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Soil Properties 15 Years after A-Horizon Windrowing in Boreal Forests of Hokkaido —A case study in the Tokyo University Forest in Hokkaido—

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I. Introduction

Yezo spruce (*Picea jezoensis* (SIEB. *et* ZUCC.) CARRIERE) is one of the dominant and economically important species in boreal forests of Hokkaido (Japan's northernmost island), where natural forest management based on selection cutting and natural regeneration has become a common management system. Natural regeneration of Yezo spruce is virtually limited to decaying fallen logs, rocky areas, or B- and C-horizon soils (HONDA, 1926; SATO, 1929; NATSUME, 1985; KURAHASHI *et al.*, 1986; TAKAHASHI, I., 1991; KUBOTA *et al.*, 1994). One of the main reasons for this besides that bamboo grass (*Sasa* MAKINO *et* SHIBATA) interferes with regeneration is because Racodium snow blight (*Racodium therryanum* THUEM.), a disease which attacks seedlings under snow during winter, is mainly distributed in A_0- and A-horizons (TAKAHASHI, I., 1991).

By removing rhizomes of bamboo grass and by exposing B- or C-horizon soils, natural regeneration of Yezo spruce became possible even in areas lacking fallen logs (MATSUDA and TAKIKAWA, 1985; NATSUME, 1985; NAKAGAWA *et al.*, 1994). This is the sole method of natural regeneration of the species in managed forests, and is occasionally implemented in natural boreal forests of Hokkaido to initiate natural regeneration in stands where the number of standing trees has been reduced and the forest floor is covered with bamboo grass (WATANABE and SASAKI, 1994).

In this article an area without an A-horizon is called an "interwindrow," and an area with piled A-horizon soil is called an "A-horizon windrow." The soil treatment for enhancement of natural regeneration of Yezo spruce, removing and piling A-horizon soil aside, will be called "A-horizon windrowing." Japanese soil survey system is used in this article (RINYAKOSAIKAI, 1982).

Soil properties would be greatly changed by A-horizon windrowing; B-horizon soils will be exposed. After such a disturbance the new soil development process would take place. Report on the development of soil after A-horizon windrowing is very limited. UJIIE (1985) reported only the physical characteristics of soil 14 years after A-horizon windrowing. In this study both physical and chemical properties of soils in non-disturbed areas and interwindrows 15 years after the soil treatment are compared to clarify the soil development after A-horizon windrowing.

II. Study Area and Methods

The study was conducted in the Tokyo University Forest in Hokkaido, which is located

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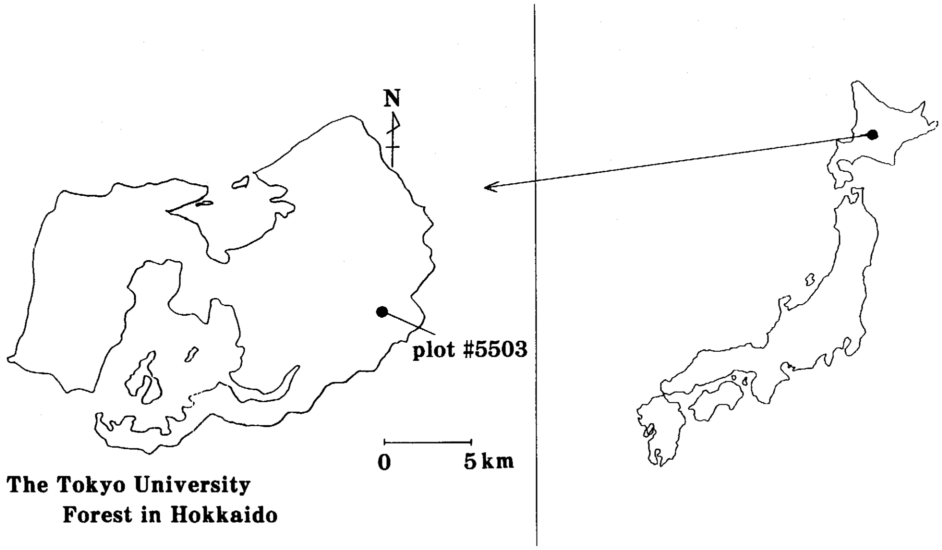

Fig. 1. The location of the experimental plot 5503 and the Tokyo University Forest in Hokkaido.

at 43°10′–20′N and 142°18′–40′E (Fig. 1). Meteorological information at the elevation of 700 m is the following. Mean annual temperature is 4.4°C, minimum monthly temperature is −9.5°C, and maximum monthly temperature is 19.4°C. Annual precipitation is about 1,200 mm, and precipitation is not so much concentrated in any particular season of the year. Maximum snow depth is about 2 m, and the ground is continuously covered with snow from the end of November to the mid of April. (The University Forest in Hokkaido, 1977)

The research was conducted in and around the experimental plot 5503 (760 m a.s.l.) (Fig. 1). It is located in a flat area with slope degree of about 0 degree. The parent material of the soil is andesite. Some volcanic ash is unevenly deposited on top horizon soil, but amount of deposition is so small that it is not forming volcanic ash horizon. The soil is dark forest soil, which is similar to brown forest soil (RINYAKOSAIKAI, 1982) but slightly podozolized, although not to the degree where characteristic podozol horizons are developed (ASAHI, 1963). The original vegetation had been a boreal forest dominated by Yezo spruce and Sachalin fir (*Abies sachalinensis* (FR. SCHMIDT) MASTERS). Japanese rowan (*Sorbus americana* MARSH. subsp. *japonica* (MAXIM.) KITAMURA), Erman's birch (*Betula ermanii* CHAM.), and itaya maple (*Acer mono* MAXIM.) had been also distributed. The forest floor had been mostly covered with kumaizasa bamboo grass (*Sasa senanensis* (FR. *et* SAV.) REHDER). The forests became open forests whose forest floors were dominated by kumaizasa bamboo grass, because regeneration had failed after timber harvesting, pest outbreak, or wind damage. A-horizon windrowing was implemented in 1979, which was 15 years before the soil sampling.

Regeneration in interwindrows after the soil treatment was successful. Density of Yezo spruce seedlings was about 150,000/ha and that of Erman's birch was about 130,000/ha. Average height of Yezo spruce in interwindrows was about 34 cm, and the maximum was about 110 cm. Average height for Erman's birch was about 80 cm, and the maximum was about 210 cm. Few seedlings of other woody species and few herbaceous species were present in interwindrows. Thin layer (0–1 cm) of A_0-horizon was formed mostly from current year's litter fall (sampling was done in late autumn).

An open forest was thickly covered with kumaizasa bamboo grass. There were a few seed trees of Yezo spruce, Erman's birch, and Sachalin fir which formed open forests. A_0-horizon of 2.5 cm thickness had been developed. These organic horizons consisted mostly of fresh or partially decayed bamboo grass leaves.

One sampling site was chosen in an interwindrow, and another was chosen in an open forest dominated by bamboo grass. They were named sampling site "Interwindrow I" and "Bamboo Grass I," respectively, and were treated as a pair of samples. The other pair of sampling sites was also chosen in the same manner, and were named "Interwindrow II" and "Bamboo Grass II." Sampling sites Bamboo Grass I and II were regarded to represent the soil conditions prior to A-horizon windrowing. Sampling sites Interwindrow I and II represented the soil conditions 15 years after A-horizon windrowing. (Fig. 2)

A soil pit was dug and a soil profile was made at each sampling site. Each soil horizon was identified, and thickness of each horizon, Munsell color values (wet and dry values), texture, structure, frequency of roots, and frequency of gravel were recorded.

In Interwindrow I and Bamboo Grass I, two 400 cc soil core samples were collected from every soil horizon except (A_1)-horizon of Interwindrow I whose thickness was too small (1 cm) for collection of a core sample. Physical properties of the soils such as maximum water holding capacity, minimum air capacity, water percolation rate, and pore space composition were obtained according to the method described by ARIMITSU (1980) using these core samples. Pore space was divided into fine and coarse pores by the boundary corresponding to a pF 2.7 tension. The average of the two samples were reported as physical properties of each horizon. However, one sample from A_1-horizon of Bamboo Grass I and one from (A_2)-horizon of Interwindrow I were ineffective due to the presence of a crack in a soil core.

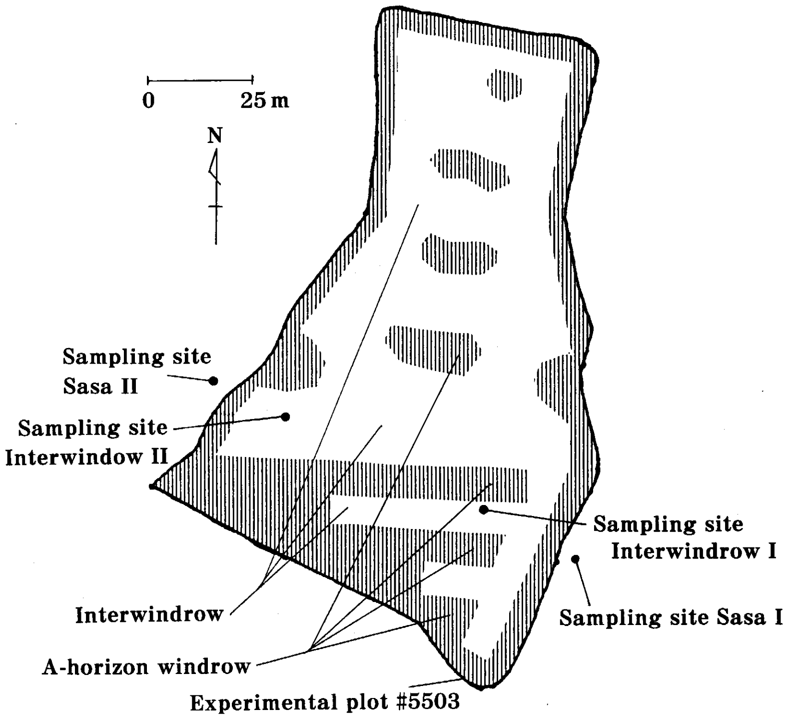

Fig. 2. The location of the soil sampling sites.

So, the data from the one (not the average of the two) valid sample were reported for each of those two horizons.

In all sampling sites, a composite core sample was collected from each soil horizon. A composite core sample is a soil sample consisting of multiple cores of soil of the same volume taken from the same soil horizon. This is a common and effective soil sampling method for chemical analysis; this method gives a representative sample for each soil horizon. At least 4 core samples were obtained from each soil horizon to make up one composite core sample. These composite core samples were air-dried and sieved to a fraction <2 mm prior to the chemical analysis. Total N and total C were determined by dry combustion/gaschromatography (NA 1500, Carlo Erba). Mineralizable soil N was measured slightly modifying the method described by POWERS (1980); concentration of NH_4^+ was measured by the indophenol method described by SOLORZANO (1969). Plant available P was extracted with mixed solution of 0.1 N HCl and 2%NH_4F (Bray No. 4) and determined by the colorimetric method (U-2000, Hitachi). Exchangeable cations were extracted with 1 N NH_4CH_3COO at pH 7.0, and exchangeable K, Ca, and Mg were measured by the atomic absorption spectrophotometry (180-60 model, Hitachi). All NH_4^+ occupying cation exchange site was extracted with NaCl solution, from which NH_3 was purified by distillation. Cation exchange capacity (CEC) was quantified by neutralizing the NH_3 solution with dilute H_2SO_4 solution. Soil pH was measured by glass electrode.

III. Results and Discussion

The description of soil profiles are shown in Table 1. There were not much difference between Bamboo Grass I and II, and between Interwindrow I and II, except that (A_1)- and (A_2)-horizons of Interwindrow II were thicker than those of Interwindrow I, respectively. (A_1)- and (A_2)-horizons of Interwindrow I and II were much thinner than A_1- and A_2-horizons of Bamboo Grass I and II, respectively. The soil textures of A_1- and A_2-horizons of Bamboo

Table 1. Characteristics of soil profiles in interwindrows, and open forests dominated by kumaizasa bamboo grass

Sampling site	Horizon	Depth (cm)	Wet color	Dry color	Texture	Structure	Root (%)*	Gravel (%)**
Bamboo Grass I	A_0	2.5						
	A_1	0–13	10YR 2/1	10YR 4/2	SiL	granular	10–20	0
	A_2	13–31	10YR 2/2	10YR 5/4	SiL	blocky	5–10	0
	B	31–72	10YR 2/3	10YR 5/4	SiCL	massive	0–1	5–10
Interwindrow I	A_0	0–1						
	(A_1)	0–1	10YR 3/2	10YR 4/4	SiCL	granular	10–20	0
	(A_2)	1–6	10YR 4/2	10YR 7/3	SiCL	granular	5–10	0
	B	6–48	10YR 3/4	10YR 8/3	SiCL	massive	0–1	0
Bamboo Grass II	A_0	2.5						
	A_1	0–13	10YR 2/1	10YR 4/2	SiL	granular	10–20	0
	A_2	13–31	10YR 2/2	10YR 5/3	SiL	blocky	5–10	0
	B	31–72	10YR 3/4	10YR 6/4	SiCL	massive	0–1	0
Interwindrow II	A_0	0–1						
	(A_1)	0–4	10YR 3/3	10YR 6/3	SiCL	granular	10–20	0
	(A_2)	4–13	10YR 3/4	10YR 7/4	SiCL	granular	5–10	0
	B	13–48	10YR 4/4	10YR 8/6	SiCL	massive	0–1	5–10

*: frequency of roots is evaluated by percentage of profile surface occupied by cut surface of roots.

**: frequency of gravel is evaluated by percentage of profile surface occupied by gravel.

Grass I and II were silt loam, whereas that of other horizons of all sampling sites were silty clay loam. The soil structures of A_1-horizons of Bamboo Grass I and II and (A_1)- and (A_2)-horizons of Interwindrow I and II were granular. Those of B-horizon of all sampling sites were massive. In all sampling sites, cut surface of the roots occupied 10–20% of the profile surface of $A_1/(A_1)$-horizons, 5–10 percent of $A_2/(A_2)$-horizons, and 0–1 percent of B-horizons. There was no gravel in $A_1/(A_1)$- and $A_2/(A_2)$-horizons of all sampling sites. A small amounts of gravel were found in B-horizon soils of some sampling sites.

Physical properties are shown in Fig. 3. Minimum air capacity, coarse pore space, and water percolation rate of upper horizon soil of Bamboo Grass I were much larger than those of lower horizon soils and those of all horizons of Interwindrow I. Coarse pore space of the upper horizon soil of Interwindrow I was larger than that of the lower horizon soils although not as large as that of the upper horizon soil of Bamboo Grass I.

Physical properties of the top soil in interwindrows right after the A-horizon windrowing must have been almost the same as those of B-horizon soil of Bamboo Grass I. Some A-horizon development had taken place in interwindrows in the first 15 years following the soil treatment; structure of (A_1)- and (A_2)-horizon soils became granular and coarse pore space of (A_2)-horizon soil became larger. However, the thickness of (A_1)- and (A_2)-horizons in the treated areas were much thinner than A_1- and A_2-horizons in non-disturbed areas, respectively. UJIIE (1985) also investigated physical properties 14 years after A-horizon windrowing in the Hokkaido University Forest in Uryu and reported that 2 cm of A-horizon was developed, whereas in non-disturbed areas the thickness of A_1-horizon was 9 cm and that of A_2-horizon was 14 cm. The result of this study is consistent with what UJIIE (1985)

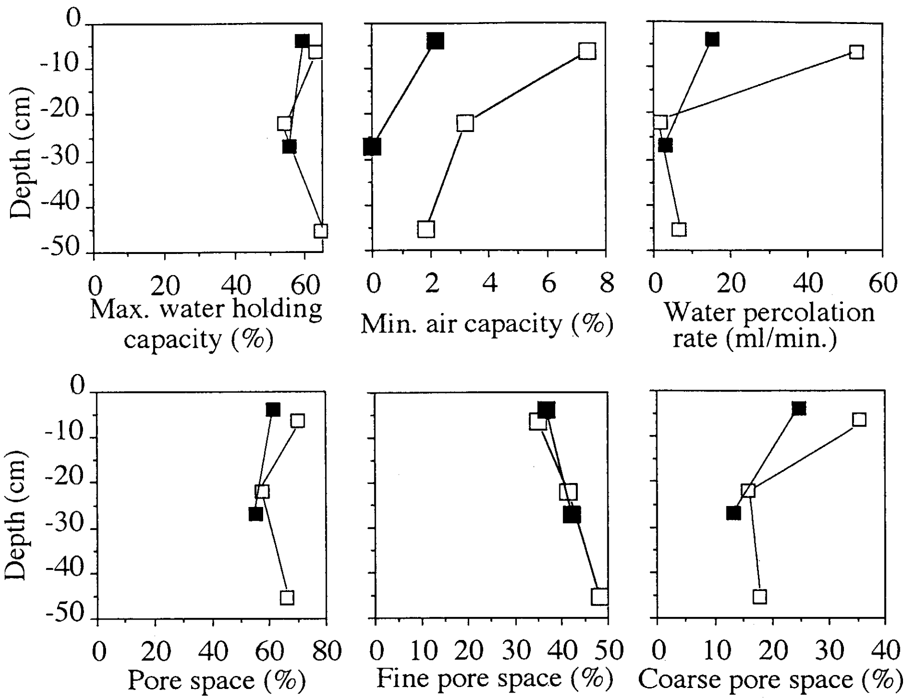

Fig. 3. Physical properties of soils in an interwindrow, and an open forest dominated by kumaizasa bamboo grass.
—□— Bamboo grass I, —■— Interwindrow I.

had reported; A-horizons in the treated areas were much thinner than that in the non-disturbed areas. Although A-horizon development is taking place after the soil treatment, it would take longer than 15 years until the A-horizon soil in the treated areas becomes similar (including thickness) to that of the original A-horizon soils.

The chemical properties are shown in Fig. 4. In general, concentrations of total C, total N, and mineralizable soil N decreased with increasing depth of soil in all sampling sites. Lower horizon soils had slightly higher pH than upper horizon soils in all sampling sites. CEC and concentrations of exchangeable K, Ca, and Mg varied among soil horizons and sampling sites; there was no general tendency in their concentrations in relation to soil

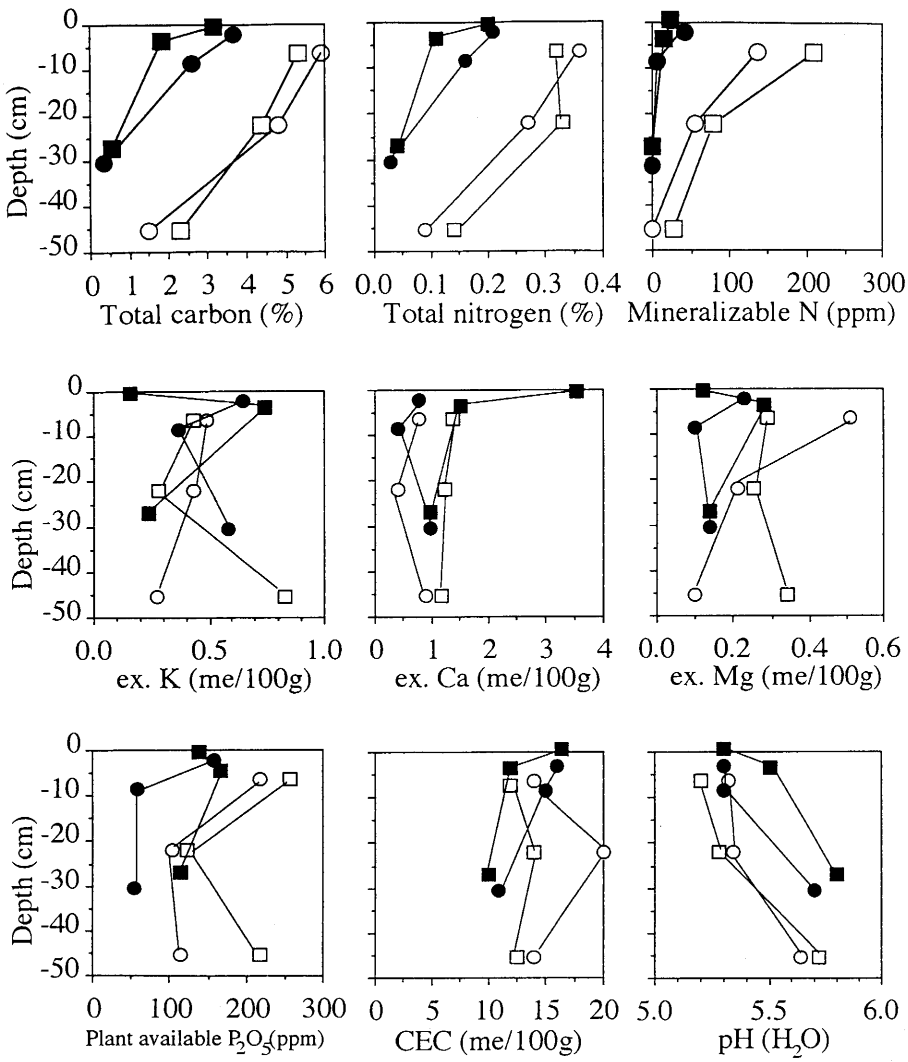

Fig. 4. Chemical properties of soils in interwindrows, and open forests dominated by kumaizasa bamboo grass.
—□— Bamboo grass I, —○— Bamboo grass II, —■— Interwindrow I, —●— Interwindrow II.

depth.

That concentrations of total soil C and total soil N in the upper horizon soils were higher than in the lower horizons, that soil pH increased with increasing soil depth, and that there were no tendencies in CEC in relation to soil depth, were also reported by ASAHI (1963) and NAKATA *et al.* (1994). NAKATA *et al.* (1994) reported that concentration of exchangeable K, Ca, and Mg decreased with increasing soil depth, whereas ASAHI (1963) found the same with K and Ca, but not with Mg. The reason for discrepant findings on exchangeable cations among three reports was not clear. There is a certain amount of volcanic ash deposits in most part of the University Forest. Amount of ash deposition varies site to site, and therefore, parent material varies site to site. Thus, it is necessary to identify the parent material of soil, especially how much and what kind of volcanic ash is mixed into a particular horizon, to find out if there is any distribution pattern of CEC and exchangeable basic nutrients in relation to soil depth.

A-horizon windrowing would result in displacement of a significant portion of carbon and nitrogen in soil because their concentrations are much higher in the upper horizons (Fig. 4). MORRIS *et al.* (1983), TUTTLE *et al.* (1985), and TEW *et al.* (1986) also reported that N and several other nutrients are displaced and concentrated into windrows by implementation of windrowing. On the other hand, displacement of plant available P, exchangeable K, Ca, and Mg associated with A-horizon windrowing would not be as significant, since their concentrations do not necessarily decrease with increasing soil depth.

Concentrations of total C and total N in A_1- and A_2-horizons of Bamboo Grass I and II were much higher than those in (A_1)- and (A_2)-horizons of Interwindrow I and II (Fig. 4), respectively. This is most likely to be due to the reduction of organic matter and litter in interwindrow after the soil treatment. Concentrations of mineralizable N in upper horizons of Interwindrow I and II were much smaller than those of Bamboo Grass I and II. Thus, in an interwindrow availability of N, the nutrient most likely to be scarce, would likely to be limited.

It can be deduced that it would take much longer than 15 years until A-horizon which is similar to the original one (including the thickness of the horizon) is re-developed in interwindrows. Chronological studies on soil development after A-horizon windrowing should be carried out in various sites to further investigate the speed and process of top soil re-development after A-horizon windrowing.

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Summary

A-horizon windrowing, removing the entire A-horizon soil (both A_1- and A_2-horizons), is a method of site preparation to initiate natural regeneration of Yezo spruce (*Picea jezoensis* (SIEB. et ZUCC.) CARRIERE) in the boreal forests of Hokkaido. Soil properties in an area treated with A-horizon windrowing and in a non-disturbed area were compared 15 years after the soil treatment.

In the treated areas, the (A_1)- and (A_2)-horizons were much thinner than the A_1- and A_2-horizons in the non-disturbed areas. Minimum air capacity, coarse pore space, and the water percolation rate of the upper horizon soil in the non-disturbed area were greater than those of the upper horizon soil in the treated area.

Concentrations of total C, mineralizable soil N, and total N in the (A_1)- and (A_2)-horizons in the treated areas were much lower than those in the A_1- and A_2-horizons in the non-disturbed areas, respectively. There were no clear differences in the concentration of plant available P, exchangeable K, exchangeable Ca, exchangeable Mg, and CEC between the soil in the non-disturbed areas and the treated areas.

Although an A-horizon development process had been taking place, it would take much longer than 15 years before top soil which is similar to the original (including the thickness of the horizon) is developed again in the areas treated with A-horizon windrowing.

Key Words: A-horizon windrowing, Soil properties, *Picea jezoensis*, *Sasa*, Site preparation

Literature Cited

ARIMITSU, K. (1980) Ch.10-Sec.8 Forest soils. In Analysis of physical properties of soil. AKATSUKA, M. (ed.), 505 pp, Yokendo, Tokyo, 465–477. (in Japanese)*

ASAHI, M. (1963) Studies on the classification of forest soils in the Tokyo University Forest, Hokkaido. Bull. Tokyo Univ. For. **58**: 1–132. (in Japanese with English summary)

HONDA, S. (1926) Notes on the natural regenerating condition of natural forest in Hokkaido. J. Soc. For. **33**: 12–31. (in Japanese) (the current name of the journal is J. Jpn. For. Soc.)

KUBOTA, Y., KON'NO, Y. and HIURA, T. (1994) Stand structure and growth patterns of understorey trees in a coniferous forest, Daisetsuzan National Park, northern Japan. Ecol. Res. **9**: 333–341.

KURAHASHI, A., MATSUURA, T., OGASAWARA, S. and HAMAYA, T. (1986) Studies on the stand structures and family composition of boreal coniferous forests of selective-cutting type in the University Forest in Hokkaido heavily damaged by the typhoon No. 15 in 1981. Bull. Tokyo Univ. For. **75**: 61–86. (in Japanese with English summary)

MATSUDA, K. and TAKIKAWA, S. (1985) Practical study on promotional treatment of natural regeneration. Bull. Coll. Exp. For. Hokkaido Univ. **42**: 909–940. (in Japanese with English summary)

MORRIS, L. A., PRITCHETT, W. L. and SWINDEL, B. F. (1983) Displacement of nutrients into windrows during site preparation of a flatwood forest. Soil Sci. Soc. Am. J. **47**: 591–594.

NAKAGAWA, M., TAKAHASHI, Y., WATANABE, S. and SUZUKI, K. (1994) Demography of naturally regenerated seedlings after soil treatment in boreal forest. Trans. 105th Mtg. Jpn. For. Soc. **105**: 385–387. (in Japanese)

NAKATA, M., TANAKA, H. and YAGI, H. (1994) Altitudinal changes in vegetation and soils on Mt. Dairoku, central Hokkaido, Japan. Jpn. J. Ecol. **44**: 33–47. (in Japanese with English summary)

NATSUME, S. (1985) Studies on the habitat conditions and early growth in the natural regeneration of *Picea jezoensis* CARR. Res. Bull. Coll. Exp. For. Hokkaido Univ. **42**: 47–107. (in Japanese with English summary)

POWERS, R. F. (1980) Mineralizable soil nitrogen as an index of nitrogen availability to forest trees. Soil Sci. Soc. Am. J. **44**: 1314–1320.

RINYAKOSAIKAI (1982) Survey methods and properties of forest soils. 328 pp, Rinyakosaikai, Tokyo. (in Japanese)*

SATO, Y. (1929) Die Naturverjungung der Eso-Fichte *Picea jezoensis* ihre Grundbedingungen nebst praktischen Anwendungen. Res. Bull. Coll. Exp. For. Hokkaido Univ. **6**: 1–354. (in Japanese with German summary)

SOLORZANO, L. (1969) Determination of ammonia in natural waters by the phenol hypochlorite method. Limnol. Oceanogr. **14**: 799–801.

TAKAHASHI, I. (1991) Studies on the mycofloral succession on Yezo spruce (*Picea jezoensis* CARR.) in various stages of growth, with special reference to the role of fungi in the natural regeneration of the host. Bull. Tokyo Univ. For. **86**: 201–273. (in Japanese with English summary)

TEW, D. T., MORRIS, L. A., ALLEN, H. L. and WELLS, C. G. (1986) Estimates of nutrient removal, displacement and loss resulting from harvest and site preparation of a *Pinus taeda* plantation in the Piedmont of North Carolina. For. Ecol. Manage. **15**: 257–267.

The University Forest in Hokkaido. (1977) Meteorological observations at different elevations of Mt. Dairoku, the Tokyo University Forest in Hokkaido.–Records in the period 1972–1975 and short discussion on them.—Misc. Infor. Tokyo Univ. For. **21**: 22–47. (in Japanese with English summary)
TUTTLE, C. L., GOLDEN, M. S. and MELDAHL, R. S. (1985) Surface soil removal and herbicide treatment: Effects on soil properties and loblolly pine early growth. Soil Sci. Soc. Am. J. **49**: 1558–1562.
UJIIE, M. (1985) Soils of Sasa bamboo-growing land and its surface treatments for natural regeneration of trees. Res. Bull. Coll. Exp. For. Hokkaido Univ. **42**: 1043–1063.
WATANABE, S. and SASAKI, S. (1994) The Silvicultural Management System in temperate and boreal forests: A case history of the Hokkaido Tokyo University Forest. Can. J. For. Res. **24**: 1176–1185.
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北海道の亜寒帯林における地搔き15年後の土壌状態
—東京大学北海道演習林での一例—

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要　　旨

北海道の亜寒帯林では，エゾマツ (*Picea jezoensis* (SIEB. *et* ZUCC.) CARRIERE) の天然更新を図るため，A層（A_1層とA_2層）を除去する地搔きが行われることがある。A層除去区と土壌未攪乱区において，地搔き15年後の土壌の理学性及び化学性を比較した。

A層除去区の(A_1)および(A_2)層の厚さは，土壌未攪乱区のA_1およびA_2層のものよりも小さかった。表層土についてみると，気相及び最小容気量，粗孔隙量，透水能については，A層除去区のもののほうが土壌未攪乱区のものよりも低かった。

A層除去区における全炭素濃度および全窒素濃度，無機化可能な窒素濃度は，土壌未攪乱区のものよりも低かった。反対に，可給態リン酸及び交換性カリウム，交換性カルシウム，交換性マグネシウム，陽イオン交換容量(CEC)については，土壌未攪乱区とA層除去区の間で明確な差はみられなかった。

A層除去区においては，A層除去後土壌の生成が進みつつあったが，(土壌層の厚さも含めて)もととおなじようなA層土壌が発達するようになるまでには，15年よりもはるかに長い期間が必要であると考えられた。

キーワード：A層除去，土壌，エゾマツ，ササ，地拵

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Although an A-horizon development process had been taking place, it would take much longer than 15 years before top soil which is similar to the original (including the thickness of the horizon) is developed again in the areas treated with A-horizon windrowing.