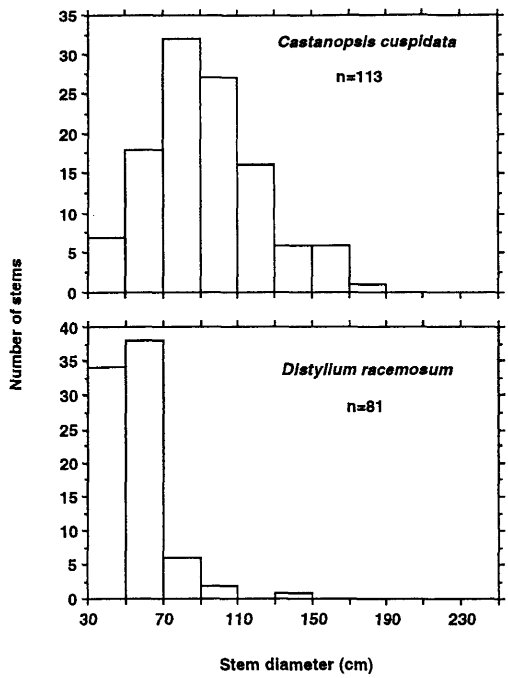

Fig. 1. Dbh distributions of stems of canopy trees for *Castanopsis cuspidata* and *Distylium racemosum* in the primary stand.

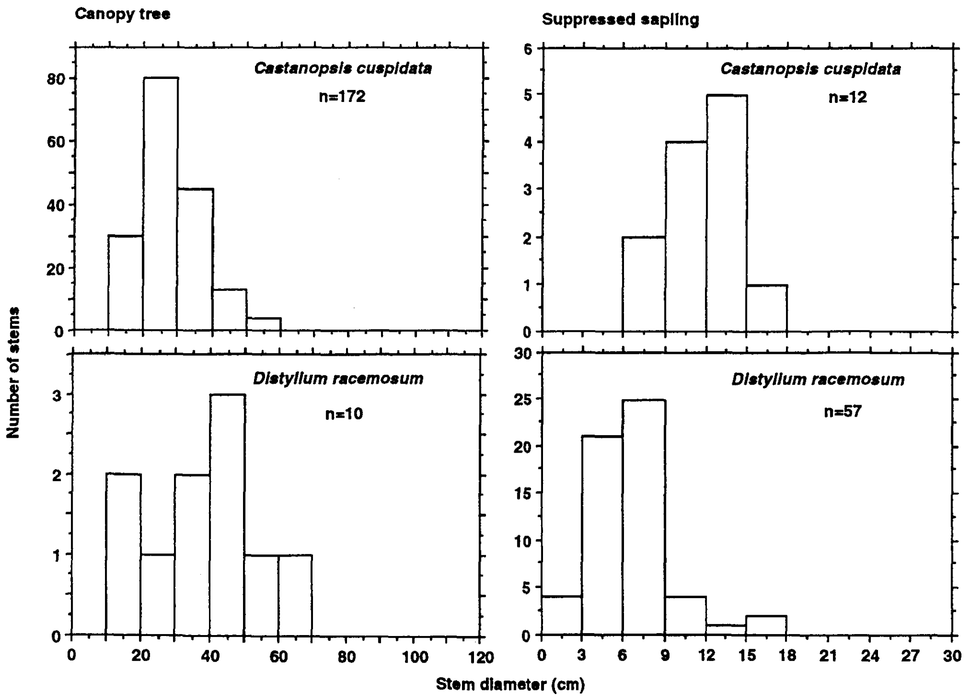

Fig. 2. Dbh distributions of stems of canopy trees and suppressed saplings for *Castanopsis cuspidata* and *Distylium racemosum* in the secondary stand.

Discussion

Regeneration pattern and developmental change

In the primary stand, *C. cuspidata* regenerates from new individuals recruited after gap formation and is considered to be pioneer tree species (Brokaw, 1985 ; Whitmore, 1989). In some cases, it replaces itself by sprouting (Yamamoto, 1992). On the other hand, *D. racemosum* regenerates from suppressed saplings recruited before gap formation and is considered to be primary (Brokaw, 1985) or climax (Whitmore, 1989) tree species ; it can not regenerate by vegetative reproduction (Yamamoto, 1992). Probably, higher shade tolerance affords *D. racemosum* to make or maintain the seedling or sapling bank under a closed canopy. Typical sub-canopy tree species, *C. japonica*, can also make the seedling or sapling bank.

In the secondary stand, *C. cuspidata* is monodominant. The sprouting ability of *C. cuspidata* may contribute to its dominance in the secondary stand after human disturbance. However, suppressed saplings of *C. cuspidata* were very few, implying the importance of this species will decrease in the canopy layer. On the other hand, *D. racemosum* was few in the canopy layer, but its suppressed saplings were abundant, implying the importance of *D. racemosum* will increase in the canopy layer. Suppressed saplings of *C. japonica* were few ; more time is needed for the return of this species.

Importance of the secondary stand

The secondary forest studied has regenerated after lumbering a few decades ago. At present, the canopy layer, ca. 20 m high, is dominated by pioneering *Castanopsis cuspidata* medium-sized trees, that have germinated from seeds or sprouted from cut stumps after the human disturbance. The well-developed second-growth forest of the present state has played apparently a role of the buffer against natural physical influences from the forest edges, and it has protected the interior structure and composition of the reserve from the natural disturbance so far. In addition, our present study revealed that *Distylium racemosum*, one of the canopy trees in the primary forest, is the major species having abundant regenerating saplings in the secondary forest as well as in the primary forest. This fact means that the secondary forest contiguous to the forest reserve will surely reach the same status as the primary forest, and merge eventually in the latter without difference in structure and composition in the future, unless man disturbs or interferes the secondary forest tract for many years. This show the ecological importance of the secondary forest in preserving the unique forest reserve on Mt. Tatera.

Acknowledgments

Financial support was provided by Grant-in Aids for Scientific Research (04304003) from the Ministry of Education, Science and Culture, and by Grant-in Aid (Bio Cosmos Program) from the Ministry of Agriculture, Fishery and Forestry, of Japan. We thank the Tsushima District Forest Office for permitting this survey. Field assistance was provided by Tohru Manabe and Tomoshi Okawa whose help is greatly acknowledged.

Summary

In the series of this study, we investigated the structure and composition of secondary forests which surround the primary forests of the Tatera Forest Reserve, Tsushima, southwestern Japan, and compared them with those of the primary forests.

1) In the primary stand, the canopy layer was dominated by *Castanopsis cuspidata* ; *Distylium racemosum* and *Quercus salicina*. *C. cuspidata* regenerated from new individuals recruited after gap formation, whereas *D. racemosum* regenerated from suppressed saplings recruited before gap formation. *Cleyera japonica* was a sub-canopy tree species and had abundant suppressed saplings.

2) In the secondary stand, the canopy layer was dominated absolutely by *C. cuspidata*. However, suppressed saplings of *C. cuspidata* were few. *D. racemosum* was few in the canopy layer, but its suppressed saplings were abundant. The importance of *C. cuspidata* will decrease and that of *D. racemosum* will increase in the canopy layer of the secondary stand.

3) The secondary stand will develop steadily to primary condition, if human disturbances will not occur. Thus, the importance of preservation or protection of the secondary stand was emphasized.

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Plate 1. Internal view of the secondary stand in the Tatera Forest Reserve. There are many suppressed saplings of *Distylium racemosum* in the understory.

Plate 2. Sprouting of *Castanopsis cuspidata* from cut stump in the secondary stand.

対馬・龍良山の照葉樹林の研究

VII. 原生林と二次林の組成と構造の比較解析

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要 約

対馬・龍良山の照葉樹林研究の一環として、本研究では原生林と二次林の組成と構造を比較解析し、原生状態への復帰過程にある二次林の保護の重要性を指摘した。

1）原生林の林冠層では、シイノキ、イスノキ、ウラジロガシが優占していた。シイノキは、ギャップ形成後、ギャップ内で定着した稚樹で更新するとともに、萌芽によっても更新していた。一方、イスノキは、ギャップ形成前に定着した稚樹がギャップ形成後、ギャップ内で成長して更新する更新様式であった。サカキは典型的な亜高木性樹種であった。

2）二次林の林冠層は、シイノキでほとんど優占されていた。このシイノキの林冠木のほとんどが萌芽起源であった。しかしながら、林内にはシイノキの稚樹や幼木が少なかった。イスノキは林冠層にはわずかしかなかったが、稚樹・幼木として多数出現した。サカキの稚樹・幼木は少なかった。

3）今後、人為撹乱がなければ、二次林の林冠層のシイノキは減少し、イスノキは増加することが予想され、この二次林は着実に原生状態へ復帰しつつあると判断された。したがって、原生状態へ復帰させるために、この二次林を人為撹乱から保護することは重要な課題といえる。