Some Forest Soil Characteristics and Their Relationship to Jack Pine Growth

S. Pawluk and H. F. Arneman (1961) *Forest science,* vol.7

Introduction

- For establishing forest growth and soil relationships,
  many approaches involve correlation of site index and various soil properties.

- SITE INDEX （地位指数）

  Site index is the height to which dominant trees of a given tree species on a given soil area will grow at some index age, usually 25 or 50 years.

Introduction – Site index

Soil factors

- Topsoil depth
- Soil texture
- Subsoil consistence class
- Limiting layers
- Fertility
- Internal drainage

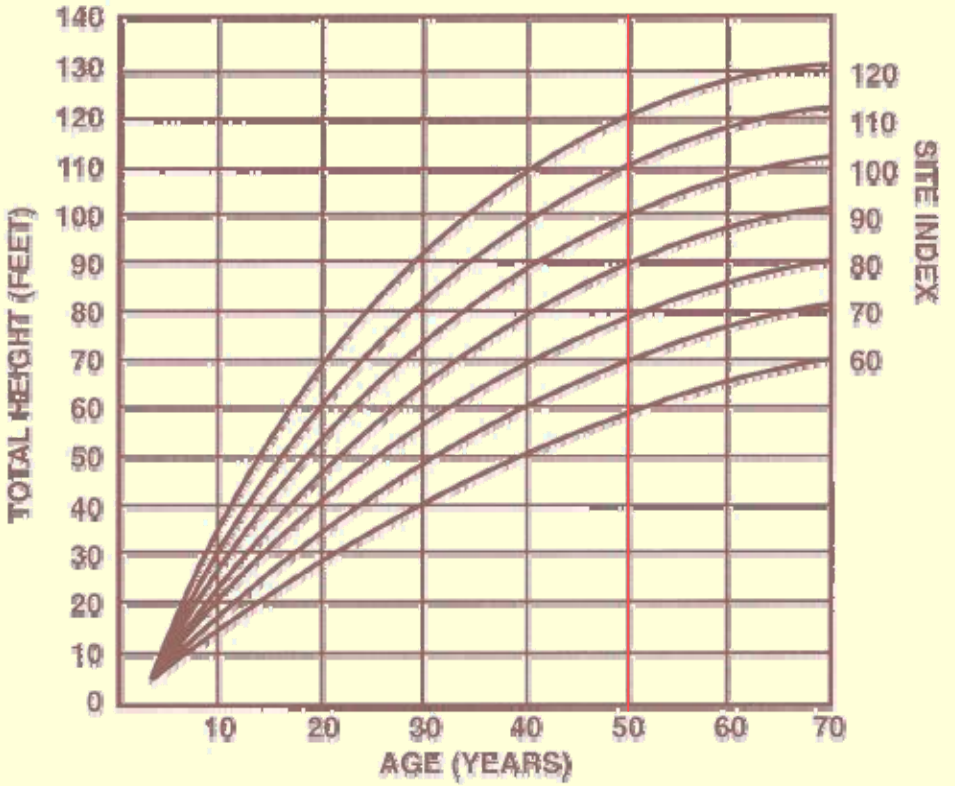

Figure 1. Site index curves for loblolly pine at index age 50 years in the Coastal Plain of Virginia, North Carolina, and South Carolina. (These curves are based on stem analysis of 40 dominant trees in the middle and lower Coastal Plain.)

(North Carolina State University, "Woodland Owner Notes")

Soil texture

(三枝・木村編　土壌サイエンス入門)

- 礫　gravel　>2mm
- 粗砂　coarse sand　0.2~2mm
- 細砂　fine sand　0.02~0.2mm
- シルト silt　0.002~0.02mm
- 粘土　clay　<0.002mm

Physical (drainage, air permeability)

Chemical (water- and nutrient holding capacity)

Objectives

- This study considers all, rather than any one characteristic of the soil

Materials & methods

- 18 jack pine (*Pinus banksiana*) plots were selected around northern U.S. (Jack pine is a boreal-tree species and is usually found on sandy soils.)

- Annual precipitation ranges from 460~560mm.
- The average July temperature varies from 20~21℃.

- Site indices were determined, using 3 dominant and 2 codominant trees nearest the center of the plot.

- Soils were measured.

Materials & methods – measured parameters

- Soil profiles
- Particle sizes
- Moisture content (for estimating available moisture holding capacity)
- Bulk density
- Exchangeable cations
  (for total cation exchange capacity, exchangeable metallic cations, exchangeable K, exchangeable H)
- pH
- Available P
- Total N
- Organic C
- Identification of light and heavy minerals

Results - 1

- 18 sites were categorized into 4 types of soil series

Soil type	Field site	Site index	Very fine sand + silt + clay (A_2 horizon, %)	Characteristics of the B horizons	Parent materials
Faunce L.F.S.	1	71	29.2	Friable color B	Well sorted outwash sand from the gray drift
Onamia S.L.	2	71	29.7	Cemented iron B	Poorly sorted outwash gravel from the gray drift
Rockwood L.F.S.	3	71	26.2	Cemented iron and textural B	Gray glacial till
Chetek S.L.	4	69	36.6	Cemented iron B	Poorly sorted outwash from the red drift
Onamia L.F.S.	5	67	27.8	Cemented iron B	Poorly sorted outwash from the gray drift
Todd L.S.	6	65	25.1	Cemented iron B	Poorly sorted outwash gravels from the gray drift
Todd F.S.L.	7	64	42.8	Cemented iron B	
Unnamed F.S.L.	8	62	48.9	Firm blocky textural B	Gray glacial till
Menahga L.F.S.	9	61	26.7	Loose color B	Well sorted outwash sands from the gray drift, clay bands in the parent material
Omega L.F.S.	10	59	22.4	Loose color B	Well sorted outwash sand from the red drift
Menahga L.F.S.	11	56	15.4	Loose color B	Sorted outwash sands from the gray drift
Menahga S.	12	55	10.0	Loose color B	Sorted outwash sand from the gray drift with clay bands in the parent material
Omega L.F.S.	13	50	16.6	Loose color B	Well sorted outwash from the red drift
Faunce S.	14	50	13.2	Loose color B	Well sorted outwash from the gray drift
Menahga L.Co.S.	15	49	17.0	Loose color B	Well sorted outwash sand from the gray drift
Menahga F.S.	16	46	8.0	Loose color B	Outwash sand from the gray drift reworked by wind
Plainfield F.S.	17	44	10.0	Loose color B	Outwash sand well sorted by the Wisconsin River
Plainfield F.S.	18	38	9.0	Loose color B	Outwash sand well sorted by the Wisconsin River

Soil series and horizons	pH	Available phosphorus (ppm) Morgan's	Bray's No. 1	Organic Nitrogen (percent)	carbon (percent)	C/N ratio	Exchangeable cations (me/100 gm) Ca	Mg	K	H	C.E.C. (me/100 gm by sum)	Base (Saturation percent)
Faunce												
Aoo & Ao	4.4	23.0	35.3	0.838	27.83	35	19.8	3.0	1.39	33.6	57.8	42
A_2	4.7	0.8	27.9	0.036	0.94	26	0.9	0.2	0.08	2.1	3.3	37
B_2	5.6	1.8	67.7	0.020	0.33	16	1.3	0.2	0.09	1.2	2.8	56
B_3	5.7	1.8	33.5	.....	.....	....	0.8	0.2	0.04	0.6	1.6	72
C_1	5.8	0.3	28.4	.....	.....	....	0.6	0.2	0.02	0.2	1.0	88
C_2	6.0	0.0	7.8	.....	.....	....	0.7	0.2	0.03	0.0	0.9	100
Onamia												
Aoo & Ao	5.2	13.3	29.3	0.289	8.00	29	10.5	1.6	0.48	6.1	18.7	66
A_2	5.0	3.0	56.7	0.031	0.57	19	1.5	0.3	0.14	1.9	3.8	53
B_2	5.4	3.5	47.9	0.021	0.25	12	2.1	0.4	0.15	0.9	3.6	73
B_3	5.7	3.0	29.9	.....	.....	....	2.8	0.6	0.09	0.6	4.1	80
C_1	5.9	1.0	16.7	.....	.....	....	1.9	0.3	0.09	0.2	2.5	91
C_2	5.9	0.5	11.4	.....	.....	....	1.8	0.4	0.06	0.2	2.5	92
Rockwood												
Aoo & Ao	6.4	14.0	24.1	0.612	16.87	28	19.8	7.8	0.94	2.5	30.2	92
A_2	5.8	2.5	70.0	0.016	0.27	17	1.3	0.3	0.09	0.4	2.1	81
B_2	5.4	1.0	18.3	0.024	0.25	10	4.8	1.5	0.20	0.7	7.2	90
B_3	6.6	1.0	4.9	.....	.....	....	9.4	3.4	0.19	0.1	13.1	99
C_1	7.3	0.5	3.4	.....	.....	....	15.7	1.0	0.14	0.0	16.8	100
C_2	7.8	0.5	2.3	.....	.....	....	16.1	1.1	0.10	0.0	17.3	100
Chetek												
Aoo	4.8	17.5	35.1	0.473	14.70	31	15.4	1.6	0.92	12.7	30.6	58
A_2	5.6	5.0	64.8	0.053	0.91	17	5.4	0.7	0.18	1.5	6.4	17
B_2	5.7	6.5	117.5	0.043	0.53	12	2.5	0.3	0.16	2.2	5.2	58
B_3	5.9	2.5	114.0	.....	.....	....	1.9	0.3	0.16	0.7	3.1	77
C_1	6.1	0.0	13.0	.....	.....	....	1.8	0.4	0.09	0.8	3.1	74
C_2	5.8	0.0	3.8	.....	.....	....	1.7	0.5	0.08	0.1	2.4	96
Todd												
Aoo & Ao	5.1	4.0	12.3	0.427	7.79	19	13.6	2.0	0.60	6.6	22.8	72
A_2	5.3	1.8	44.8	0.024	0.30	11	2.5	0.6	0.12	1.3	4.5	76
B_2	5.7	2.3	31.5	0.022	0.20	9	6.4	1.8	0.15	1.0	9.4	89
B_3	6.7	1.0	12.3	.....	.....	....	3.9	2.0	0.08	0.1	6.1	96
C_1	6.8	1.0	11.8	.....	.....	....	4.5	0.8	0.05	0.1	5.5	94
C_2	7.1	0.5	7.9	.....	.....	....	3.0	0.5	0.04	0.0	3.5	100
Unnamed	(double profile)											
Aoo & Ao	5.2	21.0	31.4	0.497	19.05	38	20.8	3.6	0.90	11.9	37.2	68
A_{2p}[1]	5.9	1.0	21.3	0.042	1.15	27	3.3	0.5	0.08	0.6	4.5	87
B_{pu}	5.9	2.0	111.3	0.066	1.20	18	3.3	0.6	0.25	2.5	6.7	63
A_2	5.3	0.5	4.4	0.009	0.12	13	1.3	0.6	0.33	0.6	2.5	76
B_2	4.8	1.0	7.2	0.016	0.16	10	6.2	3.5	0.16	1.9	11.8	84
B_3	5.2	0.0	3.1	.....	.....	....	6.3	3.8	0.12	0.9	11.1	92
C_1	5.6	0.0	3.4	.....	.....	....	7.7	1.3	0.12	0.6	9.7	94
C_2	6.3	0.0	3.6	.....	.....	....	7.8	1.2	0.11	0.2	9.3	98

TABLE 2. Linear correlations betweensite index and soil characteristics.

Soil characteristics	Soil horizons					
	A_{00} & Ao	A_2	B_2	$A_2 + B_2$	$A_2 + B_2 + B_3$	A_{00} & Ao $+ A_2 + B_2$
Mechanical fractions						
(i) Clay		.353	.523*			
(ii) Silt + clay		.724**	.783**			
(iii) Very fine sand + silt + clay		.590**	.804**	.806**	.794**	
(iv) Very fine sand + silt		.722**	.747**			
(v) Fine sand + very fine sand + silt + clay		—.228	.089			
(vi) (Very fine sand + silt + clay) depth		.583*	.616**	.702**		
Available moisture holding capacity	.440	.633**	.608**	.572**	.582*	
Bulk density			.397			
Total nitrogen content	.038	—.525*	.426			
Total carbon		—.484*				
C/N ratio	—.158	.099	.075			
Available Phosphate						
(i) Extracted with Bray's No. 1 solution	.038	.472*	—.229			
(ii) Extracted with Morgan's reagent	.330	.135	.139			
Exchangeable Cations						
(i) Total exchange capacity		.234	.537*	.489*	.595**	
(ii) Exchangeable potassium	.024	.419	.521*		.595**	
(iii) Exchangeable calcium + magnesium	.439	.320	.495*		.527*	
(iv) Exchange acidity	—.198	.419	.175	.268		
(v) % base saturation	.548*	.438	.445	.256		.580**

*Significant at 5 percent level. **Significant at 1 percent level.

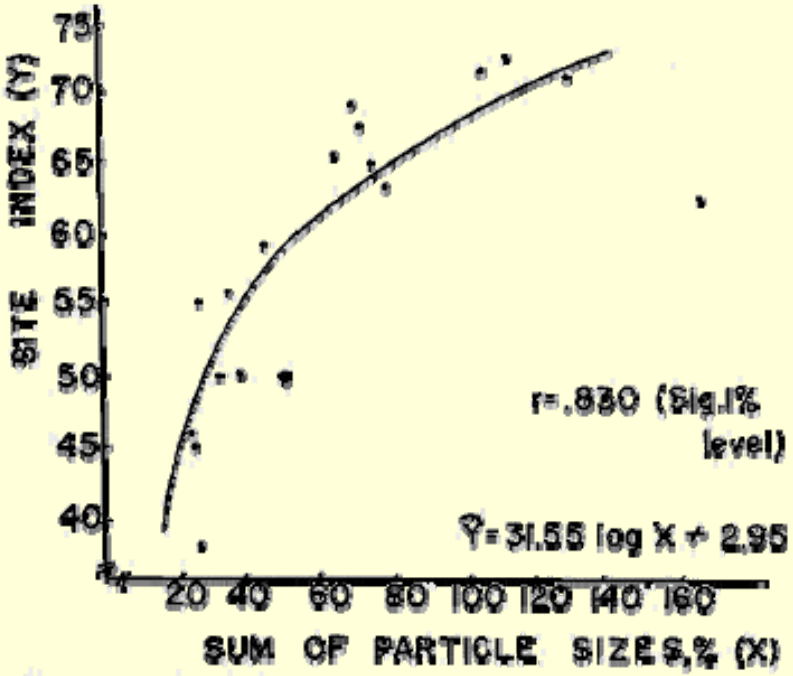

FIGURE 1. *Relationship between site index at age 50 years and the sum of the very fine sand, silt, and clay content of the A_2 and B horizons.*

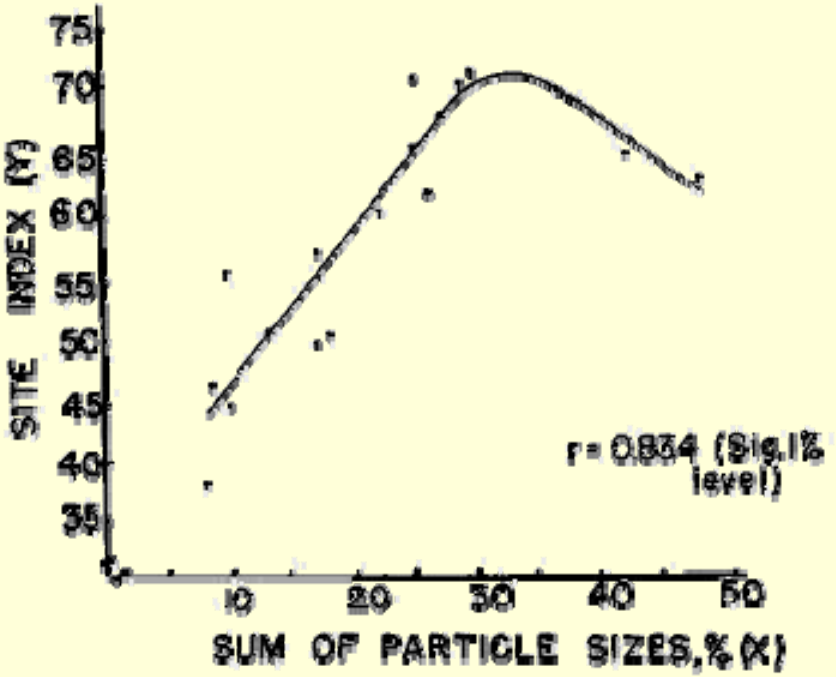

FIGURE 4. *Relationship between the sum of the very fine sand, silt, and clay content of the A_2 horizon and site index at age 50 years.*

- Available water holding capacity is one of the most important factors for tree growth

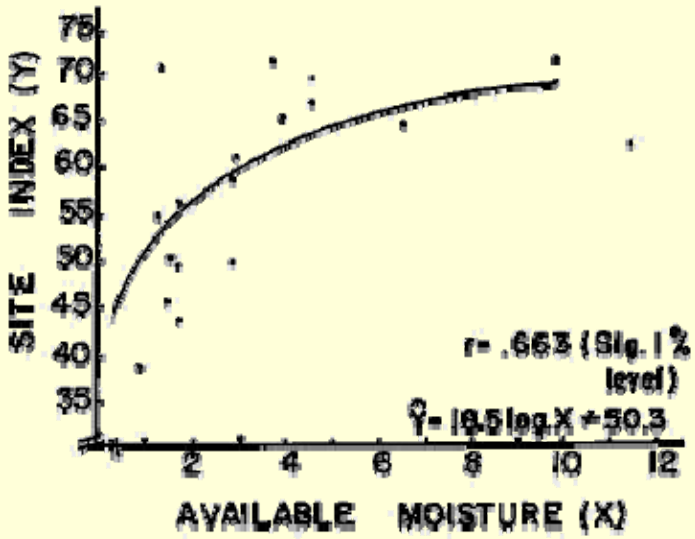

FIGURE 2. *Relationship between the sum of the available moisture holding capacity (inches) in the A_{00}, A_2, B_2, and B_3 horizons and site index at age 50 years.*

Conclusion

- Growth of jack pine in the region is closely related to those characteristics of the soil.

- Mechanical composition is the best direct measure of both moisture holding capacity and cation exchange capacity.

表 8.7　スギ林成長（地位指数）に関する環境要因の重要度（偏相関順位）

地域		土壌型	堆積様式	有効深度	土性	A層厚	土壌硬度	局所地形	方位	傾斜	地質・母材	地域区分	標高	温量指数	降水量	風衝・寒風
函館支局*	渡島半島	1	4	7	5			6	8	3	2		10			9
青森局	下北	1	2	8	11			2	6	3	5		—4—		10	9
	青森南部	1	4	10	9				6	8	5		—7—		2	3
秋田局	庄内	1	8	10	9	7		4	6	5	3		2			
	八郎潟	1	6	10	9	7		4	8	3	2		5	11		
	最上	1	6	11	10	9		3	7	8	5		2	4		
	米代川	1	7	10	9	8		3	2	5	6		4			
	山形南部	1	8	13	12	11		3	10	7	2	4	5	6		
前橋局	福島	4	8	11	13	12	2	10	5	7	1		6	14	3	9
	栃木	8	2	9	13			3	7	6	1		—5		4	10
東京局	千葉	1	4	7	8			2	5	6	3					
	天城	9	8	5	7			10	3	2	11		1	4	12	6
	管内全域	1	9	10	6			12	11	7	8		8	2	4	
長野局	千曲川上流	—4—		9	5			2	8	7	3		1		6	
名古屋支局	飛騨	4	4	9	11		8	6	7	1	2		—3—		10	
	白鳥	3	9		11	10	8	7	5	4	6		—1—		2	
	愛知	4	8	9	10		7	5	3		6		—2—		1	
	裏木曽	3	5	10	9			4	7	8	2		—1—		6	
	富山	9	3	4	10			7	6	8			1	2	5	
大阪局	山陰	1	4	9	5			3	8	7	2		—6—		10	
	近畿紀州	1	6	11	10		8	9	7	4	3	2	—5—			
	山陽東部	1	2	8	10		12	6	11	4	3	9	—7—		5	
	山陽西部	1	8	9	10		7	4	12	3	2	11	—6—		5	
高知局	四国中部	1	7	10	9			5	4	8	3		—3—			6
	土佐東部	1	4	9	7			3	8	10	2		—5—			6
	土佐西部	1	8	9	6			5	4	3	10		—2—			7
熊本局	宮崎北部	1	7	3	9			4	8	5	6		2			
	九州南部	1	7	9	8			5	3	4	2		—6—		2	
	九州全域	1	7	10	8			5	6	3	4		—9—			
	鹿児島	1	3	10	7			6	5	8	2		4		9	

林野庁営林局，支局．

（久馬編　最新土壌学）

Another article

- In many Japanese plantation sites, soil type is an important factor for site index.

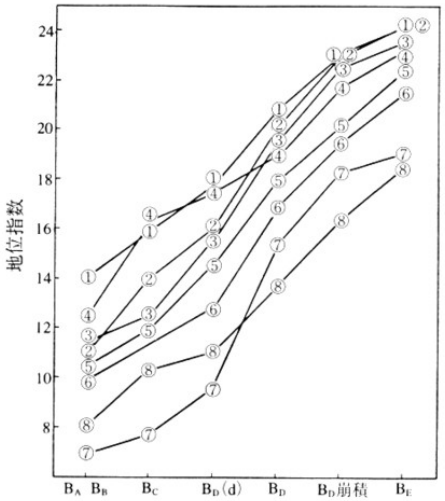

図 8.6　地域別土壌型とスギの成長（真下まとめ）
① 奈良県　吉野　④ 高知県　四国山地　⑦ 伊豆・箱根
② 大分県　日田　⑤ 新潟県　北部　⑧ 佐賀県脊振など
③ 秩父・天竜　⑥ 秋田県　北部　佐賀・武雄

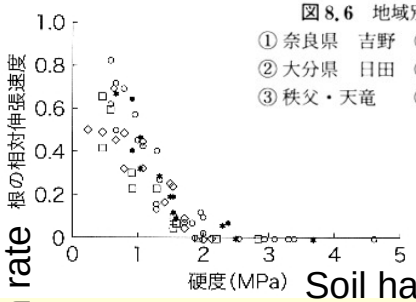

図9-4　土壌硬度と根の伸張の関係
○：壌質砂土，●：砂壌土，◇：細粒砂質壌土，□：壌土．(Taylor, H. M. et al., 1966 から作成)

Root growth rate　Soil hardness

(木村・三枝編　土壌サイエンス入門)

Another article

local

regional

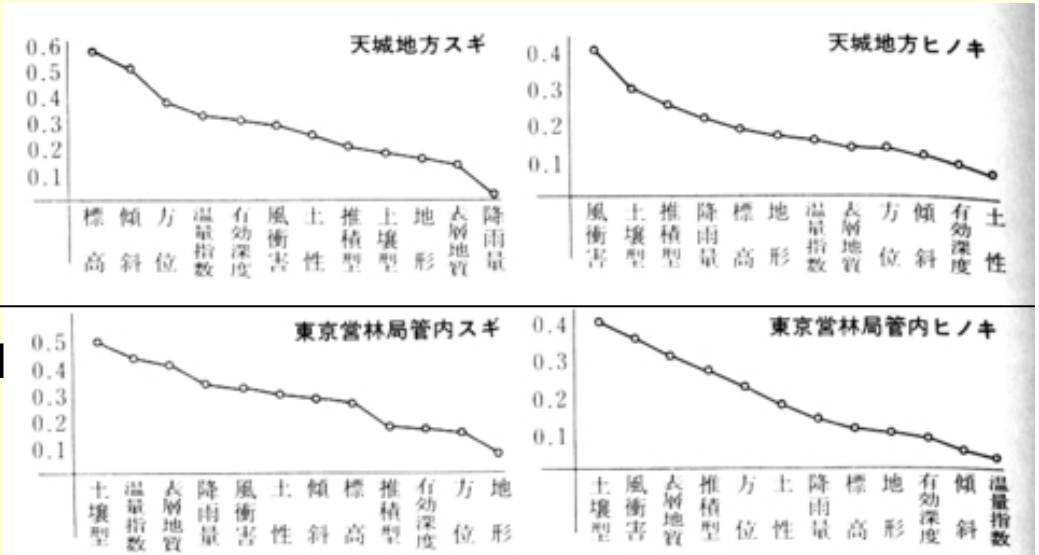

図 9.2 東京営林局管内および天城地方におけるスギ・ヒノキ地位指数推定のための数量化 I 類による立地因子の偏相関係数順位比較（渡邊ら，1966）

- Different levels of factors control site indices,
  according to tree species or sample-size.

↓ Factors controlling bamboo vegetation

表 9.2 竹林の分布と生育を制限する環境要因（沼田ら，1957）

生物レベル	環境のオーダー	一次要因 Primary factor	二次要因 Secondary factor
種社会	マクロ macro	気温の低極 temperature	風速，雨量 Wind, rain
↓	ローカル local	風速，雨量 Wind, rain	土壌の粒土組成，含水量，排水のよさ soil
個体群	ミクロ micro	表土層の厚さ，排水のよさ soil	西日の直射 sunshine

（渡邊、樹木社会学）