Relations between the Vegetation and the Base-Status of Soils in Hokkaido, Japan

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Base-status is an important part of soil fertility and criteria of soil classification. According to the text by J. S. Jenny[4], the soil is a natural body and the result of the combined activity and reciprocal influence of soil forming factors such as parent material, plant and animal organisms, climate, age of land, and topography (Dokchaev). Research on the base-status of soil and its correlation with soil-formers is significant for the development of agriculture in Hokkaido.

Bases in various soils

1) Base-status of Brown Forest soils in North-east Hokkaido

Samples were taken from the Brown Forest soils[11] in the agricultural lands and the adjacent forests along the coast of Okhotsk Sea. All of the sampling sites were on the middle of hill-slopes.

The total contents of calcium in the soils and the parent rocks were determined after HF-H_2SO_4 digestion. The cation exchange capacities were measured by N $NH_4 \cdot CH_3COO$, a modification of Schollenberger's method. Calcium and magnesium were determined by atomic-absorption spectrometry and potassium and sodium by flame photometry. The total base was shown as the sum of calcium, magnesium, potassium and sodium.

As shown in Fig. 1, soils are divided into three groups according to the base-status. Parent materials containing calcium higher than 70 me/100 g are tentatively shown as "rich" in calcium, and those containing calcium lower than 70 me/100 g are shown as "poor" in it.

The base-status of soil is parallel to the base-content of parent material in the middle of the area, but not parallel in the other area, although parent materials rich in calcium are distributed everywhere from the south to the north of the area. Generally speaking, base-saturation of soils in the north are low and those in the south are high, irrespective of calcium-contents of parent rocks. This fact reveals the presence of eutric Brown Forest soils (Eutrandepts)[8], although most of the Brown Forest soils in Hokkaido have been considered to be dystic[2] (Dystrochrepts)[8]. Base-status of B-horizon in agricultural land is as same as that of woodland. This fact shows that anthropogenic influence has not been exerted upon base status of B-horizon.

The factors such as parent materials and action of men partly and insufficiently explain the base-status of soils. Then, the influence of climate should be studied. Hokkaido is located at the border of the warm-temperate zone and the subarctic zone[3]. The northern part of the study area has cool-humid climate and has some local Sand-dune Podzols[5,7]. Yokoi[14] revealed that the southern part of the area belongs to that with least "excess water" in Japan, using the heat-balance method.

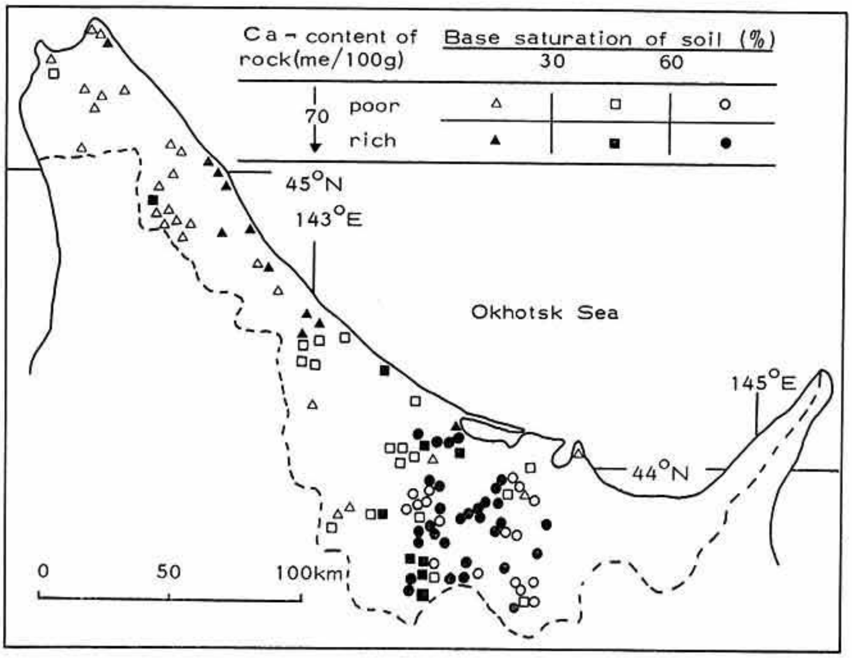

Fig. 1. Relations between Ca-contents of parent rocks and base saturations of Brown Forest soils in the north-east Hokkaido

Distribution of radiation-dry index in Hokkaido is shown in Fig. 2 (Sakuma)⁶⁾. The index is shown as Sn/Pl; where Sn is the net solar-energy received by ecosystem, and Pl is the energy consumed in evaporating the annual precipitation. The index higher than one means arid climate and that lower than one means humid climate. In summer, the north of the area is humid and the south is arid, as shown in Fig. 2.

In Fig. 3 are shown the base-saturations of soils both in the north and the south. Andesite in these area is relatively rich in calcium while rhyolite and Cretaceous shale are poor in it. Soils in the north seem to have experienced leaching of bases more intensively than those in the south. As mentioned above, base-status of soils in the north-east Hokkaido is parallel to radiation-dry index.

2) Base-status of Pseudo-gley soils

Japan has Pseudo-gley soils mainly on diluvial terraces in Hokkaido. These have clayey to heavy-clayey texture and very firm, poorly-drained subsoils. These soils are found in the north Hokkaido, as shown in Fig. 4, because the southern part is covered with volcanic ejecta.

Table 1. Percentage of Pseudo-gley soils with higher exchangeable-bases in C-horizons than B-horizons

	% of soils with C-horizons of higher bases than B-horizons				(N)*
Block	Ca & Mg	Ca	Mg	Total	
A	36	7	29	72	17
B	74	4	9	87	53
C	43	18	29	90	28
D	69	0	25	94	32
E	61	0	39	100	13

* (N): the number of soil samples

The contents of exchangeable calcium and magnesium in Pseudo-gleys are high at horizons of 35 cm below the surface. The

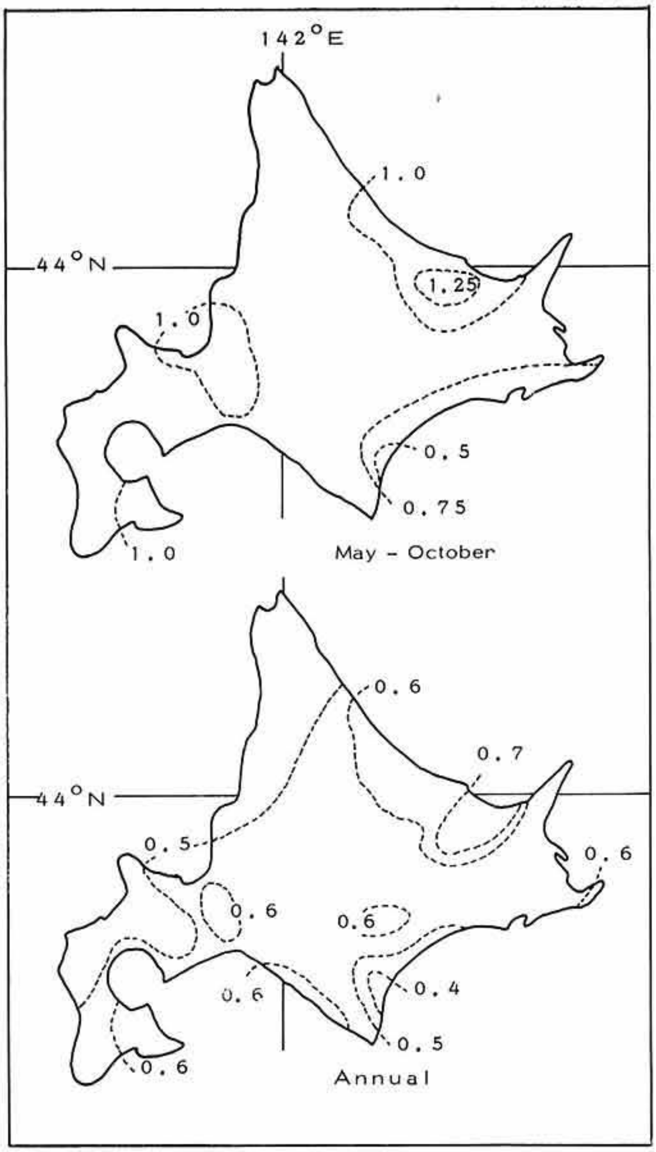

Fig. 2. Distribution of radiation-dry index in Hokkaido

magnesium contents in those horizons are dominantly high, as shown in Table 1.

Then, the thickness of the horizon which lost calcium and magnesium was checked with many soils except soils with thicker A-horizon than 20 cm (Fig. 5). Fig. 6 shows the difference of contents of exchangeable calcium and magnesium between two horizons, i.e., poor-in-base horizon and the horizon underlying just below them. Leaching of bases from Pseudo-gleys showed wide variations between A and D or E block (cf. Fig. 4). Base-status of Pseudo-gleys as well as Brown Forest soils closely correlates with the climatic condition, although water-permeability of Pseudo-gleys is much lower than those of Brown Forest soils.

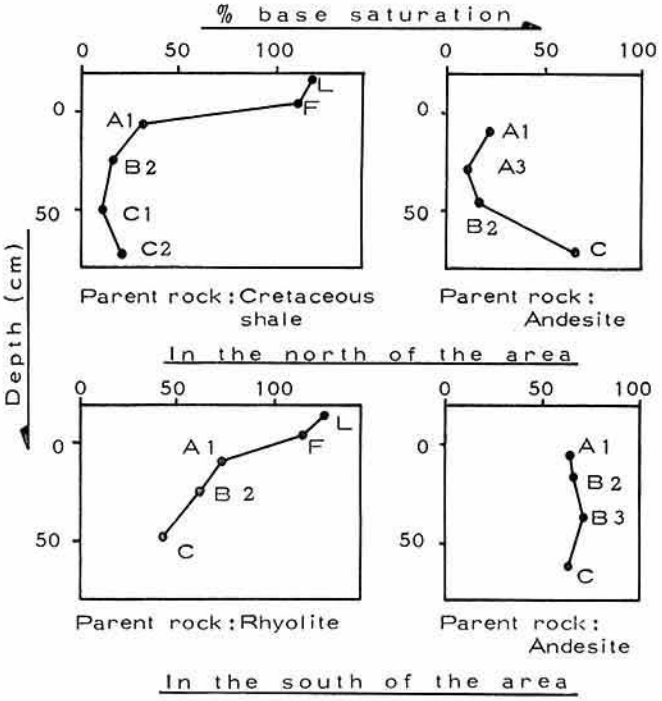

Fig. 3. Base saturations of Brown Forest soils in north-east Hokkaido

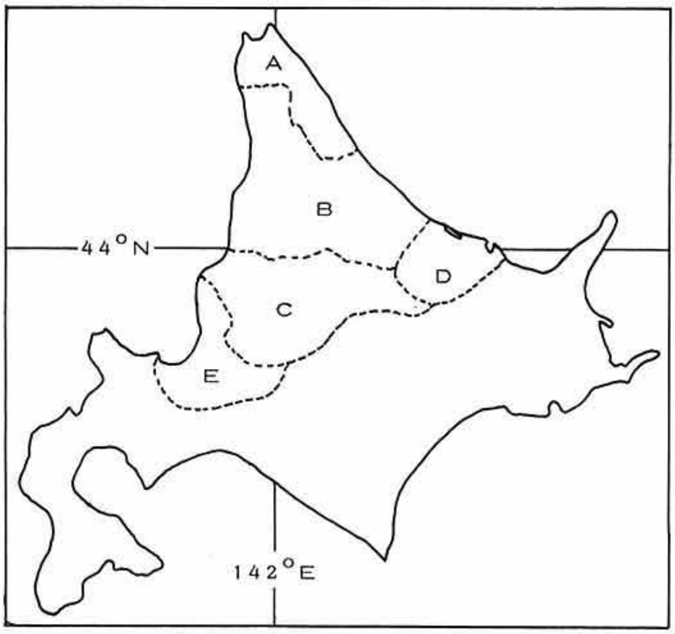

Fig. 4. Distribution area of Pseudo-gley soils

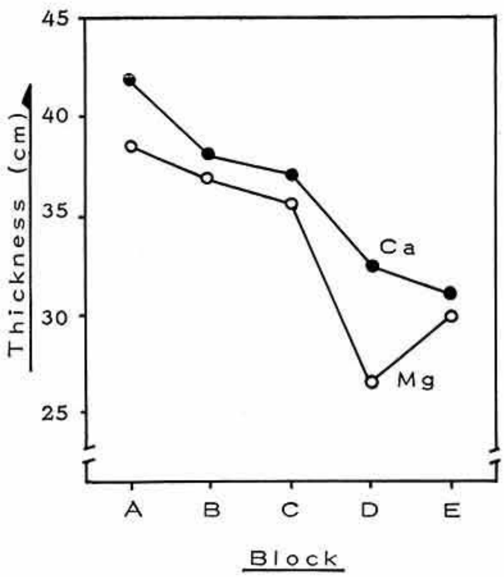

Fig. 5. Mean thickness of Ca- and Mg-poor horizons of Pseudo-gley soils in each block

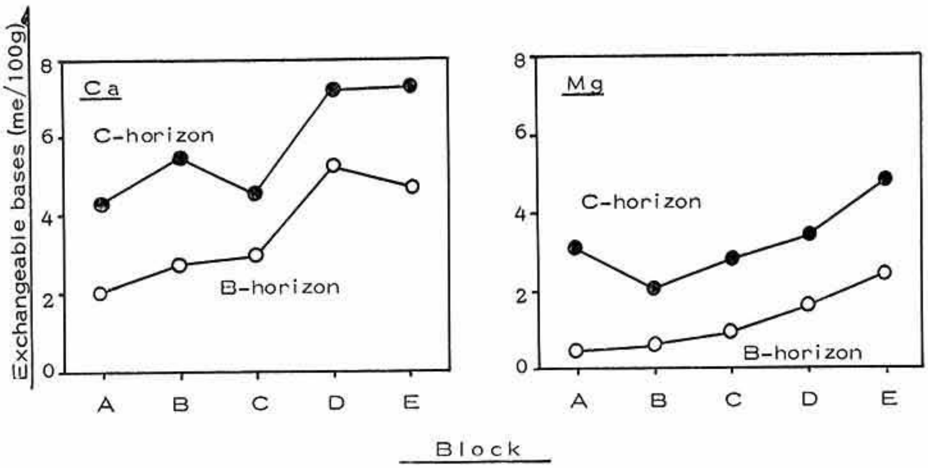

Fig. 6. Exchangeable bases in B- and C-horizons of Pseudo-gley soils in five blocks of north-east Hokkaido

3) Base-status of Volcanic-ash soils

The influence of climate on base-status was also observed on the occasion of so-called Mashu-f volcanic ash, as an example of volcanic-ash soil which is widely spread over the east Hokkaido.

Mashu-f is composed of andesitic ash and is estimated to have deposited 7,190 ± 230 years ago by radio-carbon dating. The ash extends to the D block, and Kushiro area, which is the south of D block. The precipitation in Kushiro area is considerably higher than those in D block.

The base-status shows wide difference be-

Table 2. Base-status of Andosols derived from Mashu-f volcanic ejecta

Site No.	Horizon	Depth of sampling	Texture	Humus	pH (H_2O)	CEC	Exch. bases	Base saturation
		cm		%		— me/100g —		%
D-block								
1	A	25–55	L	14.5	6.2	55.7	28.1	50
	C	55–75	SL	0.4	6.3	11.6	4.3	37
2	A	45–50	SL	7.1	6.1	33.4	15.0	45
	C	50–75	S	5.4	6.1	16.3	5.2	32
3	A	18–35	SL	9.8	6.1	25.2	17.3	69
	C	35–53	SL	5.0	6.3	15.2	6.4	42
Kushiro	(to the south of D-block)							
4	A	42–57	L	9.6	5.9	37.8	2.5	7
	C	57–77	SL	6.9	6.0	23.6	1.4	6
5	A	24–37	L	10.4	6.0	21.7	3.5	16
	C	37–57	SL	4.0	6.2	10.3	1.5	15
6	A	29–39	L	6.5	5.6	18.3	2.1	11
	C	39–51	SL	3.9	5.6	10.6	1.4	13

tween soils of the two areas, as shown in Table 2. Humus in soils increases and bases dominantly decrease with increase in elevation of the study sites.

Base-status of soils, as described above, tells us the strong influence of climate to soils. The base-saturation of soils is the lowest in the A block[10], or the most humid and cold area in Hokkaido, while most of soils have high or intermediate base-saturation in the D block, or the most arid but cool area.

Relations between the vegetation and the base-status of soils

1) Bases of tree-leaves

The contents of bases in leaves of various kinds of tree[13] grown in the area adjacent to the Hokkaido Agricultural Experiment Station were examined (Table 3). The forest was natural and many kinds of tree could be observed. The specimens were sampled just before coloring of leaves, or at the beginning of September.

Relations between base-content of leaves and shade-tolerance of the trees[15] were examined[13]. As shown in Table 4, base-contents are the lowest in the needles of coniferous-trees and in the leaves of broad-leaved light-

Table 3. Bases in leaves from various trees

Tree-species	Base content		
	Ca	Mg	K
	me/100 g dry-matter basis		
Cornus controversa	179.2	44.4	27.9
Prunus ssiori	167.0	34.7	42.7
Ulmus laciniata	151.9	21.1	54.8
Juglans ailanthifolia	142.8	25.2	24.8
Tilia japonica	126.4	35.1	42.4
Fraxinus mandshurica	122.3	34.4	31.9
Ulmus davidiana	112.4	25.1	36.7
Phellodendron amurense	112.0	18.6	24.3
Astrya japonica	106.9	22.4	12.5
Tilia maximowicziana	103.1	23.4	42.4
Acer mono	97.0	34.3	34.7
Kalopanax pictus	95.6	22.6	51.1
Magnolia kobus	95.3	31.9	35.1
Quercus serrata	92.2	23.7	19.9
Quercus dentata	87.9	20.8	18.1
Maackia amurensis	86.5	22.3	20.4
Alnus hirsuta	77.5	22.1	19.1
Sorbus alnifolia	74.4	22.1	34.7
Acer palmatum	70.3	30.3	25.7
Betula platyphylla	68.3	23.9	15.3
Magnolia obovata	66.6	26.0	45.0
Populus sieboldii	65.4	16.6	26.4
Quercus mongolica	74.0	16.0	23.1
do.	60.4	17.3	22.2
do.	55.6	18.5	21.0
Alnus japonica	51.3	22.3	23.6
do.	44.8	14.9	25.1
Abies mayriana	53.7	8.6	16.4
Picea jezoensis	47.6	9.2	19.2

Table 4. Relation between shade-tolerance of trees and base-content of leaves

Shade-tolerance	Contents of Ca, Mg and K in leaves*			
	Poor in all of them	Poor in two of them	Rich in two of them	Rich in all of them
Coniferous tree				
Very strong	*Abies mayriana*			
	Picea jezoensis			
Deciduous, broad-leaved tree				
Very weak	*Quercus dentata*			
	Maackia amurensis			
	Alnus hirsuta			
	Betula platyphylla			
	Populus sieboldii			
	Quercus mongolica			
	Alnus japonica			
Weak		*Phellodendron amurense*		*Cornus controversa*
		Astrya japonica		
		Sorbus alnifolia		
		Quercus serrata		
Strong			*Tilia maximowicziana*	*Tilia japonica*
			Kalopanax pictus	
Intermediate			*Ulmus laciniata*	*Prunus ssiori*
			Acer palmatum	*Juglans ailanthifolia*
			Magnolia obovata	*Fraxinus mandshurica*
				Ulmus davidiana
				Acer mono
				Magnolia kobus

*) "rich" : Ca>95me/100 g dry-matter basis : Mg and K>25me/100 g dry-matter basis

Table 5. Bases in peat-moor plants

Plant		Base content (me/100 g dry-matter)		
Species	Organ	Ca	Mg	K
Phragmites communis	leaf	28.6	25.3	11.3
do.	stem	6.5	6.9	3.3
Sasa senanensis	leaf	22.1	19.6	16.5
do.	stem	5.1	7.5	7.2
do.	root	6.0	8.0	7.9
Moliniopsis japonica	leaf & stem	12.9	12.5	19.4
do.	root	9.3	6.0	8.5
Eriophorum vaginatum	leaf & stem	12.2	8.9	18.1
do.	root	8.9	7.9	8.2
Carex Middendorffii	leaf & stem	15.5	10.4	11.4
do.	root	16.2	8.1	4.0
Sphagnum spp.	whole	32.5	19.7	9.5
Vaccinium oxycoccus	leaf	51.9	20.9	16.9
do.	stem	17.0	5.0	9.3
Myrica Gale	leaf	20.0	10.3	19.8
Ledum palustre	leaf	34.5	14.2	11.8

demanders, and the highest in the leaves of intermediate trees. This fact reveals that the level of bases in leaves is closely related to the shade-tolerance of trees, as Zonn[16] described that the coniferous trees and shade-intolerant broad-leaved trees demand low level of soil fertility, comparing with broad-leaved shade-bearers.

2) Bases of vegetation in peat-moor

Sasa senanensis, a kind of grass extending widely on the forest floor in Hokkaido, shows high content of potassium and very low content of calcium and magnesium. This is the same results as Asahi's[1]. The base-status of herbs should be much different from that of trees. Then, the base-status of vegetation on peat-moor was studied at Bibai during the same season as that of the study on bases of trees. Bibai city is located at western part of Hokkaido.

As shown in Table 5, calcium contents of these leaves are about one-fifth of tree leaves, magnesium contents are half, and potassium contents are one-third. Moreover, the stems and roots are poorer in bases than leaves. Base contents of *Sphagnum* spp., *Carex Middendorffii*, *Eriophorum vaginatum* and *Moliniopsis japonica* grown on the most oligotrophic high-moor and the transitional-moor are lower than those of *Phragmites communis* and *Sasa senanensis* grown on the relatively eutrophic low-moor. Shrub plants such as *Myrica gale*, *Vaccinium oxycoccus* and *Ledum palustre* have higher contents of bases than herbs. Generally speaking, herbs are poorer in bases than tree leaves.

Close relationships are also found between base-levels of soils and those of vegetation in the case of peat-moor. The poor vegetation in high-moor or transitional-moor also reveals the low level of soil-bases and cycling of the least bases between plant and soil.

3) Relations between forest-type and base-status in soils

Base-status of soils and forest-type on the Brown Forest soils along Okhotsk Sea are shown in Fig. 7.

The ratio of tree-species rich in bases is usually parallel to the level of bases in soils. Considerations, however, have to be given to some exceptions. Namely, the tree-leaves are poor in bases at site 1 and 2, while the soils are rich in them. *Quercus mongolica*, *Quercus dentata* and *Populus sieboldii* were dominant

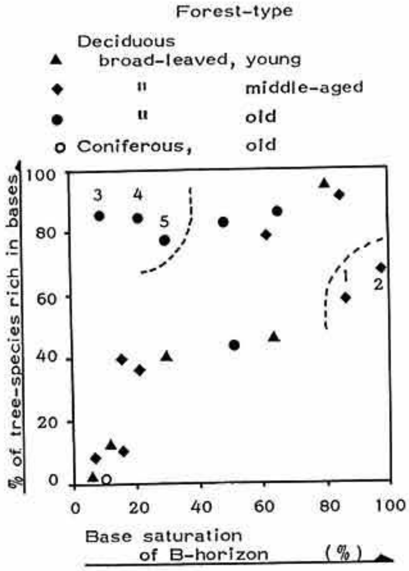

Fig. 7. Relation between forest-type and base saturation of Brown Forest soils

on the hill-tops adjacent to the study sites, as there are gravelly and droughty soils. The vegetation of the study sites is considered to be excessively influenced by the flora on the hill-tops.

At the site 3 to 5 are found high ratios of base-rich trees in spite of the presence of base-poor soils. These sites are covered with deciduous broad-leaved or mixed-stand forest of old age. The percentages of shade-tolerant broad-leaved trees might have become higher due to the selection-cutting of coniferous trees.

Close relations between soil conditions and flora are frequently observed in Hokkaido. The presence of *Ulmus davidiana*, for example, has been a good index of fertile and well-drained soils in lowland since the beginning of the history of land reclamation. *Quercus dentata* prevails on the infertile soils derived from dune-sand or coarse volcanic ejecta. On the various infertile soils is frequently developed *Betula platyphylla* which is one of the representative trees of Hokkaido. *Phragmites communis* is dominant on lowmoor peats. *Alnus japonica* and *Fraxinus mandshurica* appear on the peats relatively rich in mineral fractions. According to Tatewaki⁹⁾, the representative forests in the southeast Hokkaido consist mainly of *Quercus mongolica* and *Quercus dentata*, and partly of *Betula ermanii*, *Alnus hirsuta*, *Alnus japonica*, *Abies mayriana* etc. All of them are poor in bases. It is remarkable that these rather uniform flora has long been sustained on the infertile Andosols in the east Hokkaido.

Above-mentioned studies reveal that vegetation has close relation to the base-status as an index of soil fertility.

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