論　文

Plant Succession on the Face of Slopes of Forest Roads (IX)*

The transition of woody plants on banking slopes in the warm-temperate zone

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林道のり面の植生遷移に関する研究(IX)

暖温帯地域の盛土のり面における木本植物の推移について

江崎次夫・藤久正文

要　旨　亜熱帯および温帯地域における林道のり面の植生遷移を正確に把握するために，1984年12月に，主として暖温帯林に位置する愛媛大学農学部米野々森林研究センターと周辺の林道盛土のり面を利用して，1970年より1981年までの開設年別に5m×3mのコドラートを設定した。すでに，コドラート内の侵入木本植物の葉の形態，種数および優占種の変化とコドラート近辺の侵入木本植物の樹幹解析並びにその周辺での土壌調査とから，わずかながらも植生遷移が進行していることを，明らかにしている。今回，1987年12月，これらのコドラートの第2回目の調査を実施した。その結果，全コドラートの侵入木本植物総数は3年間で402本から618本に，種数は33種から47種に，それぞれ増加していた。先駆種のヌルデ，バイカウツギは本数が減少し，衰退傾向が認められた。しかし，それにともなって，ネズミモチ，ヤブツバキ等の常緑で比較的耐陰性の強い樹種の侵入が確認された。また，各コドラート内の侵入木本植物の樹高および根元直径分布は，典型的なL字型を示しており，稚樹は，林道のり面の侵食・崩壊防止，林道を走行する車両の安全確保あるいは木材搬出の際の支障木の伐採等の見地より，理想と考えられている連続的な更新をしていることが確認された。以上のことから，林道のり面の植生遷移は，好ましい状態で，引続き確実に進行しているものと推察された。

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* A part of this report was presented at the 99th Annual Meeting of the Jpn. For. Soc., April 1988, Niigata

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Summary: In order to clearly understand plant succession on the face of slopes of forest roads in subtropical and temperate zones, utilizing mainly the banking slopes of a forest road in the Komenono Forest Research Center, the University Forest, Ehime University and the surrounding forest situated in a warm-temperate zone, a 5m × 3m quadrat was established for every year of clearing of forest road between 1970 and 1981.

The second investigation in the quadrat established on December 12, 1984, was carried out on December 22, 1987. The results showed that the total stem number of invading woody plants increased from 402 to 618 while species number increased from 33 to 47 over the 3-year period. A tendency of atrophy of pioneer species was recognized, as the stem number of pioneer species such as *Rhus javanica* LINN. and *Philadelphus satsumanus* MIQ. decreased. However, the invasion of evergreen trees with shade tolerance, such as *Ligustrum japonicum* THUNB. and *Camellia japonica* LINN. was observed along with this change. Also, the frequency distribution of tree height and diameter at ground level of invading woody plants in each quadrat showed the typical L-form shape, and it was ascertained that seedlings were regenerating favorably. The above results indicated that continuous plant succession was definitely in progress.

Ⅰ. Introduction

The purpose of this study was to clarify the succession of vegetation in a district where the clearing of forest roads is predetermined in a subtropical and temperate zone and then to determine a method of turf work, focusing fundamental attention on the turf work executed on the face of slopes after clearing (*1, 2, 3*).

The previous paper dealt with the invasion of woody plants on banking slopes and the process of their growth as well as the degree of soil formation present (*1, 2, 3*). The second investigation of invading woodly plants in the same quadrat was carried out in December 22, 1987. With the date thus obtained, an attempt was made to discuss the growth, atrophy, total stem number and species number of invading woody plants, and the results are reported in this paper.

Ⅱ. Outline of the study area and study methods

Table. 1 General description of study area

Elevation	550~650m
Bed-rock	Grano diorite
Annual mean temperature	10.7~11.3℃
Annual mean precipitation	1,908mm
Warmth index (W.I.)	83.3~87.1℃ · month
Coldness index (C.I.)	−14.0~−11.6℃ · month

Notes : Lower limit of distribution in cool-temperate deciduous broadleaved forest zone is 85℃ · month.
Upper limit of distribution in warm-temperate evergreen broadleaved forest zone is −10℃ · month.

Part of the study area is shown in Photos. 1 and 2. Since the method of study was the same as described in the previous paper (*1, 2, 3*), details have been omitted here, and an outline of the study area is shown in Table 1. The warmth and coldness indices were obtained by the simple calculation of monthly mean temperature between 1969 and 1986 in the Komenono Forest Research Center, the University Forest, College of Agriculture, Ehime University, at an altitude of 400m with a lapse rate of temperature of 0.6°C/100m (*4, 5, 6, 8, 9, 11*). The broadleaved forests in this region were com-

posed mainly of deciduous trees such as *Quercus mongolica* FISH. var. *grosseserrata* REHD. et WILS., *Clethra barbinervis* SIEB. et ZUCC., *Pterostyrax corymbosus* SIEB. et ZUCC., *Celtis sinensis* PERS. var *japonica* NAKAI, and it was judged that the distribution zone of these forests corresponds closely to the zone delineated by these index values (*12*).

Ⅲ. Results

1. Outline of investigative results

An outline of the results of the first and second investigation of every year is shown in Table 2. Species number and total stem number tended to increase generally. However, as to mean diameter at ground level, mean stem height, and species with maximal stem height, the second measured values were not always larger than the first values due to the influence of new invaders, wind, disease, insects, etc.

Among the decreasing species, shade intolerant species with comparatively large leaves and showing fast-growth at the initial stage, such as *Rhus javanica* LINN., *Philadelphus satsumanus* MIQ., *Mallotus japonicus* MÜELLER, ARG. were conspicuous. Conversely, invaders included deciduous trees such as *Weigela floribunda* K. KOCH, *Rubus palmatus* THUNB., *Zanthoxylum piperitum* DC., and evergreen trees with comparatively strong shade tolerance, such as *Ligustrum japonicum* THUNB. and *Camellia japonica* LINN..

2. Invading woody plants

The details of invading woody plants for each year is shown in Table 3. The stem number of the germination, growth and the disappearance of woody plants for each plot for a period of 3 years from 1984 to 1987 is shown in Table 4. In the data of the first investigation, invading woody plants included a stem number of 402 for 33 species, but in the data of the second investigation the stem number became 618 for 47 species, the rates of increase being 42.4% for species number and 53.7% for stem number. The highest value with regard to frequency of appearance was 80% for *Philadelphus satsumanus* MIQ., followed by *Morus bombycis* KOIDZ. and *Rhus javanica* LINN. in that order.

However, as mentioned before, *Rhus javanica* LINN., *Philadelptus satsumanus* MIQ. and *Mallotus japonicus* MÜELLER, ARG. declined gradualy. Furthermore, the appearance of *Cladrastis platycarpa* MAKINO, *Broussonetia kazinoki* SIEB., and *Sambucus racemosa* L. subsp. *Sieboldiana* HARA was not observed.

3. Total stem number and passage of time

The relationship between total stem number and the passage of time is shown in Fig. 1. The stem number was larger than at the time of the previous investigation in each experimental plot. Plot No. 10 showed the highest rate of increase at 206%, followed by No. 5 at 188% and No. 4 at 107%.

Conversely, the lowest rate of increase was 9% for No. 8, followed by plots No. 9 and 4 at 14% and 32%, respectively. At the experimental plot after a short period it appeared that there was a general tendency toward an abundant invading stem number.

Although a conclusion cannot be made because of the lack of data from the 2nd to the 5th

Table. 2 Outline of investigative results

Plot No.	Passage of time (yrs)		Species and total stems number		Mean diameter at ground level (mm)		Mean tree height (m)		Species and height with the maximal tree height (m)		Decreasing species	Invading species
	I	II	I	II	I	II	I	II	I	II		
1	14	17	7 18	10 30	92	81	5.41	3.83	A 11.95	A 12.28	G	F and 3 species
2	13	16	5 15	4 31	83	58	3.23	2.23	B 10.50	C 11.81	B and 2 species	H and 1 species
3	12	15	12 52	16 72	33	19	1.37	1.30	D 6.20	D 5.96	G and 1 species	I and 5 species
4	11	14	8 41	9 54	25	30	1.36	1.35	E 4.85	E 4.62	J	K and 1 species
5	10	13	9 16	13 45	38	27	3.04	1.42	A 6.71	A 8.94	G and 1 species	H and 5 species
6	9	12	11 30	15 44	41	34	2.26	1.74	G 7.48	C 8.73	Nothing	H and 3 species
7	8	11	8 45	13 71	46	42	2.51	1.78	G 8.07	G 9.14	L and 1 species	F and 8 species
8	7	10	17 112	23 120	16	23	1.14	1.23	G 5.67	G 8.14	M and 2 species	N and 8 species
9	6	9	14 37	11 41	33	45	1.99	2.13	G 5.54	A 7.82	C and 6 species	O and 3 species
10	1	4	6 36	10 110	3	11	0.12	0.21	F 0.33	H 1.50	C and 1 species	H and 5 species

Notes : I was investigated on Dec. 12, 1984 II was investigated on Dec. 22, 1987

A : *Fagara ailanthoides* ENGL.
B : *Albizzia Julibrissin* DURAZZINI
C : *Mallotus japonicus* MÜELLER, ARG.
D : *Lindera erythrocarpa* MAKINO
E : *Clerodendron trichotomum* THUNB.
F : *Ligustrum japonicum* THUNB.
G : *Rus javanica* LINN.
H : *Weigela floribunda* K. KOCH
I : *Lindera umbellata* THUNB.
J : *Philadephus satsumanus* MIQ.
K : *Neolitser sericea* KOIDZ.
L : *Aralia elata* SEEM.
M : *Broussonetia kazinoki* SIEB.
N : *Camellia japonica* LINN.
O : *Zanthoxylum pipertum* DC.

Table. 3 Detailed list of invading woody plants

(No. per a plot, %)

Species	Plot No.										Total	Frequency of appearance
	1	2	3	4	5	6	7	8	9	10		
Philadelphus satsumanus MIQ.	2	—	3	—	2	4	2	7	1	1	22	80
Morus bombycis KOIDZ.		2		9	1	5	5	1	3		26	70
Rhus javanica LINN.	1	1	—		—	1	5	8	3	7	26	70
Cornus macrophylla WALLICH	6		3		2	5		5	15	3	39	70
Mallotvs japonicvs MÜELLER, ARG.	3	6			1	8	2	2	—	—	22	60
Weigela floribunda K. KOCH		22			2	3	11	4		7	49	60
Wisteria brachybotrys SIEB. et ZUCC.			3		1	5	3				12	40
Acer rufinerve SIEB. et ZUCC.				11	2	1		4	—		18	40
Stachyvrvs praecox SIEB. et ZUCC.	10	—					3	1	1		15	40
Aralia elata SEEM.							1	1	2	1	5	40
Pterostyrax hispidvs SIEB. et ZUCC.						1		3	12		16	30
Euptelea polyandra SIEB. et ZUCC.					1	2				1	4	30
Prunus Jamasakura SIEB.			1					1	1		3	30
Rvbvs palmatvs THUNB.			1	3	22						26	30
Fagara ailanthoides ENGL.	1		—		1				1	—	3	30
Garpinvs Tschonoskii MAXIM.								3		1	4	20
Gastanea crenata SIEB. et ZUCC.			1	1							2	20
Lindera erythrocarpa MAKINO			2					5			7	20
Albizzia Julibrissin DURAZZINI		—				2		2			4	20
Rosa polyantha SIEB. et ZUCC.	1						2				3	20
Acer palmatum subsp. *Matsvmurae* KOIDZ.					1			48			49	20
Acer momo MAXIM. *var marmorat* HARA *from. heterophllum* NAKAI								9	1		10	20
Styrax japonicum SIEB. et ZUCC.				3		2			—		5	20
Smilax china LINN.	2		3								5	20
Quercus serrata THUNB.								2			2	10
Carpinus laxiflora BLUME								1			1	10
Magnolia obovata THUNB.					1						1	10
Lindera umbellata THUNB.			1								1	10
Lindera glauca BLUME						1					1	10
Parabenzoin trilobum NAKAI			32								32	10
Hydrangea scandens SERIGE.								1			1	10
Orixa japonica THUNB.							28				28	10
Zanthoxylum piperitum DC.									1		1	10
Ilex macropoda MIQ.			1				—		—		1	10
Edgeworthia papyrifera SIEB. et ZUCC.				7							7	10
Rhododendron decandrum MAKINO								3			3	10
Kalopanax pictus NAKAI			1								1	10
Clerodendron trichotomum THUNB.				4							4	10
Cephalotaxus Harringtonia K. KOCH			3	15		3	7	1			29	50
Ligustrum japonicum THUNB.	3		12				1			1	17	40
Camellia japonica LINN.	1		2					1			4	30
Cryptomeria japonica D. DON			3							81	84	20
Neolitsea sericea KOIDZ.				1			1	—			2	20
Abies firma SIEB. et ZUCC.						1					1	10
Chamaecyparis obtusa SIEB. et ZUCC.										7	7	10
Euyrya japonica THUNB.								7			7	10
Broussonetia kazinoki SIEB.					—		—	—	—		0	0
Cladrastis platycarpa MAKINO									—		0	0
Sambucus racemosa L. subsp. *sieboldiana* HARA	—										0	0
Sasamorpha purpurasccens NAKAI					8						8	10
Total 31 families 46 genera 50 species	20	31	72	54	45	44	71	120	41	110	618	

Note : — Disappearance

Table. 4 Stem number of each plot on the period of 3 years from 1984 to 1987

(No. per a plot, %)

Species	Plot No.										Total
	1	2	3	4	5	6	7	8	9	10	
Philadelphus satsumanu MIQ.	△	− 5	2	− 2	△	1	−12	−11	− 1	△	−28
Morus bombycis KOIDZ.		2		− 1	1	− 1	5	1	3		10
Rhus javanica LINN.	△	− 4	− 4		− 2	2	− 3	△	− 1	3	− 9
Cornus macrophylla WALLICH	3		− 1		− 1	3		− 3	10	2	13
Mallotus japonicus MÜELLER, ARG.	2	4			△	4	− 1	− 4	− 4	−30	−29
Weigela floribunda K. KOCH		22			2	3	11	4		7	49
Wisteria brachbotrys SIEB. et ZUCC.			3		1	5	3				12
Acer rufinerve SIEB. et ZUCC.				1	− 2	△		− 2	− 1		− 4
Stachyurus praecox SIEB. et ZUCC.	1	− 1					− 4	− 5	− 1		−10
Aralia elata SEEM.							− 2	△	− 3	△	− 5
Pterostyrax hispidus SIEB. et ZUCC.						△		3	7		10
Euptelea polyandra SIEB. et ZUCC.					△	△				1	1
Prunus Jamasakura SIEB.			1					1	1		3
Rubus palmatus THUNB.			1	3	22						26
Fagara ailanthoides ENGL.			− 1							− 1	− 2
Carpinus Tschonoskii MAXIM.								2		1	3
Castanea crenata SIEB. et ZUCC.			△	△							0
Lindera erythrocarpa MAKINO			− 1					1			0
Albizzia Julibrissin DURAZZINI		− 2						1			− 1
Rosa polyantha SIEB. et ZUCC.	1						2				3
Acer palmatum subsp. *Matsumurae* KOIDZ.					1			14			15
Acer momo MAXIM. *var marmoratum* HARA *from. heterophyllum* NAKAI								9	1		10
Styrax japonicum SIEB. et ZUCC.				− 1		1			− 3		− 3
Smilax china LINN.	2		3								5
Quercus serrata THUNB.								1			1
Carpinus laxiflora BLUME								1			1
Magnolia obovata THUNB.					△						0
Lindera umdellata THUNB.			1								1
Lindera glauca BLUME						1					1
Parabenzoin trilobum NAKAI			10								10
Hydrangea scadens SERIGE.								1			1
Orixa japonica THUNB.							28				28
Zanthoxylum piperitum DC.									1		1
Ilex macropoda MIQ.			− 1				− 6		− 2		− 9
Edgeworhia papyrifera SIEB. et ZUCC.				− 1							− 1
Rhododendron decandrum MAKINO								− 2			− 2
Kalopanax pictus NAKAI			1								1
Clerodenron trichotomum THUNB.				− 1					− 1		− 2
Cephalotaxus Harringtonia K. KOCH			− 1	14		− 2	4	1			16
Ligustrum japonicum THUNB.	3		6				1				9
Camellia japonica LINN.	1		1					1			3
Cryptomeria japonica D. DON			△					− 4		81	77
Neolitsea sericea KOIDZ.				1			1	− 1			1
Abies firma SIEB. et ZUCC.						1					1
Chamaecyparis obtusa SIEB. et ZUCC.										7	7
Euyrya japonica THUNB.								2			2
Broussonetia Kazinoki SIEB.					− 1		− 1	− 3	− 1		− 6
Cladrastis platycarpa MAKINO									− 1		− 1
Sambucus racemosa L. subsp. *sieboldiana* HARA	− 1										− 1
Sasamorpha purpurascens NAKAI					8						8
Total	12	16	20	13	29	18	26	8	4	70	216

Notes : Not marks; Germination and growth, Minus marks; Disappearance, △; Not changes

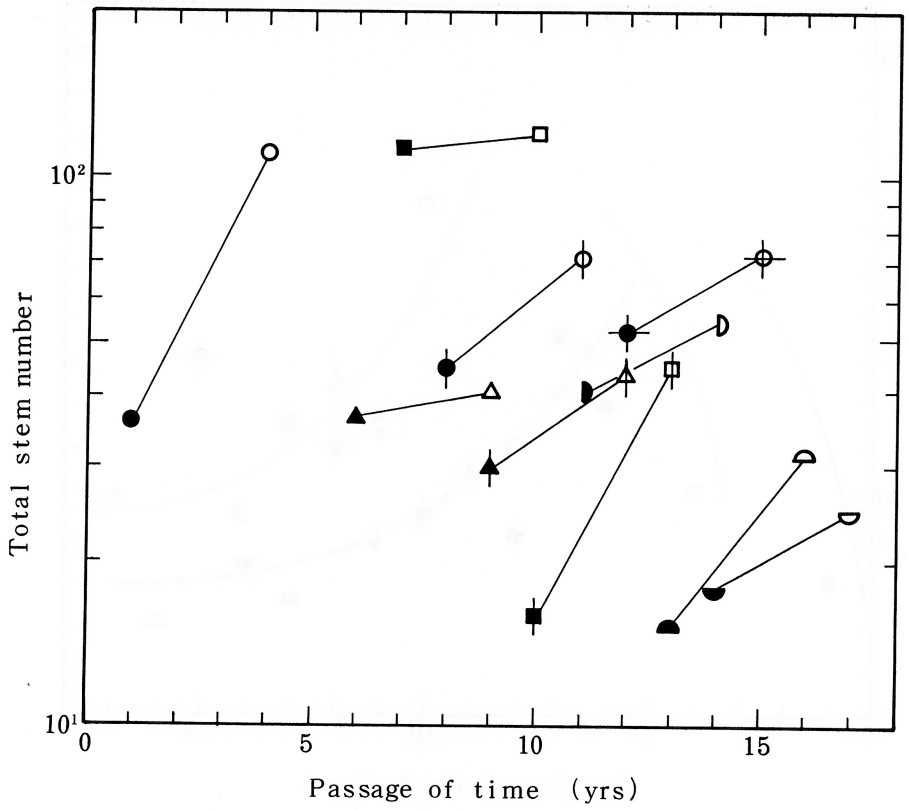

Fig. 1 Relationship between the total stem number and the passage of time

Closed marks indicate the value measured on Dec. 12, 1984.
Open marks indicate the value measured on Dec. 22, 1987.

year of the first investigation and from 5th to the 8th year of the second invesigation, it does appear that the total stem number increases and reaches a peak in about 5 to 8 years, then decreases. However, with regard to the pattern of general succession, it was considered that total stem number may increase again with the invasion of tree species with a strong shade tolerance (*1*).

4. Species number and passage of time

The relationship between species number and the passage of time is shown in Fig. 2. But species number decreased from 5 to 4 in plot No. 2 and from 14 to 11 in No. 9, species number in the order 8 exprimental plots increased from one to six species. Generally, species number tended to increase and move in parallel, unlike the results of the first investigation. Since the invasion of *Ligustrum japonicum* THUNB., *Camellia japonica* LINN. and other species was recognized in plot No.

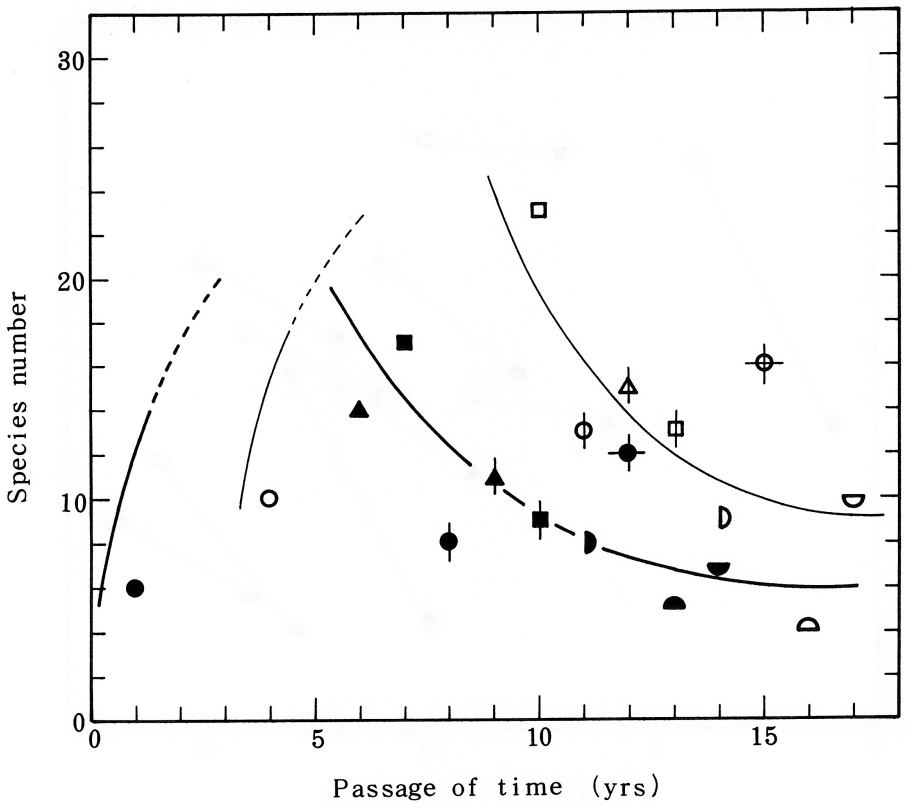

Fig. 2 Relationship between the species number and the passage of time

Plot No. 1 Plot No. 2 Plot No. 3 Plot No. 4
Plot No. 5 Plot No. 6 Plot No. 7 Plot No. 8
Plot No. 9 Plot No. 10

Closed markes indicate the value measured on Dec. 12, 1984.
Open markes indicate the value measured on Dec. 22, 1987.

1, it was presumed that tree species with a strong shade tolerance would show subsequent contiouous invasion.

5. Frequency distribution of tree height and diameter at ground level

The frequency distributions of tree height and diameter at ground level in each experimental plot are shown in Fig. 3 and the coefficients of variation are shown in Table 5. The frequency distribution of tree height and diameter showed the typical L-form shape (*7, 10*). The presence of an L-form shape and large values of coefficient of variation seem to depend on the favorable regeneration of seedlings (*14*).

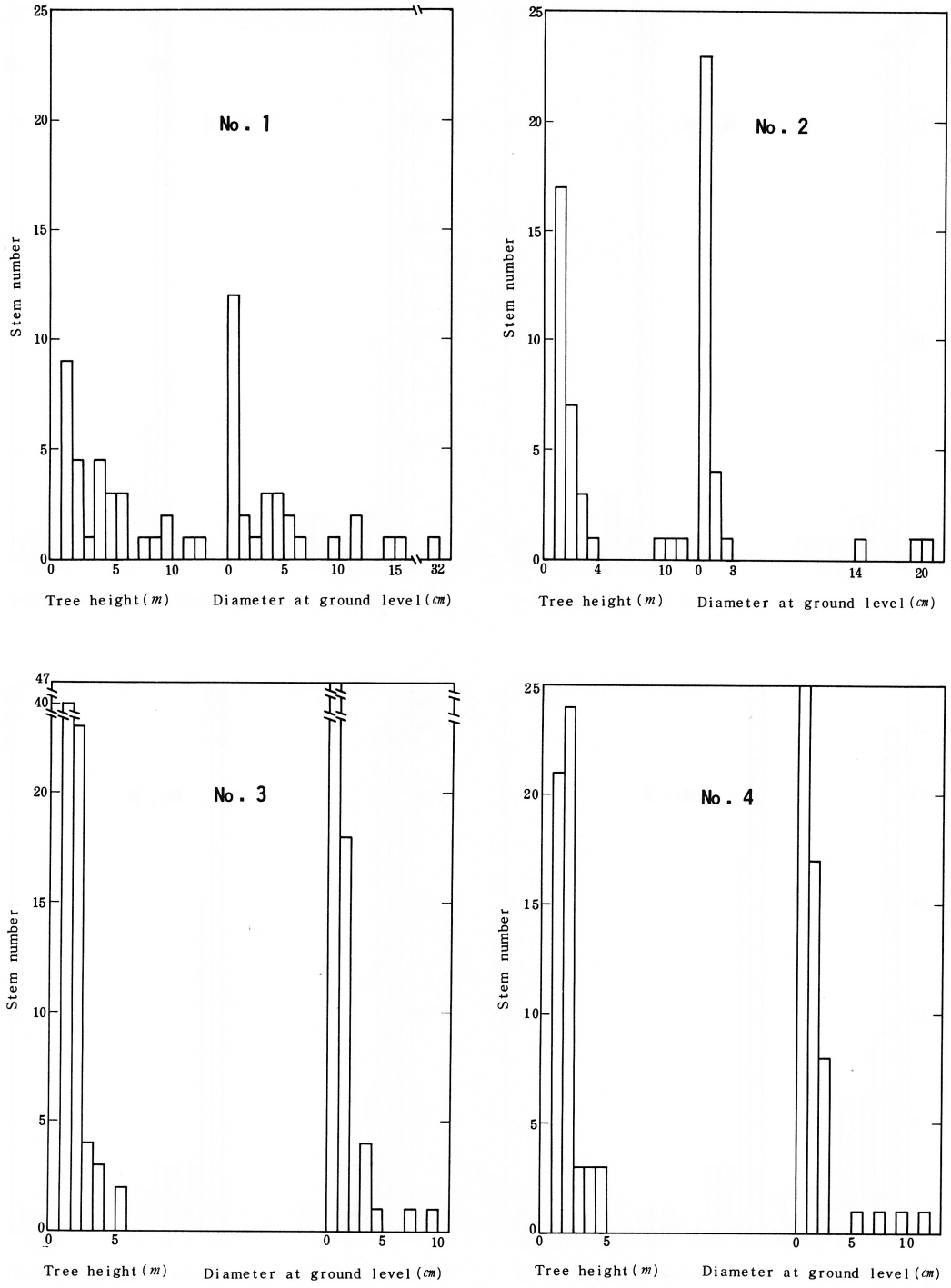

Fig. 3–1 Frequency distribution of stem number for each tree-height and diameter at ground level class on each plot

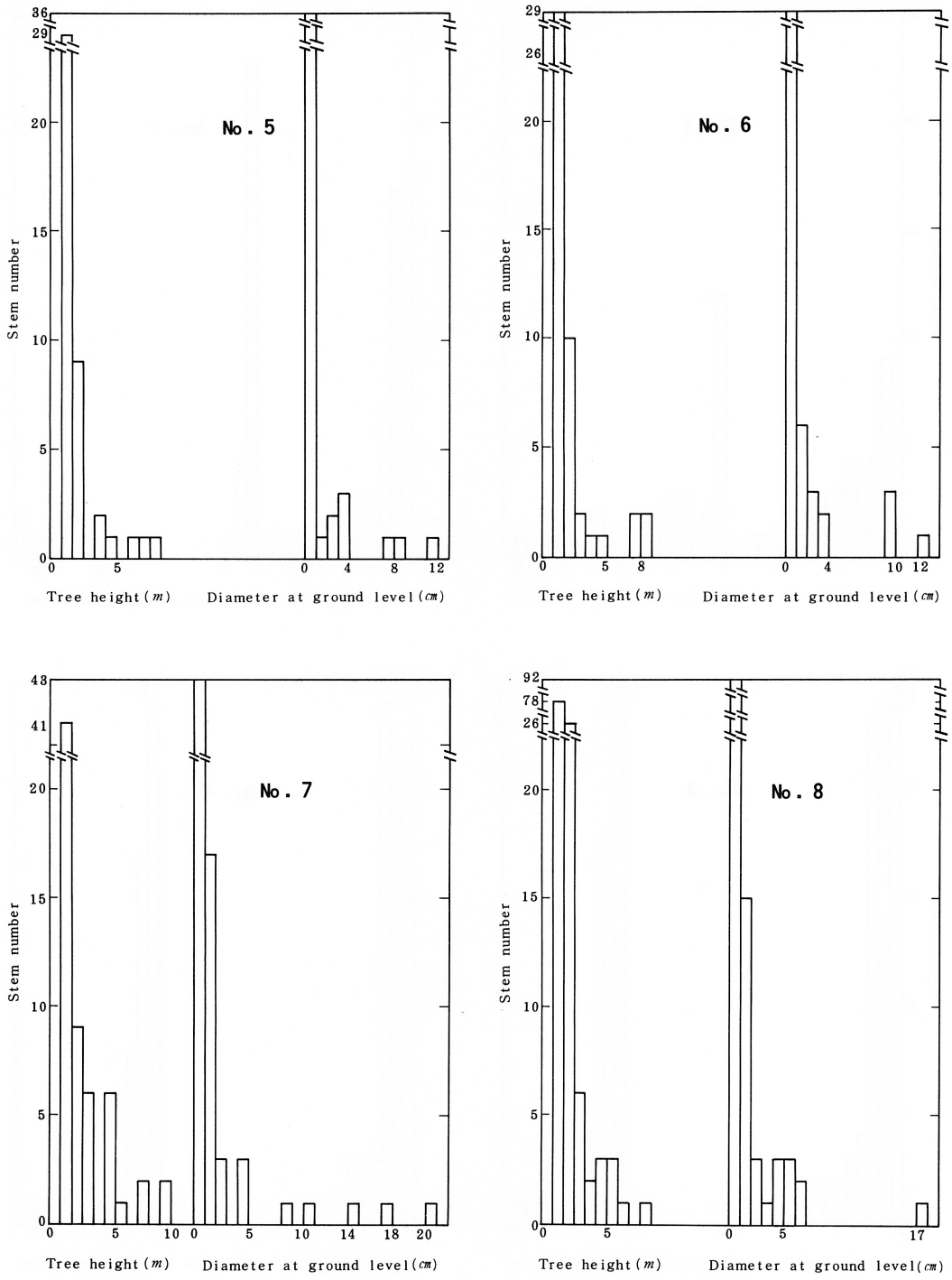

Fig. 3–2 Frequency distribution of stem number for each tree-height and diameter at ground level class on each plot

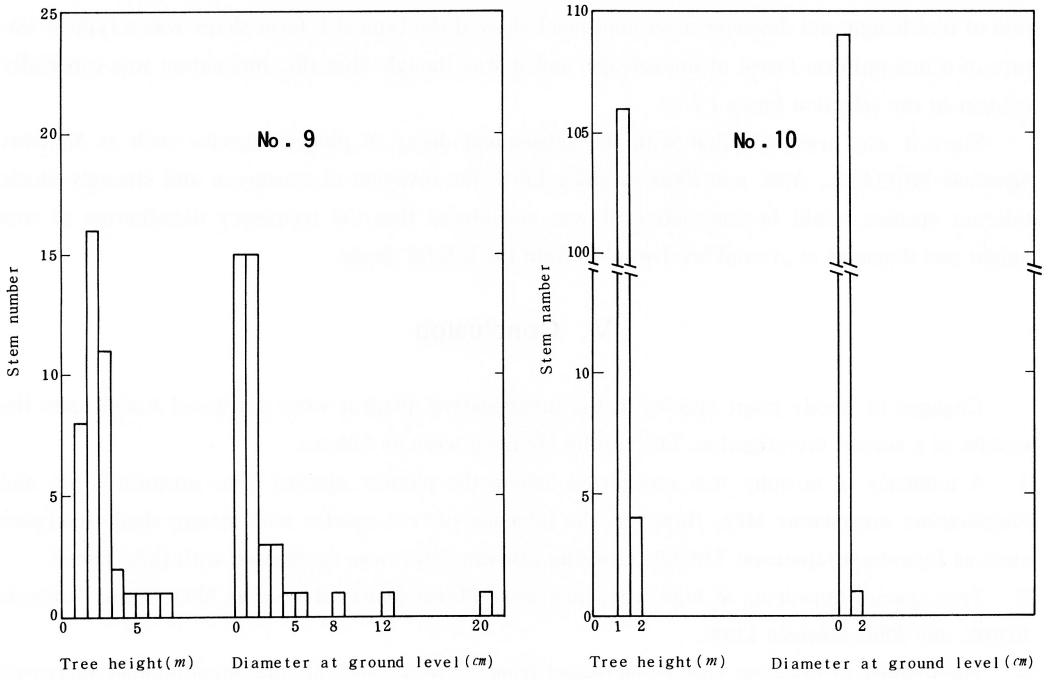

Fig. 3–3 Frequency distribution of stem number for each tree-height and diameter at ground level class on each plot

Table. 5 Coefficients of variation in distribution of stem number for each tree-height and diameter at ground level class on each plot

Unit : %

Plot No.	Tree-height	Diameter at ground level
1	61	92
2	76	90
3	72	69
4	52	70
5	59	74
6	65	88
7	62	79
8	57	93
9	54	90
10	47	47

Ⅳ. Discussion

From the findings that tree species with strong shade tolerance were invading each experimental plot, species number and stem number showed a tendency to increase and also the frequency distribution of tree height and diameter at ground level showed the typical L-form shape, it

was judged that plant succession was definitely proceeding. The fact that the frequency distribution of tree height and diameter at ground level showed the typical L-form shape was a typical feature of a non-uniform forest of uneven-age, and it was thought that this inclination was especially evident in the selection forest (*13*).

Since it was presumed that with the subsequent decay of pioneer species such as *Mallotus japonicus* MÜELLER., ARG. and *Rhus javanica* LINN. the invasion of evergreen and strongly shade tolerant species would become active, it was considered that the frequency distribution of tree height and diameter at ground level would retain the L-form shape.

V. Conclusion

Changes in woody plant species in the investigative quadrat were discussed based upon the results of a second investigation. The results obtained were as follows.

1. A tendency of atrophy was recognized among the pioneer species *Rhus javanica* LINN. and *Philadelphus satsumanus* MIQ.. However, the invasion of tree species with strong shade tolerance such as *Ligustrum japonicum* THUNB., *Camellia japonica* LINN. was recognized with this change.
2. Tree species appearing at high frequency were *Philadelphus satsumanus* MIQ., *Morus bombycis* KOIDZ. and *Rhus javanica* LINN..
3. The number of invading species increased from 33 to 47 and the total stem number increased from 402 to 618 during the period of 3 years from 1984 to 1987
4. The frequency distribution of tree height and diameter at ground level in each experimental plot showed the typical L-form shape, and it was recognized that seedlings were favorably regenerating.
5. The above results indicated that continuous plant succession was definitely in progess.

Acknowledgements

The authors thank Professor Tomomichi FUSHIMI, Professor Shigeru OGAWA, Professor Koji FUJIMOTO and Associate Professor Ikuo NINOMIYA, Department of Bioresources, College of Agriculture, Ehime University for their helpful advice and critical reading of the manuscript, and Mr. Shuichi KOHNO, Mr. Kiyotoshi OGAMI, Mr. Masao YAMAMOTO and Miss Naomi TOYOSAKI of the Komenono Forest Research Center, the University Forest, Ehime University for their assistance in the field and office. The authors are deeply indebted to Dr. Takeshi YAMAMOTO of the Forest Resources, Department of Boiresouces, College of Agriculture, Ehime University for his considerable assistance with the computer programs.

The authors also thank Professor Yoshio IDO, Faculty of Education, Ehime University for the critical reading of the manuscript.

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The titles in the parentheses are tentative translation from the original Japanese titles by the present authors.

(Received July 29, 1988)

Photo. 1–1

Condition of No.1 plot on banking slope cleared at forest road in 1970 (taken on July 24, 1988)

Photo. 1–2

Condition of No.2 plot on banking slope cleared at forest road in 1971 (taken on July 24, 1988)

Photo. 1–3

Condition of No.3 plot on banking slope cleared at forest road in 1972 (taken on July 24, 1988)

Photo. 2–1

Condition of No.5 plot on banking slope cleared at forest road in 1974 (taken on July 24, 1988)

Photo. 2–2

Condition of No.9 plot on banking slope cleared at forest road in 1978 (taken on July 24, 1988)

Photo. 2–3

Condition of No.10 plot on banking slope cleared at forest road in 1983 (taken on July 24, 1988)