Quantification of Environment Factors for Estimation of Site Index

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"A knowledge of the growth responses of forest trees to the factors of the environment is important to forest management."[1] "The relationship of the growth of forest trees to their environment, or, as it is commonly referred to, their site, is a difficult one to measure. The factors of the site and the plants themselves are interacting and interdependent, making it difficult to assign cause and effect relationships. A considerable amount of effort has been directed toward investigating the characteristics of the soil in an attempt to find some one environmental factor to serve as a reliable indicator of site quality."[1]

Nishizawa, Mashimo and Kawabata have studied, in 1965, an estimated or predicted method of site index from soil conditions and environment factors by means of the quantification in the multi-variate analysis.

In this report, the author tried to prepare "score of environment factors" for Japanese larch (*Larix leptolepis* Gordon) forests and Japanese red pine (*Pinus densiflora* S. et Z.) forests in Eastern Shinshu district by means of quantitification method by Nishizawa, Mashimo and Kawabata.

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I The Items and Categories of Environment Factors

The items and categories of environment factors surveyed in this report were shown as the following.

(1) Warm Index

① ~65°C ② 65~75°C ③ 75~85°C ④ 85~95°C ⑤ 95°C~

(2) Wind Damage

① severe ② weak ③ none

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(3) Frost Damage, Snow Damage

① receive ② none

(4) Parent Material

① Mesozoic strata, Paleozoic strata ② Tertiary stratum

③ Quaternary stratum ④ granite, diorite ⑤ andesite, basalt

⑥ volcanic ashes, volcanic clastic materials ⑦ volcanic mud

(5) Altitude

① ～600m ② 600～800m ③ 800～1,000m ④ 1,000～1,200m

⑤ 1,200～1,400m ⑥ 1,400～1,600m ⑦ 1,600～1,800m

⑧ 1,800～2,000m ⑨ 2,000m

(6) Aspect

① N (north) ② NE (north-east) ③ E (east) ④ ES (east-south)

⑤ S (south) ⑥ SW (south-west) ⑦ W (west) ⑧ WN (west-north)

⑨ none

(7) Inclination

① ～10°(flat) ② 10～20°(gentle slope) ③ 20～30°(slope)

④ 30～40°(steep slope) ⑤ 40°～(very steep)

(8) Local Topography

① erosive ridge ② erosive mountainside ③ erosive mountainfoot

④ silting ridge ⑤ silting mountainside ⑥ silting mountainfoot

⑦ balanced ridge ⑧ balanced mountainside ⑨ balanced mountainfoot

⑩ gentle slope ridge ⑪ gentle slope mountainfoot ⑫ upland

(9) Type of Soil

① BA (driest brawn forest soil) ② BB (drier brawn forest soil)

③ BC (dry brawn forest soil) ④ BD (dry) (weakly dry brawn forest soil)

⑤ BD (moderately moist brawn forest soil)

⑥ BE (slightly wet brawn forest soil) ⑦ BF (wet brawn forest soil)

⑧ BlB, BlC (dry black soil) ⑨ BlD (moderately moist black soil)

⑩ BlE (slightly wet black soil) ⑪ PDI, PDII, PDIII (podzolized soil)

⑫ PW (wet podzolized soil)

(10) Depth to the Bedrock

① ～30cm (very shallow) ② 30～60cm (shallow) ③ 60cm～ (deep)

(11) Soil Structure

① sandy soil ② loam ③ clay ④ gravel soil

(12) Type of soil silting

① residual soil ② colluvial soil ③ fluvial soil ④ creep soil

And site index was estimated by average tree height of 1 m interval at 35 years of age in Japanese larch forest, and at 40 years of age in Japanese red pine forest. Site index at each sampling point was determined by "site index curve", which prepared by means of "Der Bestandesaufbau und der Zuwachsverlauf in der Shinshulärchenbestände in der Gegend um Ueda (1970)",[5] "Actual yield table for Japanese larch forests in Eastern Shinshu district (1967)" and "Actual yield table for natural Japanese red pine in Central and Southern Shinshu district (1966)".

Average tree heights for each age class and each site index were tabulated

Table 1 Average tree heights in Japanese larch forest for each age class and each site index

(Unit : height, m ; age, year)

age class → / site index ↓	10	15	20	25	30	35	40	45	50
8	3.96	4.55	5.91	6.87	7.42	8.00	8.76	9.41	10.07
10	4.64	5.98	7.21	8.40	9.21	10.00	10.90	11.68	12.44
12	5.31	6.99	8.51	9.93	11.30	12.00	13.04	13.95	14.82
14	5.98	8.00	9.81	11.46	12.79	14.00	15.18	16.22	17.20
16	6.65	9.01	11.11	12.99	14.58	16.00	17.33	18.49	19.58
18	7.32	10.02	12.41	14.53	16.37	18.00	19.48	20.77	21.95
20	7.99	11.03	13.71	16.06	18.16	20.00	21.62	23.05	24.32
22	8.66	12.04	15.01	17.60	19.95	22.00	23.76	25.32	26.69
24	9.33	13.05	16.31	19.14	21.74	24.00	25.91	27.60	29.06
26	10.00	14.06	17.61	20.67	23.53	26.00	28.06	29.87	31.43

Table 2 Average tree heights in Japanese red pine forest for each age class and each site index

(Unit : height, m ; age, year)

age class → / site index ↓	10	15	20	25	30	35	40	45	50	55	60	65	70
6	1.80	3.10	3.90	4.50	5.00	5.50	6.00	6.50	6.90	7.20	7.60	7.90	8.10
8	2.82	4.38	5.43	6.20	6.82	7.42	8.00	8.58	9.06	9.44	9.90	10.26	10.50
10	3.85	5.66	6.96	7.90	8.65	9.34	10.00	10.66	11.22	11.68	12.20	12.62	12.90
12	4.87	6.95	8.49	9.60	10.47	11.25	12.00	12.74	13.38	13.92	14.50	14.98	15.30
14	5.90	8.23	10.02	11.30	12.30	13.17	14.00	14.82	15.54	16.16	16.80	17.34	17.70
16	6.92	9.51	11.55	13.00	14.12	15.09	16.00	16.90	17.70	18.40	19.10	19.70	20.10
18	7.94	10.79	13.08	14.70	15.94	17.01	18.00	18.98	19.86	20.64	21.40	22.06	22.50
20	8.97	12.07	14.61	16.40	17.77	18.93	20.00	21.06	22.02	22.88	23.70	24.42	24.90
22	9.99	13.36	16.14	18.10	19.59	20.84	22.00	23.14	24.18	25.12	26.00	26.78	27.30
24	11.02	14.64	17.67	19.80	21.42	22.76	24.00	25.22	26.34	27.36	28.30	29.14	29.70

in Table 1 and Table 2.

II Field Sample

The basic data of this report have been gathered in Eastern Shinshu district, Nagano Prefecture, in August and September 1972, by the members of our seminary.

Sample plots were taken at random from Japanese larch and Japanese red pine forests. In each sample plot, were surveyed the environment factors and its site index. These samle plots distribute as in Table 3.

And for this report, an additional 104 sample plots, which surveyed in 1967, were annexed in the case of Japanese larch forests.

Table 3 Number of Sample Plots

	Larch	Red Pine	Total
Saku T.	13	5	18
Koumi T.	12	6	18
Kawakami V.	28	5	33
Kitaaiki V.	13	2	15
Yachiho V.	15	4	19
Minamisaku Total	81	22	103
Saku C.	21	18	39
Komoro C.	13	13	26
Mochizuki T.	12	10	22
Tateshina T.	7	8	15
Kitasaku Total	53	49	102
Maruko T.	—	10	10
Shioda T.	—	10	10
Sanada T.	11	6	17
Takeshi V.	2	18	20
Kawanishi V.	—	24	24
Aoki V.	3	16	19
Josho Total	16	84	100
Total	150	155	305

III Analysis of Data

The results surveyed in field were rearranged to the cross table between each item and category as in Table 4 and Table 5.

Table 4 Cross Table for Japanese Larch

Item →			Warm Index				Wind Damage			Frost, Snow Damage		Parent Material							Altitude					Aspect									Inclination				Local Topography									Type of Soil						Depth to the Bedrock			Soil Structure			Type of Soil Silting			
↓	Category		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59
Warm Index	~65°C	1	70																																																										
	65~75°C	2		62																																																									
	75~85°C	3			75																																																								
	85°C~	4				47																																																							
Wind Damage	severe	5	6		1		7																																																					
	weak	6	7	5	8	6		26																																																				
	none	7	57	57	66	41			221																																																			
Frost Snow Damage	receive	8	6		3		5		4	9																																																	
	none	9	64	62	72	47	2	26	217		245																																																
Parent Material	Mesozoic strata 1)	10	17	31	2			3	47		50	50																																															
	Tertiary stratum	11	3	7	16	13	1	4	34	1	38		39																																														
	Quaternary stratum	12	27	8				1	34		35			35																																													
	granite diorite	13			6			3	3	1	5				6																																												
	andesite, basalt	14	23	10	45	17	6	8	81	7	88					95																																											
	volcanic ashes 2)	15		1	6	17		7	17		24						24																																										
	volcanic mud	16		5					5		5							5																																									
Altitude	~800m	17			5	11		1	15		16		9			3	4		16																																								
	800~1,000m	18	8	7	43	30		9	79	2	86	9	22	1	3	34	19			88																																								
	1,000~1,200m	19	18	15	25	6		7	57	2	62	7	7	12	3	31		4			64																																							
	1,200~1,400m	20	34	28	2		6	5	53	4	60	22	1	18		21	1	1				64																																						
	1,400m~	21	10	12			1	4	17	1	21	12		4		6							22																																					
Aspect	N	22	10	14	11	12		3	44		47	11	5	4		23	3	1	2	25	6	9	5	47																																				
	NE	23	4	11	8	6		1	28	1	28	11	4	2	3	8	1		2	9	7	8	3		29																																			
	E	24	2	3	6	7	1	6	11	1	17	3	4		2	5	4		3	8	3	3	1			18																																		
	SE	25	6	6	11	6	1	5	23		29	1	9	5		9	3	2	1	8	9	10	1				29																																	
	S	26	5	3	9	2		1	18		19	2	3	3		8	2	1	1	6	8	3	1					19																																
	SW	27	6	12	8		1	4	21	1	25	6	4	6		8	2		1	7	8	7	3						26																															
	W	28	16	6	12	3	3	3	31	4	33	4	8	4		20	1		2	9	13	9	4							37																														
	NW	29	13	5	10	9		3	34	2	35	9	1	6	1	13	7		2	16	7	9	3								37																													
	none	30	8	2		2	1		11		12	3	1	5		1	1	1	2		3	6	1									12																												
Inclination	~10°	31	39	24	23	15	2	9	90	2	99	25	13	17	2	33	7	4	5	29	24	32	11	20	13	3	10	7	6	13	17	12	101																											
	10~20°	32	14	25	24	13	2	7	67	3	73	17	15	10	3	25	5	1	5	28	19	16	8	16	5	6	9	6	12	13	9			76																										
	20~30°	33	11	11	23	11	3	6	47	3	53	7	9	4		29	7		4	22	15	13	2	9	6	6	7	6	4	10	8				56																									
	30°~	34	6	2	5	8		4	17	1	20	1	2	4	1	8	5		2	9	6	3	1	2	5	3	3		4	1	3					21																								
Local Topography	steep slope ridge	35				3		1	2		3					1	2			3				1	1						1				2	1	3																							
	erosive mountainside	36	2	4	5	2		1	12		13	4	3	3	1	2			1	4	5	3		1	2	1			5	2	2		2	3	6	2		13																						
	erosive mountainfoot	37	1	3		4		1	7		8	3	2				2	1	1	4	1	2		1	1	1	1		1		3		3	2	2	1			8																					
	silting mountainside	38	8	8	9	4		1	28	3	26	9	2	3	2	12	1			8	10	8	3	3	6	2	3	2	2	5	6		9	8	8	4				29																				
	silting mountainfoot	39	20	10	30	10		5	65		70	10	16	10	2	25	5	2	7	29	18	14	2	20	5	6	12	6	2	9	7	3	39	20	10	1					70																			
	balanced mountainside	40	16	25	25	15	3	12	66	3	78	22	8	8	1	33	8	1	2	29	23	17	10	13	11	7	10	7	8	12	12	1	17	28	25	11						81																		
	gentle slope ridge	41	7	6	3	1	4	3	10	3	14	1	2	2		9	2	1		5	3	5	4	1		1	1	1	4	5	1	3	6	7	3	1							17																	
	gentle mountainfoot	42	10		2	2			14		14	1		8		4	1		1	3	1	7	2	4	1			2	1		3	3	13	1										14																
	upland	43	6	6	1	6		2	17		19		6	1		9	3		4	3	3	8	1	3	2		2	1	3	4	2	2	12	7											19															
Type of soil	BA・BB・BC	44	5	5	6	2	3	3	12	2	16	2	2	3	2	8	1		1	3	6	6	2	2	3	1	2	1	3	4	1	1	4	4	5	5		6		1	2	6	3			18														
	BD(dry)	45	3	5	7	2		1	16		17	7	1	1		7	1		3	8	2	3	1	5	2	1	1	2	2		2	2	6	5	6			1	2	2	3	6	2		1		17													
	BD	46	40	23	44	20	3	6	118	4	123	33	18	19		52	5		11	44	36	26	10	22	16	8	12	8	13	18	25	5	43	40	32	12	1	6		18	32	55	4	7	4			127												
	BE・BF	47	3	9	11	5		4	24	1	27	7	10		2	9			3	9	8	6	2	6	7	3	3	3	1	4	1		14	8	5	1			3	5	20								28											
	BlD	48	18	15	7	10	1	9	40	2	48	1	8	11	2	15	8	5	4	16	11	18	1	9		2	8	5	7	11	5	3	26	17	7		2		1	3	7	12	8	7	10					50										
	BlE	49	1	5		8		3	11		14			1		4	9			8	1	5		3	1	3	3				3	1	8	2	1	3			2		6	2			4						14									
Depth	very shallow	50	4	2	4	6		3	13		16	1	6	2		3	3	1	3	9	2		2	3		1	4	3	1		4	6	6	5	2	3		1	2		6	4	2	1		1	3	3	5	2	2	16									
	shallow	51	19	27	37	21	5	14	85	6	98	22	17	6	6	37	12	4	7	39	25	25	8	15	13	7	15	6	7	18	17	6	47	33	18	6	2	6	3	15	26	30	8	7	7	11	8	47	12	21	5		104								
	deep	52	47	33	34	20	2	9	123	3	131	27	16	27		55	9		6	40	37	39	12	29	16	10	10	10	18	19	16	6	48	38	36	12	1	6	3	14	38	47	7	6	12	6	6	77	11	27	7			134							
Soil structure	sandy soil, gravel soil	53	3	4	1	5		1	12		13	2	2	4		1	3	1	2	4	1	4	2	1	2	2	1	2		1	2	2	7	1	3	2		1	1	1	4	2		4		2		3	4	3	1	3	5	5	13						
	loam	54	31	11	31	3	1	8	67	1	75	15	10	20	2	22	4	3	7	19	29	20	1	10	10	1	16	4	9	7	13	6	28	22	16	10		6	2	6	29	24	3	5	1	6	8	41	6	14	1	7	33	36		76					
	clay	55	36	47	43	39	6	17	142	8	157	33	27	11	4	72	17	1	7	65	34	40	19	36	17	15	12	13	17	29	22	4	66	53	37	9	3	6	5	22	37	55	14	5	18	10	9	83	18	33	12	6	66	93			165				
Soil Silting	residual soil	56	22	16	21	14	5	9	59	5	68	6	17	6	1	33	9	1	7	30	11	14	11	9	5	5	6	3	14	17	8	6	26	25	15	7	1	7		2	8	22	17		16	9	6	32		25	1	5	31	37	1	16	56	73			
	colluvial soil	57	21	11	29	12		6	67	3	70	15	16	10	2	24	4	2	7	29	22	13	2	14	9	7	10	5	2	11	14	1	34	23	13	3		2	3	14	47	7				1	3	40	22	4	3	5	32	36	3	31	39		73		
	fluvial soil	58	13	6	6	2		2	25		27	6	2	11	2	4	1	1	1	7	3	12	4	6	2	1	1	4	2		6	5	21	6					1	2	7	3		14			1	10	3	12	1	3	12	12	5	8	14			27	
	creep soil	59	14	29	19	19	2	9	70	1	80	23	4	8	1	34	10	1	1	22	28	25	5	18	13	5	12	7	8	9	9		20	22	28	11	2	4	4	11	8	49			3	8	7	45	3	9	9	3	29	49	4	21	56				81
	Site Index Total		1,367	1,200	1,609	947	104	482	4,537	156	4,967	1,012	828	681	125	1,909	466	102	343	1,877	1,291	1,194	418	981	629	363	590	387	498	676	765	234	2,038	1,508	1,152	425	55	241	158	619	1,504	1,614	283	294	355	328	327	2,665	610	951	247	325	2,069	2,729	274	1,586	3,263	1,417	1,563	573	1,570

1) and Paleozoic strata 2) and volcanic clastic materials

Table 5 Cross Table for Japanese Red Pine Forests

Item →	Category	No.	Warm Index					Parent Material				Altitude				
↓			1	2	3	4	5	6	7	8	9	10	11	12	13	14
Warm Index	~65°C	1	11					5		6						11
	65~75°C	2		15				6	3	4	2		2	2	9	2
	75~85°C	3			26				4	17	5		5	20	1	
	85~95°C	4				71			61	5	5	8	30	29	2	2
	95°C~	5					32		32			19	12	1		
Parent Material	Mesozoic strata 1)	6						11					1		4	6
	Tertiary stratum	7							100			27	40	29	2	2
	andesite, basalt	8								32			5	15	5	7
	volcanic ashes 2)	9									12		3	8	1	
Altitude	~600m	10										27				
	600~800m	11											49			
	800~1,000m	12												52		
	1,000~1,200m	13													12	
	1,200m~	14														15
Aspect	N. NE	15														
	E	16														
	SE	17														
	S	18														
	SW	19														
	W	20														
	NW	21														
	none	22														
Incli-nation	~10°	23														
	10~20°	24														
	20~30°	25														
	30°~	26														
Local Topography	steep slope ridge	27														
	gentle slope ridge	28														
	erosive mountainside	29														
	balanced mountainside 3)	30														
	silting mountainfoot	31														
	upland	32														
Type of soil	BA	33														
	BB	34														
	BC	35														
	BD(dry)	36														
	BD, BE	37														
	BlD	38														
Depth	very shallow	39														
	shallow	40														
	deep	41														
Soil Structure	sandy soil	42														
	loam	43														
	clay	44														
	gravel soil	45														
Soil Silting	residual soil	46														
	colluvial soil	47														
	creep soil	48														
Site Index Total			156	244	422	1,059	438	166	1,430	513	210	362	761	807	193	196

Item →	Category	No.	Aspect								Inclination				Local Topography					
↓			15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
Warm Index	~65°C	1		1	3	1	0	3	1	2	3	4		4	1	5	1	3		1
	65~75°C	2	1		1	5	2	3	2	1	5	3	7		1	5	2	1	2	4
	75~85°C	3	1		1	9	5	8	2		3	12	4	7	3	12	1	7		3
	85~95°C	4	7	5	8	19	13	10	8	1	7	19	21	24	10	19	11	23	4	4
	95°C~	5	5	9	7	3	1	4	3		4	11	10	7	3	11	5	8	2	3
Parent Material	Mesozoic strata 1)	6			1	3	1	4		2	3	1	5	2		8	2	1		
	Tertiary stratum	7	11	14	13	27	11	13	11		7	29	31	33	15	29	15	31	6	4
	andesite, basalt	8	1	1	5	6	8	8	3		5	16	4	7	3	12	3	7	2	5
	volcanic ashes 2)	9	2		1	1	1	3	2	2	7	3	2			3		3		6
Altitude	~600m	10	5	7	3	3	3	4	2		2	9	10	6	3	11	3	8	2	
	600~800m	11	4	5	8	12	7	6	5	2	8	14	13	14	3	12	6	19	3	6
	800~1,000m	12	3	2	4	15	9	12	7		5	18	13	16	8	18	9	11	1	5
	1,000~1,200m	13	2		2	4	1	2	1		3	4	4	1	1	5	1	1	2	2
	1,200m~	14		1	3	3	1	4	1	2	4	4	2	5	3	6	1	3		2
Aspect	N. NE	15	14								1	5	4	4	1	6	1	4	2	
	E	16		15							1	5	5	4	3	2	2	7		1
	SE	17			20						3	7	4	6	2	8	4	5		1
	S	18				37					3	13	9	12	7	13	5	8	1	3
	SW	19					21				4	7	4	6		8	2	8	1	2
	W	20						28			2	9	9	8	3	10	4	8	1	2
	NW	21							16		4	3	7	2	2	3	2	2	3	4
	none	22								4	4					2				2
Incli-nation	~10°	23									22					7		1	2	12
	10~20°	24										49			3	32	2	7	2	3
	20~30°	25											42		7	10	10	11	4	
	30°~	26												42	8	3	8	23		
Local Topography	steep slope ridge	27													18					
	gentle slope ridge	28														52				
	erosive mountainside	29															20			
	balanced mountainside 3)	30																42		
	silting mountainfoot	31																	8	
	upland	32																		15
Type of soil	BA	33																		
	BB	34																		
	BC	35																		
	BD(dry)	36																		
	BD, BE	37																		
	BlD	38																		
Depth	very shallow	39																		
	shallow	40																		
	deep	41																		
Soil Structure	sandy soil	42																		
	loam	43																		
	clay	44																		
	gravel soil	45																		
Soil Silting	residual soil	46																		
	colluvial soil	47																		
	creep soil	48																		
Site Index Total			210	209	302	536	337	429	230	66	357	775	615	572	210	794	297	633	145	240

Item →	Category	No.	Type of Soil						Depth to the Bedrock			Soil Structure				Type of Soil Silting		
↓			33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48
Warm Index	~65°C	1		2	1	4	1	3	4	4	3	2	3	4	2	9		2
	65~75°C	2	1		4		3	7	4	6	5		6	8	1	12	1	2
	75~85°C	3	2		5	8	9	2	11	11	4	3	12	10	1	23		3
	85~95°C	4	9	12	6	22	18	4	31	24	16	3	10	53	5	49	9	13
	95°C~	5	11	8	2	7	4		22	9	1	10	6	12	4	23	2	7
Parent Material	Mesozoic strata 1)	6			4	3	4		4	5	2	2	6	2	1	8		3
	Tertiary stratum	7	23	20	10	27	19	1	57	30	13	14	18	57	11	68	12	20
	andesite, basalt	8		2	3	10	8	9	9	11	12	2	11	18	1	28		4
	volcanic ashes 2)	9			1	1	4	6	2	8	2		2	10		12		
Altitude	~600m	10	4	9	1	8	5		19	7	1	10	6	7	4	17	2	8
	600~800m	11	10	4	5	13	14	3	27	17	5	3	10	34	2	31	7	11
	800~1,000m	12	8	5	7	16	12	4	16	21	15	3	12	34	3	45	2	5
	1,000~1,200m	13		1	4		2	5	4	4	4		6	6		10	1	1
	1,200m~	14	1	3	1	4	2	4	6	5	4	2	3	6	4	13		2
Aspect	N. NE	15	4	4	2	1	2	1	6	6	2	3	5	6		10	2	2
	E	16	4	5		3	3		9	4	2	3	3	8	1	9		6
	SE	17	4	1	3	4	4	4	11	4	5	3	4	13		16		4
	S	18	5	4	3	16	8	1	18	12	7	4	7	21	5	28	4	5
	SW	19		4	4	5	6	2	8	10	3		7	13	1	13	3	5
	W	20	2	4	4	8	8	2	14	10	4	3	7	14	4	23	1	4
	NW	21	4		1	4	3	4	6	4	6	1	3	10	2	13	2	1
	none	22			1		1	2		4		1	1	2		4		
Incli-nation	~10°	23	3		2	4	2	11	7	11	4	1	5	16		21	1	
	10~20°	24	4	5	8	17	10	5	25	13	11	5	10	31	3	45	1	3
	20~30°	25	8	6	5	9	14		21	15	6	5	12	21	4	32	4	6
	30°~	26	8	11	3	11	9		19	15	8	7	10	19	6	18	6	18
Local Topography	steep slope ridge	27	5	5	1	6	1		13	4	1	1	5	5	7	16	1	1
	gentle slope ridge	28	6	5	11	19	10	1	27	14	11	3	15	27	2	52		
	erosive mountainside	29	5	2	5	3	4	1	8	8	4	3	4	12	1	17	1	2
	balanced mountainside 3)	30	5	10	1	9	16	1	19	16	7	5	9	25	3	13	5	24
	silting mountainfoot	31				2	4	2		5	3	1	3	4		3	5	
	upland	32	2			2		11	5	7	3		1	14		15		
Type of soil	BA	33	23						19	3	1	3	6	9	5	20		3
	BB	34		22					13	6	3	3	6	9	4	12	2	8
	BC	35			18				9	9		3	6	8	1	16	1	1
	BD(dry)	36				41			16	16	9	8	8	22	3	33	3	5
	BD, BE	37					35		13	13	9	1	9	25		19	6	10
	BlD	38						16	2	7	7		2	14		16		
Depth	very shallow	39							72			9	19	32	12	56	4	12
	shallow	40								54		8	15	30	1	35	7	12
	deep	41									29	1	3	25		25	1	3
Soil Structure	sandy soil	42										18				13	1	4
	loam	43											37			27	2	8
	clay	44												87		65	9	13
	gravel soil	45													13	11		2
Soil Silting	residual soil	46														116		
	colluvial soil	47															12	
	creep soil	48																27
Site Index Total			285	272	283	617	588	274	974	871	474	258	552	1,398	111			

1) and Paleozoic strata, Quaternary stratum 2) and volcanic clastic materials, volcanic mud 3) and silting mountainside

By quantification, site index can estimate or predict from the sum of estimated quantities of each item and category. That is, site index is estimated by the next linear equation.

$$\hat{Y} = X_1 + X_2 + \cdots\cdots\cdots\cdots\cdots + X_M$$

$\hat{Y}$: estimate of site index

X_1, X_2, , ……, X_j, , ……, X_M : variable of each item

Variable X_j is the one of categories C_{j1}, C_{j2}, , …………, C_{jr_j}, and for each category, quantity is given as t_{j1}, t_{j2}, , …………, t_{jr_j}.

So these quantities were determined so as to maximize the correlation coefficient (ρ) between Y and $\hat{Y}$.

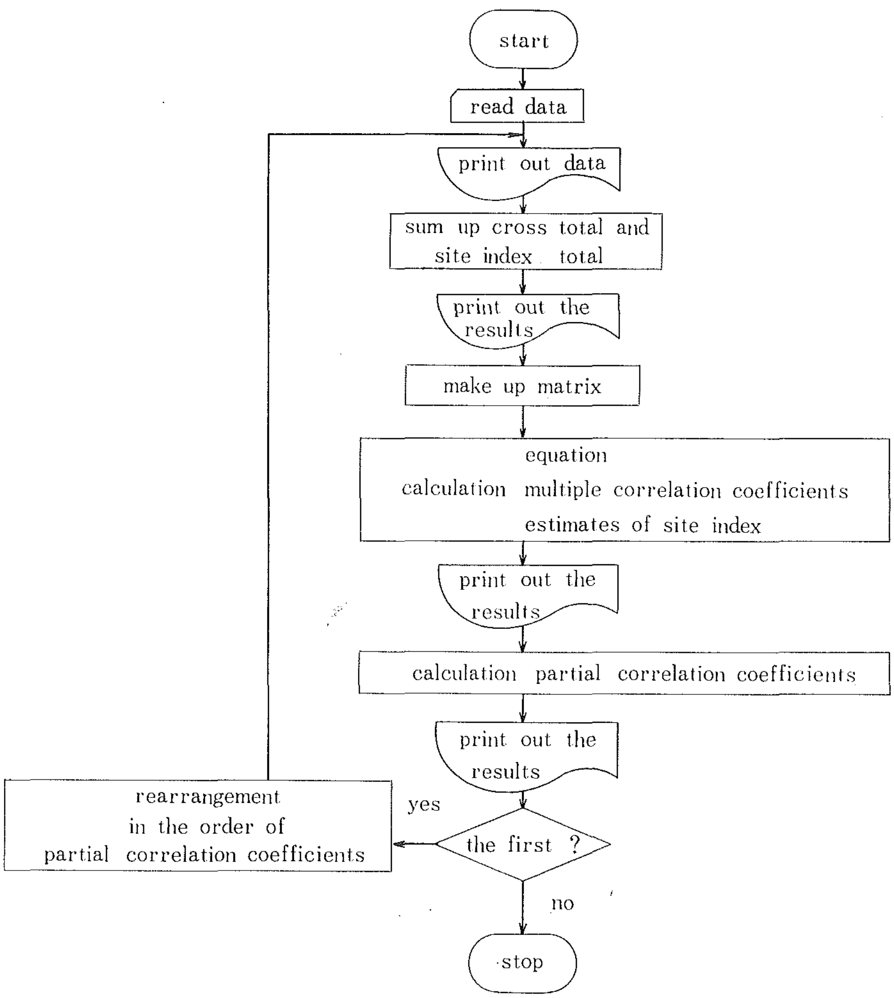

Fig. 1 Flow Chart of Calculation

Table 6 Score of Factors for Japanese Larch Forest

Item		Category		Site Index Total	Check Number	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}
X_1	Altitude	~800m	1	343	16	21.44	18.39	16.94	16.27	17.14	15.59	14.45	15.37	16.61	16.51	16.44	16.21
		800~1,000m	2	1,877	88	21.33	18.33	17.51	16.85	17.64	16.11	15.10	16.21	17.04	16.97	16.86	16.60
		1,000~1,200m	3	1,291	64	20.17	17.08	16.01	15.49	16.50	14.99	14.02	14.98	15.68	15.67	15.49	15.23
		1,200~1,400m	4	1,194	64	18.66	15.68	14.88	14.16	15.11	13.78	12.79	13.82	14.35	14.36	14.18	13.88
		1,400m~	5	418	22	19.00	16.35	15.27	14.69	15.37	13.97	13.15	14.30	14.83	14.83	14.67	14.38
X_2	Local Topography	steep slope ridge	6	55	3		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		erosive mountainside	7	241	13		1.29	1.48	2.43	1.98	1.36	1.67	1.20	0.85	0.93	0.84	0.84
		erosive mountainfoot	8	158	8		2.23	2.89	3.62	3.36	2.92	3.48	3.14	2.79	2.66	2.49	2.47
		silting mountainside	9	619	29		4.38	3.92	4.70	4.45	3.93	4.41	4.17	3.73	3.72	3.62	3.68
		silting mountainfoot	10	1,504	70		4.06	3.86	4.75	4.33	3.83	4.49	4.02	3.51	3.51	3.31	3.29
		balanced mountainside	11	1,614	81		2.75	2.53	3.35	3.13	2.83	3.36	3.03	2.59	2.57	2.43	2.45
		gentle slope ridge	12	283	17		−0.22	0.10	1.25	0.66	0.76	1.43	1.20	0.69	0.66	0.58	0.56
		gentle mountainfoot	13	294	14		4.36	4.24	4.64	3.42	2.86	3.38	2.75	2.46	2.48	2.45	2.47
		upland	14	355	19		1.76	2.60	3.48	2.87	2.44	3.33	3.20	2.72	2.64	2.44	2.40
X_3	Type of Soil	BA・BB・BC	15	328	18			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		BD(dry)	16	327	17			0.17	−0.15	−0.09	−0.57	−0.69	−0.87	−0.79	−0.93	−0.84	−0.80
		BD	17	2,665	127			1.67	1.63	1.66	1.24	1.21	1.21	1.30	1.16	1.09	1.12
		BE・BF	18	610	28			1.78	1.59	1.62	1.32	1.25	1.31	1.45	1.28	1.35	1.40
		BlD	19	951	50			0.41	0.74	0.54	0.12	0.18	0.07	0.27	0.20	0.05	0.12
		BlE	20	247	14			−1.99	−2.29	−1.97	−2.28	−2.28	−2.15	−1.80	−1.87	−1.86	−1.76
X_4	Aspect	N	21	981	47				0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		NE	22	629	29				1.23	1.16	1.06	1.06	0.89	0.88	0.98	0.94	0.96
		E	23	363	18				−0.29	−0.45	−0.08	−0.22	−0.12	−0.13	−0.04	−0.08	−0.09
		ES	24	590	29				0.12	0.09	0.23	0.15	−0.08	−0.03	0.00	0.14	0.12
		S	25	387	19				−0.42	−0.53	−0.56	−0.70	−0.72	−0.81	−0.81	−0.72	−0.73
		SW	26	498	26				−0.48	−0.65	−0.56	−0.49	−0.57	−0.75	−0.66	−0.68	−0.68
		W	27	676	37				−1.92	−2.03	−1.92	−1.99	−2.00	−2.10	−2.10	−2.03	−2.01
		WN	28	765	37				0.13	−0.06	−0.06	−0.10	−0.24	−0.22	−0.17	−0.07	−0.03
		none	29	234	12				0.45	−0.01	−0.05	0.02	−0.32	−0.24	−0.12	−0.17	−0.21
X_5	Soil Silting	residual soil	30	1,417	73					0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		colluvial soil	31	1,563	73					−0.54	−0.51	−0.37	−0.49	−0.49	−0.42	−0.46	−0.45
		fluvial soil	32	573	27					0.60	0.66	0.94	0.96	0.82	1.04	1.05	1.01
		creep soil	33	1,570	81					−0.87	−0.91	−0.97	−0.98	−0.92	−0.89	−0.93	−0.97

X_6	Wind Damage	severe	34	104	7						0.00	0.00	0.00	0.00	0.00	0.00	0.00
		weak	35	482	26						1.30	1.43	1.36	1.24	1.53	1.46	0.78
		none	36	4,537	221						2.35	2.53	2.52	2.38	2.67	2.52	1.88
X_7	Inc-lination	～10°	37	2,038	101							0.00	0.00	0.00	0.00	0.00	0.00
		10～20°	38	1,508	76							-0.11	-0.17	-0.15	-0.06	-0.08	-0.07
		20～30°	39	1,152	56							1.06	0.97	0.95	0.97	0.86	0.87
		30°～	40	425	21							0.50	0.19	0.33	0.40	0.33	0.38
X_8	Soil Struc-ture	sandy soil, gravel soil	41	274	13								0.00	0.00	0.00	0.00	0.00
		loam	42	1,586	76								0.03	-0.21	-0.21	-0.21	-0.25
		clay	43	3,263	165								-0.73	-0.78	-0.84	-0.92	-0.93
X_9	Warm Index	～65°C	44	1,367	70									0.00	0.00	0.00	0.00
		65～75°C	45	1,200	62									0.06	-0.16	-0.11	-0.14
		75～85°C	46	1,609	75									0.01	-0.20	-0.18	-0.22
		85°C～	47	947	47									-0.89	-1.11	-1.04	-1.11
X_{10}	Parent Material	Mesozoic strata 1)	48	1,012	50										0.00	0.00	0.00
		Tertiary stratum	49	828	39										0.07	0.11	0.12
		Quaternary stratum	50	681	35										-0.71	-0.79	-0.79
		granite, diorite	51	125	6										-0.79	-0.61	-0.47
		andesite, basalt	52	1,909	95										0.07	0.06	0.08
		volcanic ashes 2)	53	466	24										0.01	0.03	0.03
		volcanic mud	54	102	5										0.33	0.63	0.64
X_{11}	Depth	very shallow	55	325	16											0.00	0.00
		shallow	56	2,069	104											0.33	0.34
		deep	57	2,729	134											0.74	0.74
X_{12}	Snow Frost Damage	receive	58	156	9												0.00
		none	59	4,967	245												0.92
		Multiple Correlation Coefficients				0.34	0.52	0.59	0.64	0.65	0.66	0.67	0.68	0.68	0.68	0.69	0.69
		Partial Correlation Coefficients of Factors					0.42	0.32	0.30	0.14	0.16	0.16	0.12	0.10	0.07	0.08	0.05
		Partial Correlation Coefficients				0.35	0.33	0.32	0.31	0.23	0.16	0.14	0.13	0.13	0.12	0.09	0.06
		Range				2.72	3.12	3.17	2.97	1.98	1.88	0.94	0.93	1.11	1.43	0.74	0.92

1) and Paleozoic strata 2) and volcanic clastic materials

Table 7 Score of Factors for Japanese Red Pine Forest

Item		Category		Site Index Total	Check Number	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}
X_1	Soil Structure	sandy soil	1	258	18	14.37	12.91	12.52	11.34	11.88	12.95	15.26	15.21	15.72	15.45
		loam	2	552	37	14.92	13.05	12.41	11.31	11.81	12.73	15.02	14.97	15.50	15.24
		clay	3	1,398	87	15.98	13.70	12.87	11.86	12.49	13.33	15.93	15.93	16.52	16.22
		gravel soil	4	111	13	8.67	7.93	7.72	7.09	7.50	8.43	11.00	11.10	11.55	11.34
X_2	Type of Soil	BA	5	285	23		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		BB	6	272	22		-0.00	0.36	0.28	-0.14	-0.03	0.03	-0.05	-0.06	-0.14
		BC	7	283	18		2.69	2.82	2.58	2.29	2.12	2.02	1.77	1.68	1.65
		BD(dry)	8	617	41		2.05	2.22	1.96	1.75	1.67	1.63	1.44	1.39	1.39
		BD BE	9	588	35		3.29	3.49	2.96	2.66	2.62	2.59	2.48	2.34	2.27
		BlD	10	274	16		3.50	4.08	4.41	4.46	3.89	3.80	3.67	3.98	3.99
X_3	Altitude	~ 600m	11	362	27			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		600~ 800m	12	761	49			0.84	0.98	1.00	1.06	1.13	1.08	1.07	1.11
		800~1,000m	13	807	52			0.76	1.04	1.02	1.14	1.10	0.97	0.91	1.01
		1,000~1,200m	14	193	12			0.19	0.04	-0.01	0.23	0.04	-0.00	-0.05	0.12
		1,200m~	15	196	15			-0.70	-0.53	-0.57	-0.40	-1.98	-2.11	-2.11	-1.92
X_4	Local Topography	steep slope ridge	16	210	18				0.00	0.00	0.00	0.00	0.00	0.00	0.00
		erosive mountainside	17	297	20				0.90	0.79	0.90	0.73	0.68	0.61	0.64
		balanced mountainside 1)	18	633	42				1.27	1.05	1.14	0.90	0.84	0.75	0.49
		silting mountainfoot	19	145	8				2.96	3.12	2.75	2.65	2.46	2.52	2.20
		gentle slope ridge	20	794	52				1.37	1.19	0.57	0.41	0.47	0.33	0.37
		upland	21	240	15				0.00	-0.21	-0.71	-0.90	-0.96	-1.18	-1.25
X_5	Aspect	N・NE	22	210	14					0.00	0.00	0.00	0.00	0.00	0.00
		E	23	209	15					0.03	-0.19	-0.39	-0.30	-0.25	-0.24
		ES	24	302	20					-0.68	-0.66	-0.82	-0.67	-0.63	-0.62
		S	25	536	37					-0.27	-0.28	-0.34	-0.27	-0.22	-0.22
		SW	26	337	21					0.21	0.19	0.24	0.25	0.39	0.38
		W	27	429	28					0.39	0.41	0.24	0.30	0.32	0.39
		WN	28	230	16					-1.54	-1.46	-1.63	-1.46	-1.43	-1.43
		none	29	66	4					0.16	0.03	-0.32	-0.65	-0.89	-0.79
X_6	Inclination	~10°	30	357	22						0.00	0.00	0.00	0.00	0.00
		10~20°	31	775	49						-0.07	-0.14	-0.08	0.11	0.05
		20~30°	32	615	42						-0.91	-0.79	-0.79	-0.68	-0.71
		30°~	33	272	42						-1.37	-1.31	-1.28	-1.14	-1.36

X_7	Warm Index	~65°C	34	156	11							0.00	0.00	0.00	0.00
		65~75°C	35	244	15							−1.86	−1.90	−2.04	−2.07
		75~85°C	36	422	26							−1.81	−1.89	−1.51	−1.43
		85~95°C	37	1,059	71							−2.51	−2.57	−2.40	−2.36
		95°C~	38	438	32							−2.04	−2.18	−1.97	−1.92
X_8	Depth	very shallow	39	974	72								0.00	0.00	0.00
		shallow	40	871	54								0.62	0.60	0.57
		deep	41	474	29								−0.04	0.01	0.10
X_9	Parent Material	Mesozoic strata 2)	42	966	11									0.00	0.00
		Tertiary stratum	43	1,430	100									−0.77	−0.58
		andersite, basalt	44	513	32									−1.07	−0.89
		volcanic ashes 3)	45	210	12									−0.43	−0.17
X_{10}	Soil Silting	residual soil	46	1,722	116										0.00
		colluvial soil	47	199	12										0.59
		creep soil	48	398	27										0.59
Multiple Correlation Coefficients						0.57	0.69	0.70	0.72	0.74	0.75	0.76	0.76	0.76	0.77
Partial Correlation Coefficients of Factors							0.46	0.18	0.26	0.23	0.18	0.16	0.12	0.09	0.07
Partial Correlation Coefficients						0.47	0.44	0.30	0.28	0.24	0.22	0.22	0.11	0.11	0.10

1) and silting mountainside 2) and Palezoic strata, Quaternary stratum 3) and volcanic clastic materials, volcanic mud

After determination of these quantities, the multiple correlation coefficients, the partial correlation coefficients and the partial correlation coefficients of factors are calculated by the formulae.

These calculations were carried out by electronic computor FACOM 230-60 in Nagoya University.

The flow chart of these calculations is as following Figure 1.

IV Score Table

The score table are given in Table 6 and Table 7.

The estimate of site index for Japanese larch forests from Table 6 is distributed from 5.24 to 28.70. The estimate of site index from these table has a centripetal character, so it is apt to estimate as greater value in the lower part, and as smaller value in the upper part.

The items, which has acted effectively for the estimation of site index, were the "Altitude", the "Aspect", the "Local Topography", the "Type of Soil" and the "Soil Structure".

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地位指数推定のための環境因子の数量化

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要　　約

地位指数を推定する方法として環境因子を数量化する方法があり，それについては以前にも報告したが，[8] 今回は東信地方の信州カラマツ林とアカマツ林に対して地位指数を推定するために，環境因子を数量化することを試みた。

本報告でとりあげた環境因子項目は，温量指数・風害・霜雪害・表層地質・標高・傾斜方位・傾斜度・局所地形・土壌型・土壌有効深度・土性・土壌堆積型である。

現地調査を行なった標本点数は，信州カラマツ林で 150 点，アカマツ林で 155 点（表３）であったが，信州カラマツ林については1967年に調査した 104 点[8]を加えることができた。

また，地位指数としては，信州カラマツ林では林齢35年の，アカマツ林では林齢40年の林分平均樹高を用いたが，現地での地位指数判定基準としては，以前に調整した林分平均樹高生長曲線[5]を用いた（表１，表２）。

調査結果を地位指数，環境因子項目でクロス集計したものは表４および表５のようであり，それらの結果から算定した各カテゴリーの数量は表６および表７のスコアー表に与えられている。

このように環境因子を数量化して地位指数を推定していく場合，もともと統計的手法というものが，集団の性質を追求していくものだけに，集団の平均的情報については比較的正しく与えるが，個体の情報については充分に有効なものとはなり得ないのであり，強い求心性をもっていることに注意しなければならない。

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