On the rehabilitation of soil properties in Sabô-forests *.

Hidehiro ISHIBASHI

(Laboratory of Forest Engineering)

砂防林における土壌諸性質の回復について

石　橋　秀　弘　(林業工学研究室)

(I) Introduction

It has been repeatedly pointed out that denuded lands distributed in the granite regions have historic backgrounds and relations with the advances of civilization. On the other hand, however, we know a great many non-denuded lands which border on the denuded granite regions and seem to had been attacked by same intensities of human agencies.

This leads to the conclusion that the denuded mountain is a landscape characteristic of the geology.

Therefore it is probable that the process of devastation and rehabilitation of the forest soils in those regions is quite peculiar.

Mie Prefecture is one of the most famous regions which has immense areas of the denuded lands. They were once productive forests. At the later period a great many trees in those forests had been felled down and transported for the construction of the Tôdaiji Temple and other temples or shrines in Nara City and its neighborhood.

Since the forest had continued to be devastated increasingly more severely until the Sabô-work based on modern scientific technics had been carried out in the Meiji era (1868−1911 A. D.).

The writer had a favorable chance to survey the Sabô-forests in Mie Prefecture by request from Kinki Chihô Kensetsukyoku (Kinki Regional Construction Bureau) Authorities.

On completion of this report, I express my profound gratitude to Mr. T. Tsutsumi, Assistant Professor of Kyôto University, for his kind and valuable guidance. His reports concerning the soils of Sabô-forests in Kurita, Rokkô, Tamano, Saijô, and Kure District have offered me many instructive ways of investigation.

Thanks are extended also to Dr. T. Shidei, Dr. N. Shibata of Kyôto University and Dr. K.

* Since each country has its own devastated conditions of lands and the characteristics in erosion control works, we can hardly find out appropriate technical terms whose peculiar nuance fits in well with the works which have feen carried out in Japan.

In this paper, therefore, I will use the term "Sabô-" untranslated, which, according to Dr. Lowdermilk, foreigners also seem to be able to pronounce fluently by euphoniousness.

The forest or stand on which the Sabô-works were carried out will be expressed as "Sabô-forest" or "Sabô-stand".

Murakami, Prof. T. Narita, Prof. T. Tooyama, and Assistant Professor T. Miyake of Shimane Agricultural College, for their helpful advices.

(II) General aspects of the investigated territories

In the regions within the jurisdiction of the Kizugawa Sabô Construction Office, i. e., from Nabari City to Iga-Ueno City in Mie Prefecture, there are a great many mountains or hills on which the Sabô-works (erosion control works on hillside) had been carried out.

They include regions of granite, gabbro, and fluviatile deposit.

The investigation was carried in only the granite region which has most extensive areas and most serious problems from the point of erosion control.

Some Sabô-stands of various age and several natural stands in this vicinity were picked out for investigation; the former to trace the development of soil with increasing years, the latter to obtain the values to which the Sabô-forests in this vicinity will approach.

The Sabô-forests in this district have rehabilitated satisfactorily and the planted trees have grown vigorously except a few exceptions. The poor natural stands were also picked out intentionally for comparison.

The kinds of the hill side Sabô-works applied in this district were Tsuminaekô (terracing with sod), Ishizumikô (hill side masonry), Sujikô (terracing without sod). Most prevailing work in this district was the first, whereas the second and the third were confined to the places of special topographies.

To serve the consideration of measured data, the samples were collected from only the terraces of Tsuminaekô. The sampling depths were 1 : 0 cm, 2 : 15 cm, 3 : 30 cm. (In this paper the depths will be indicated concisely; 1, 2, 3.)

Table 1. Investigated Plots.

Number of plot	Age of stand	species	Growth of plants
I	5	A. pendula P. Thunbergii	good
II	27	A. pendula P. Thunbergii	good
III	19	A. pendula R. pseudacacia	good
IV	11	A. firma A. pendula	good
V	26	A. tinctoria R. pseudacacia	good
VI	19	A. pendula R. pseudacacia	good
VII	1	P. Thunbergii A. pendula	good
VIII	5	P. Thunbergii A. pendula	good
IX	25	P. Thunbergii —	poor
X	1	A. pendula P. Thunbergii	good
101	N. S.	P. densiflora	good
103	N. S.	P. densiflora	good
104	D. L.	—	—
201	65	P. Thunbergii	poor
204	N. S.	P. densiflora	poor
206	64	P. Thunbergii	poor
208	N. S.	P. densiflora	poor
209	N. S.	P. densiflora	good
211	N. S.	P. densiflora	poor
9	26	P. Thunbergii	poor

(Note)
1. Number of plot
   Roman numerals : Permanent Plot (P.P.).
2. N. S. : Natural Stand, D. L. : Denuded Land
3. Botanical name of species
   Alnus tinctoria Sarg. var. obtsiloba Carr.
   Alnus firma Sieb. et Zucc.
   Alnus pendula Matsum.
   Robinia pseudacacia L.
   Pinus Thunbergii Parl.
   Pinus densiflora Sieb. et Zucc.
4. Plot No. VI. : Pinus Thunbergii has disappeared.

Uniformity of the deepest sampling depth in 30 cm is due to the fact that the majority of the terraces reach the bed rock in 30−40 cm, except a few plots where the depths of soil materials are irregular from the topographical roughness before the execution.

The investigated plots are shown in Table. 1.

In this table only two species are described in the predominant order. It must be added, however, that the planted Kuromatsu (Pinus Thunbergii Parl.) survives even in the plots whose columns make no mention of it, except in Plot No. Ⅵ.

The soils in those investigated territories will be conveniently referred to as "Kizugawa Soil" in this paper to distinguish from other soils whose data will be often referred to.

(III) Method of experiment

Physical and chemical properties of the soil sample collected with metal cylinder (100 cm^2 base area, 4 cm height) and bag respectively were measured according to the "National Forest Soil Surveying Method"(1).

(IV) Results and discussion

(1) Accumulation of organic matter

A part of the organic matter which has been supplied annually on the newly afforested land is decomposed and added to the mineral soil, while the remainder accumulates on the surface.

Many workers who had studied the accumulating process of organic matter have generally acknowledged that the amount of accumulating substance increases rapidly in the early period, and slowly in the later period approaching to the value which is peculiar to the locality and the species.

Thicknesses of A_0 layers are presented in Fig. 1. Because of the substantial difference in thickness of an accumulating layer between the terrace and the side-slope, the values in the figure have been corrected by the area ratio of the terrace and the side-slope in respective stands.

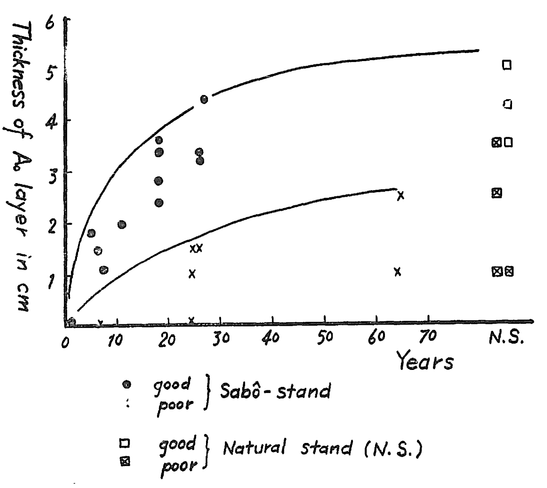

Fig. 1 Accumulation curve of organic matter.

Some investigators have pointed out that a simple equation exists between thickness and dry weight of organic matter, though the coefficients in those equations differ in different species. According to data obtained in the Sabô-stands in Rokkô (Hyôgo Prefecture), Kurita (Shiga Prefecture), Tamano (Okayama Prefecture), Saijô (Hiroshima Prefecture), and Kure (Hiroshima Prefecture) District by Tsutsumi(2)(3), dry weight of litter of Akamatsu (Pinus densiflora S. et Z.) is about 2.5 times as heavy as that of Oobayashabushi (Alnus firma Sieb. et Zucc. var. Sieboldiana Winkl.) and Yamahan-noki (Alnus tinctoria var. obtusiloba Carr.) corresponding to any given accumulating thickness.

As stated in Table. 1, the good old Sabô-stands in this district consist principally of broad-leaved trees, and natural stands, by way of contrast, of conifers.

Therefore, it can be deduced from the figure that the accumulated organic matter in even the 26-year-old good Sabô-stand is no more than one half the weight of that in natural stands.

Regarded the natural stands a probable final state which the forest in this neighborhood would reach to, the accumulation curve drawn here is similar to ones reported by many workers.

Good stands and poor stands are plotted in different symbols in Fig. 1. The figure indicates that accumulated amounts in the poor stands are less than half of that in the good stands of the identical age. This is due to the scanty supply of the litter and removal by rain water, and not to rapid decomposition.

(2) Specific gravity of fine soil

There are two major factors which influence the specific gravity value of fine soil.

(a) Mineral composition of soil

The first and primary factor which determines the kinds and contents of minerals in the soil is the mineral composition of the parent rock, especially the ratio of heavy minerals to light minerals.

All of the soils investigated here are derived from granite. However, there are some differences in contents of individual minerals among granites themselves. Furthermore, the intensity and the duration of weathering agents which differ much in different environments exert influences on the mineral composition of the soils.

(b) Organic matter

Because of the fact that the specific gravity of soil organic matter is smaller than that of mineral soil, the increase in the content of organic matter in soil leads to the decrease in the soil specific gravity. Under the conditions that the specific gravities of mineral soil and organic matter are constant, Tsutsumi [5] worked out the following formula from data on the Sugi (Cryptomeria japonica D. Don) forest of Kitô, Hinoki (Chamaecyparis obtusa Sieb. et Zucc.) forest of Owase and others.

$$Y = Ax + B$$

Where Y : reciprocal of specific gravity of soil

x : Carbon content (%)

A, B : constant.

Fig. 2 represents the relationship between the organic carbon content and the specific gravity of fine soil.

The variation of the specific gravity value corresponding to a certain carbon content value is due to the difference in mineral composition or the degree of decomposition of soil organic matter.

Fig. 2 shows that within the limits of about 0.5% of carbon content the specific gravity of soil seemed to be independent of the carbon content and, beyond that limit it began to decrease

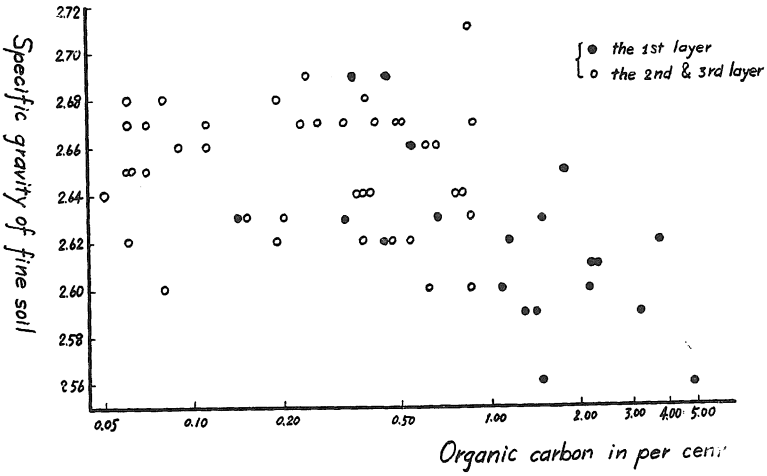

Fig. 2 Relationship between specific gravity and carbon contents.

with increasing carbon content. It suggests that the decrease in the specific gravity value caused by the addition of less than 0.5% of organic carbon did not attain to measurable magnitude.

Therefore, the decrease of the specific gravity has occured only in the first layer, which is abundant in carbon content, and not in the second or the third layer, which is scanty of carbon content.

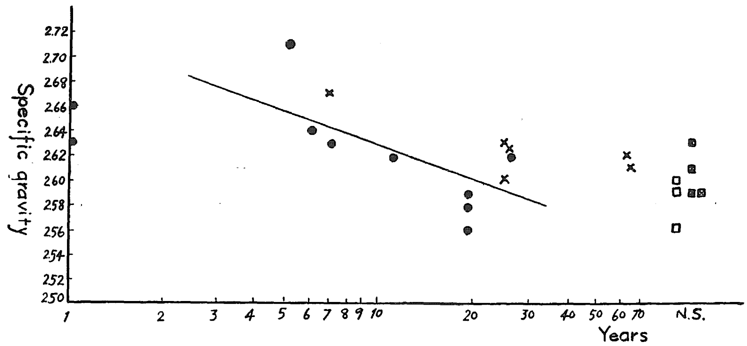

Fig. 3 Relationship between specific gravity and years of stand.

The decrease of the specific gravity of the surface soil with years is represented in Fig. 3. The changes occur rather rapidly in early 30 years after execution and slowly afterwards.

(3) Volume weight, Pore volume

A change of volume weight of the first layer soils with advancing stand age is represented in Fig. 4 (fresh soil). The fine soils also exhibited very similar tendency. The figure indicates decreasing tendency by years.

The decrease in the volume weight is principally due to the increase in the pore volume. Becauce, as mentioned in the foregoing section, the changes of specific gravity of fine soil were not so great as to produce the great changes in the value of volume weight.

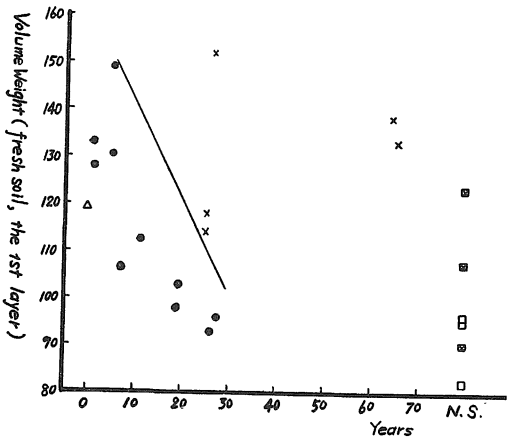

Fig. 4　Change of volume weight with years.

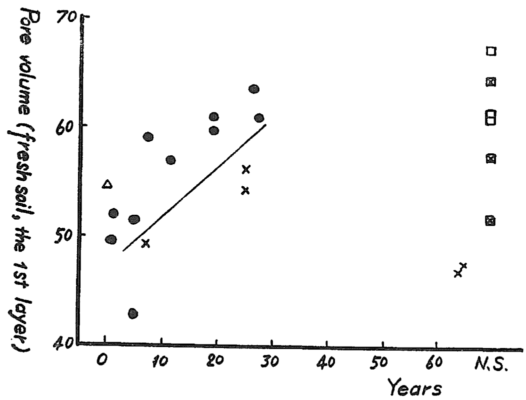

Fig. 5　Change of pore volume with years.

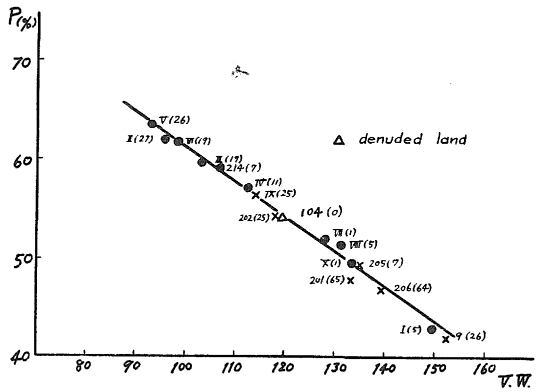

Fig. 6　P-V. W. relationship of fresh soil in Sabô-stand (the first layer)

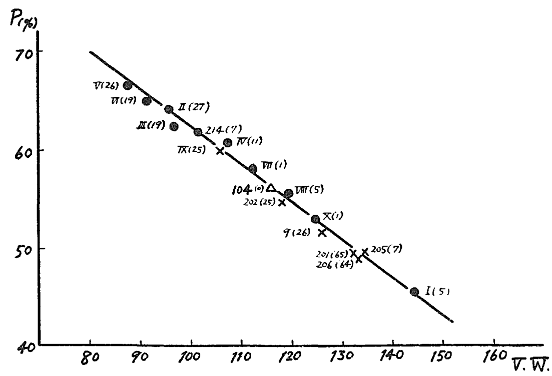

Fig. 7　P-V. W. relationship of fine soil in Sabô-stand (the first layer)

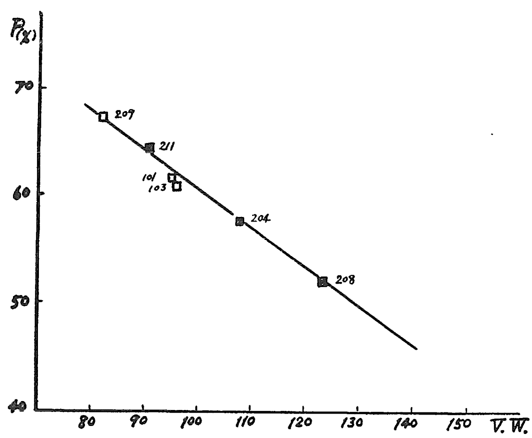

Fig. 8　P-V. W. relationship of fresh soil in natural stand (the first layer).

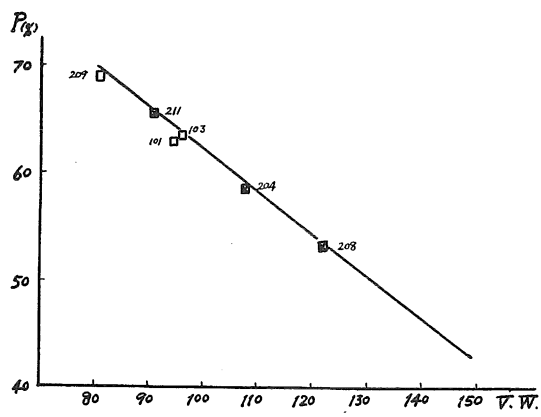

Fig. 9　P-V. W. relationship of fine soil in natural stand (the first layer).

Fig. 5 shows the increasing tendency of pore volume with years.

P—V. W. graph, which has been proposed by Tsutsumi [6], is convenient for an easy understanding of the soil development from the standpoint of the relationship between volume weight and pore volume.

Fig. 6 and Fig. 7 represent those relationships in Sabô-stands, and Fig. 8 and Fig. 9 those in the natural stands.

The progress in soil formation means the decrease in volume weight and increase in pore volume, that is, upward removal along the P—V. W. line. Numerals in the parenthesis indicate the years after afforestation, i. e. the age of the stand.

Trends of the upward removal with years can be found in those graphs. Differences in the positions of the stands of the same year are due to the differences in initial conditions, and the inversion of the order of the position in the graphs of fine soil and fresh soil means a difference in the contents of gravel in fresh soils.

Only brief explanation concerning growth of the planted trees will be given here.

In Fig. 4 the drawn line separates the points of the good stands from those of the poor stands. The former are plotted in the lower part of this line, and the latter the upper part.

A similar tendency is observed in Fig. 5. In this figure the good stands are plotted in the upper part and the poor stands lower part.

Moreover the plotted positions on the P—V.W. line of the good stands are much higher than that of the poor stands of the identical age.

Though the points of the natural stands are generally plotted on the higher position, it must be worthy of note that the 26-year-old Sabô-stand is located near the natural stand.

Various stages of the soil-forming process are observed among the different depths of a profile as well as among the stands of different age.

A measured length between the point of the third layer and that of the first layer of the identical profile along the P—V. W. line was presented in Fig. 10. The points plotted on the upper part of the dotted horizontal line mean that the point of the first layer of the soil profile on the P—V. W. line is situated higher than that of the third layer. In other words, the soil of the first layer is in more progressed state of weathering than that of the third layer. On the lower part of the dotted line, the situation is just the opposite. Fig. 10 indicates that during several years after execution the first layer soils have more higher volume weight and lower pore volume than the third layer soils. In this period, therefore, it seemed as if the first layer soil was in less progressed stage of weathering than the third layer soil. After this period the points are plotted on the upper part of the line. Results of the mechanical analysis illustrated that there was no significant difference in contents of the fine-grained fractions between the first layer soil and the third layer soil in

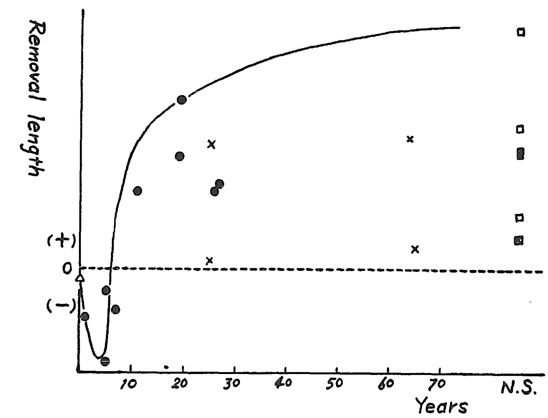

Fig. 10 Removal length on P-V. W. line from the 3rd- to the 1st layer (fresh soil)

this period. Therefore the above-mentioned reversed phenomenon seems to be caused by compaction in the surface layer by rain water, and not by retarded weathering.

Surface layer soils have much more chances to be compacted by rain water than the lower layer soils, especially when the precipitation is not sufficient to reach to the lower layer.

Subsoils have been compacted by the weight of upper soils which seemed to be not so great as compaction by rain water applied to the surface soils.

In the old stands the degree of soil maturation which is determined principally by production of the finer-grained fraction and development of aggregates was superior to the agent of compactness by rain water. Therefore they were plotted in the upper part of that line, and the absolute values tend to be greater gradually. It must be added, however, that the significance of a given absolute value differs in different position on the P.－V. W. line.

The value approach to the definite one which is determined by the parent materials and the environments.

The similar relationship was also observed between the first layer and the second layer.

Wide variation in the initial conditions of the each soil makes it impossible to find out the reversing phenomenon in the first layer soils of young stands in Fig. 4, 5.

Compacting tendencies of the topsoils in the younger forests had been observed also by Tsutsumi [4] in the above-mentioned forests. Moreover he had confirmed the facts successfully by direct measuring of compactness by the penetrometer.[7]

(4) Maximum Water Capacity ($W_{max.}$) and Minimum Air Capacity ($A_{min.}$)

As was mentioned above, the increase of pore volume results in the decrease of volume weight.

It has been generally recognized that soil pores consist of capillary pores and noncapillary pores.

Capillary pores, indicated by Maximum Water Capacity; $W_{max.}$, are considered to be responsible for holding water against the force of gravity.

Noncapillary pores, expressed in Minimum Air Capacity; $A_{min.}$, have an important significance in soil aeration.

The increasing tendency of $A_{min.}$ with advancing years is illustrated in Fig. 11. Fig. 12 and

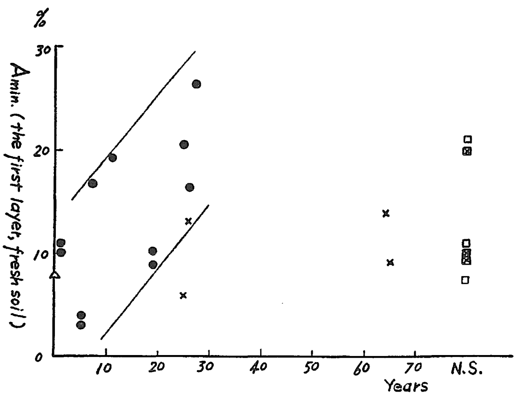

Fig. 11 Change of Minimum Air Capacity with years.

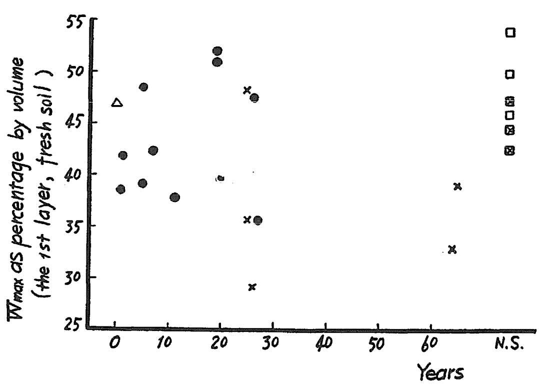

Fig. 12 Change of Maximum Water Capacity with years (fresh soil).

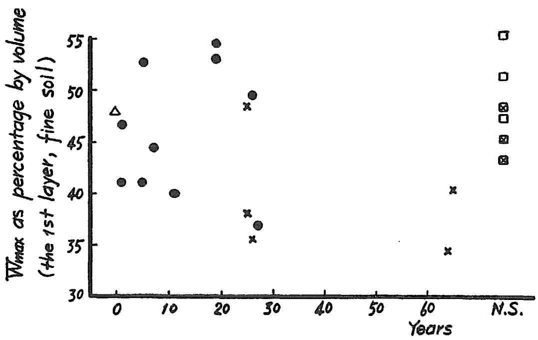

Fig. 13 Change of Maximum Water Capacity with years (fine soil).

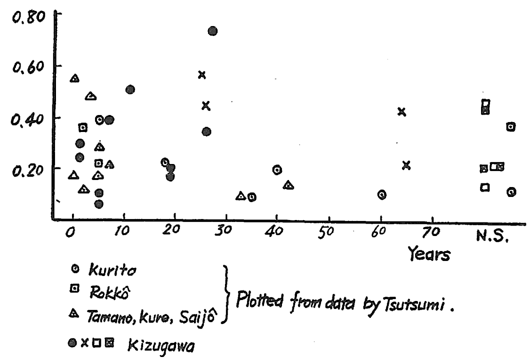

Fig. 14 Change of $A_{min.}/W_{max.}$ with years (fresh soil, the 1st layer)

Fig. 13 show the similar processes of $W_{max.}$.

A ratio of noncapillary pores to capillary pores, $A_{min.}/W_{max.}$, increases in early about thirty years, and decreases afterwards approaching the value of the natural stands (Fig. 14).

In the younger forests, therefore, noncapillary pores seemed to increase more rapidly than capillary pores.

It seems to require some consideration that the data obtained here are somewhat different from that obtained from soils in Kurita, Rokkô, Tamano, Saijô, Kure, and Yamanouchi (Ehime Prefecture) District by Tsutsumi. (2)(3)(4)

His data indicate the monotonous decreasing process of the Minimum Air Capacity with years.

As the changes of the values with years are liable to be confused by the wide variations in each plot, relationships between volume weight (V. W.) and $W_{max.}$ or $A_{min.}$ shall be investigated, on the assumption that the lower volume weight means the more developed stage of weathering or the older age of forest.

The values of $W_{max.}$ or A_{min} corresponding to a certain V. W. differ in different ratio of noncapillary pores to capillary pores.

The correlation coefficients of volume weight and $A_{min.}$ or $W_{max.}$ in the first layer of Kizugawa Soils are represented in Table 2.

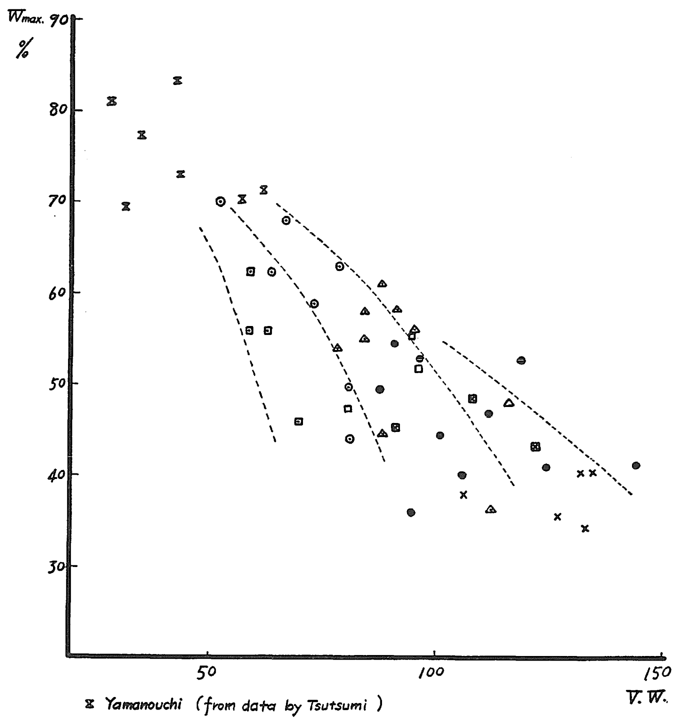

Fig. 15 Relationship between $W_{max.}$ and V. W. of fine soil in the 1st layer.
(Refer to Fig. 14 for legend)

Table 2.

	$A_{min.}$	$W_{max.}$
V. W.	- 0.49 *	- 0.62 **
	- 0.49 *	- 0.53 *

upper figures : fresh soil
lower figures : fine soil
* significant at the 5 per cent level
** highly significant at the 1 per cent level

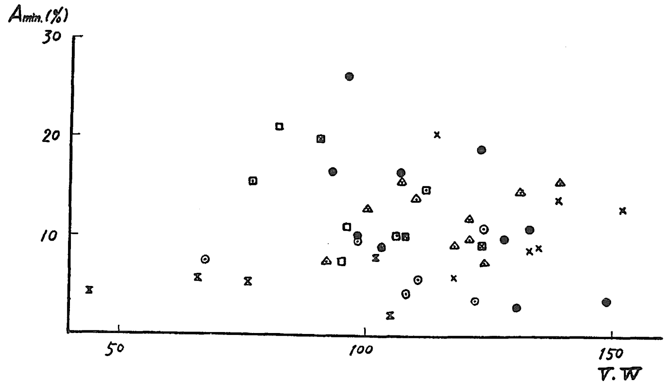

Fig. 16 Relationship between $A_{min.}$ and V.W. of fresh soil in the 1st layer.

Plotted positions of soils in Kurita, Rokkô, etc. differ much in the V. W.－$W_{max.}$ graph (Fig. 15) and little in the V. W.－$A_{min.}$ graph (Fig. 16) from those of Kizugawa Soil.

Yamanouchi Soils plotted in those figures from data by Tsutsumi (7) are derived from granite and well matured. Therefore they can be considered to be in an almost extremely advanced state of weathering to which soil of the identical material seems to be able to reach.

In general the values of V. W. corresponding to a certain $W_{max.}$ of Kizugawa Soils are larger than those of Rokkô, Kurita, Tamano Soils, etc.

This suggests the coarser-grained texture of Kizugawa Soils, compared with the Rokkô, Kurita Soils, etc.

The increases of $W_{max.}$ which occur concurrently with that of $A_{min.}$ would inevitably follow the some amount of decrease in $A_{min.}$. Therefore the measured value of $A_{min.}$ seems to express a sum of the original increase (＋) of noncapillary pore and the converted amount (－) from noncapillary pore to capillary pore. The absolute values of those two agencies determine the symbol.

One of the most effective agencies which promotes an increase in $A_{min.}$ would be disintegration of the rather coarse particles. And the increase in $W_{max.}$ seems to be caused to a large extent by disintegration of the finer particles which are responsible for the development of aggregates.

As a rule, the agencies to promote the increase of $A_{min.}$ seems to be constant through the period, whereas that of $W_{max.}$ become greater in the later period when the supply of organic colloids is expected to be abundant.

The relationship between $W_{max.}$ and $A_{min.}$ of fine soil is presented in Fig. 17. Based on the tendency shown in Fig. 17, I should like to advance a proposal on the explanation of changes of $W_{max.}$ and $A_{min.}$ which is illustrated diagramatically in Fig. 18.

In the early period when the supply of organic matter is not plentiful the noncapillary pores are likely to increase at more rapid rate than the capillary pores. This results in the increase in measured $A_{min.}$. $W_{max.}$ also increases, though in a slight degree. (A－B).

After some years the situation turns out somewhat different, which results in the increase in $W_{max.}$ and the decrease in $A_{min.}$. (B－E). In this period the production of capillary pores is superior to that of noncapillary pores.

Therefore, the contrary changing in the early period is not the reverse of maturing, but

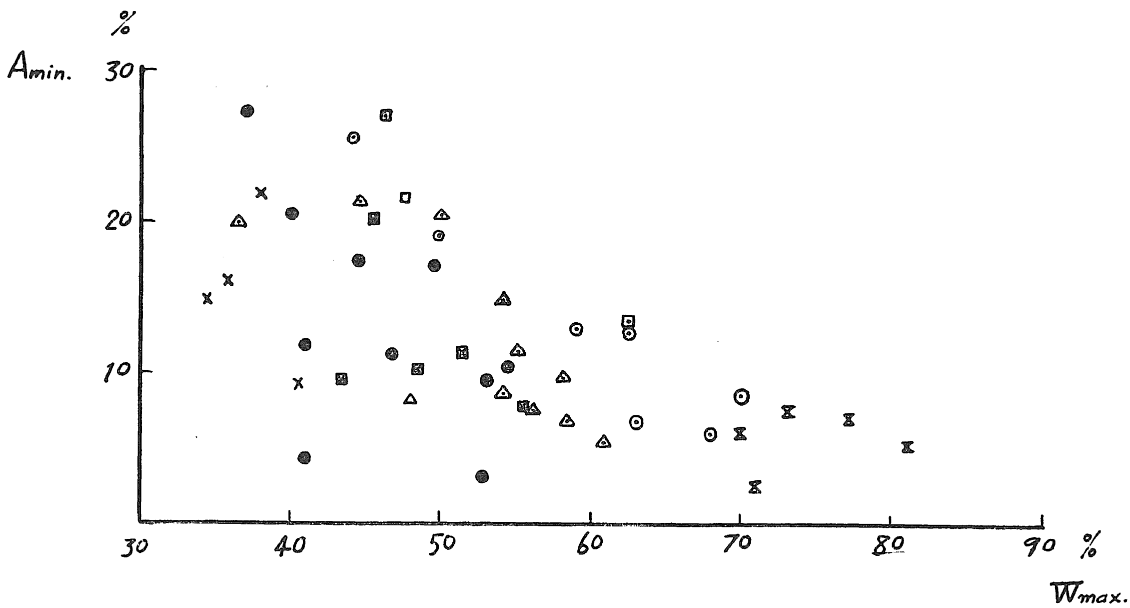

Fig. 17 Relationship between Wmax. and Amin. of fine soil.

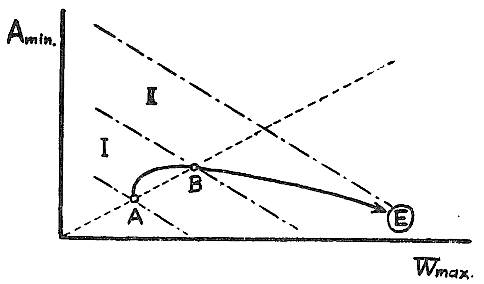

Fig. 18 Diagrammatic representation of a course which the development of soil seems to advance.
(E : extreme point of weathering)

merely the paradoxical process of it.

A position of the soil on the A—E curve must be determined by the properties of parent material and the degree of weathering.

I should like to propose a tentative explanation that Kizugawa Soils are located in I zone, whereas Rokkô, Kurita Soils, etc. in II zone.

Great differences in the values of volume weight between Kizugawa Soils and Rokkô, Kurita Soils, etc. seem to have some significance. The further investigation should be required for complete explanation.

(5) Textural development

Volume of the gravel and the fine soil in 1,000 cc fresh soil of the first layer, as influenced by ages, is presented graphically in Fig. 19 and Fig. 20, respectively.

The trend of the curve was approximately the same in both cases; namely, the change occured relatively rapidly during early about thirty years, and slowly afterwards.

The results of a mechanical analysis of the fine soils are illustrated by data in Table 3.

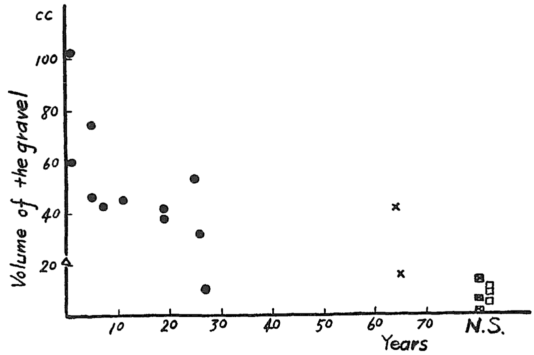

Fig. 19 Change of the gravel volume in 1,000cc of the 1st layer, fresh soil.

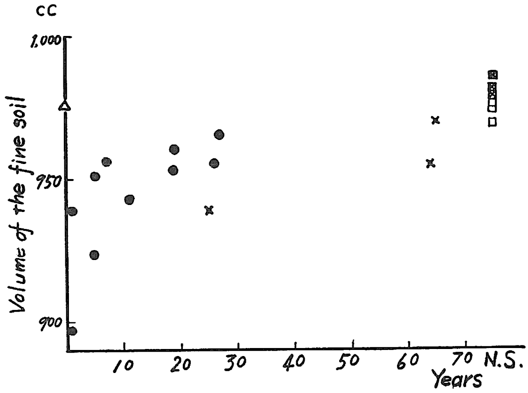

Fig. 20 Change of the fine soil volume in 1,000 cc of the 1st layer, fresh soil.

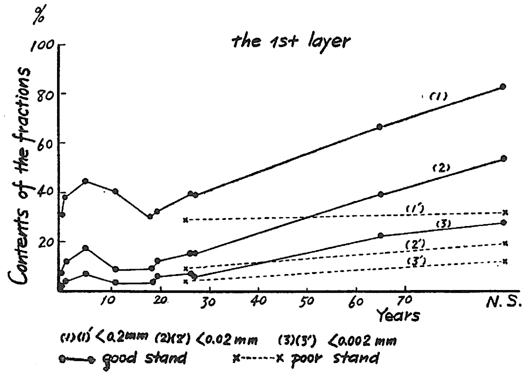

Fig. 21 Change of the contents of the [illegible] fractions with years.

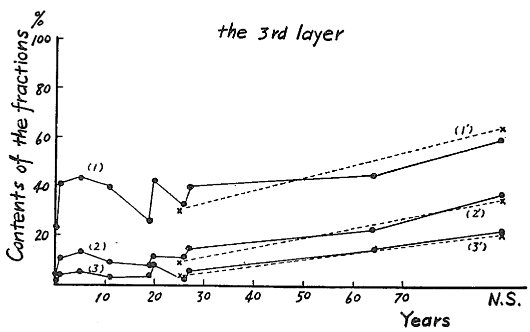

Fig. 22 Change of the contents of the fractions with years.

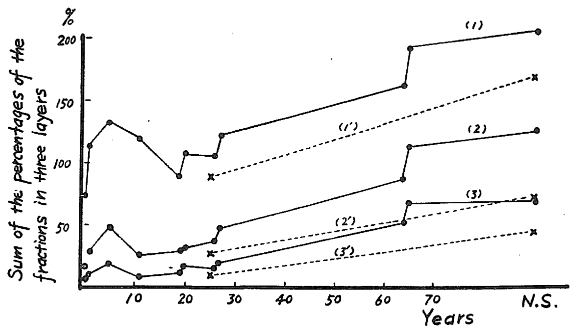

Fig. 23 Change of the sum of the percentages of the fractions in three layers.

And the relationships between the content of the fractions (<0.2mm, <0.02mm, <0.002mm) in the fine soil and the age of the stand are presented in Fig. 21 (the first layer) and Fig. 22 (the third layer).

In those figures only one representative stand was selected from several good and poor natural stands, respectively. If violent soil erosion did not occur, the amount of small particles must increase progressively from year to year. Therefore, irregularities in the curves mean the differences in initial conditions of the soils. In the third layer this irregularity was greater and changes by years were smaller than in the first layer. In the first layer the appreciable intensity of weathering agencies tended to compensate for differences in initial conditions of the soils.

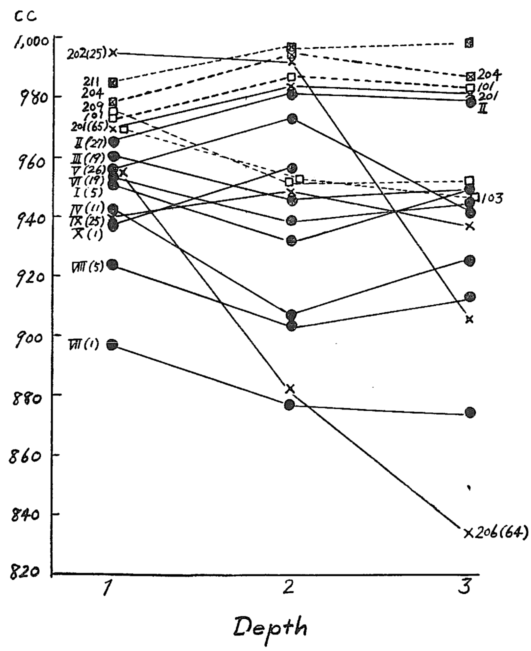

Fig. 24 Vertical distribution of the fine soil volume in the 1,000 cc fresh soil.

Consequently the irregularity was diminished and the changes with years became greater. (Practically speaking, however, a soil erosion was likely to occur to some extent in the first layer.)

The similar tendency is shown in Fig. 23 which represents the sum of the percentage values of same fraction in three layers.

Vertical distribution of volume and weight of the fine soil in 1,000 cc fresh soil is presented in Fig. 24 and Fig. 25. Fig. 24 shows that the volume of fine soil increases with increasing years. On the contrary, the weight of that decreases.

This tendency becomes quite evident from Fig. 26 and Fig. 27. They represent the changing process of them by years in the first layer where the weathering intensity is most drastic.

Production of fine soils in poor stands seemed to be not so active as in good stands. However, generally speaking, the amount of fine soil in Sabô-stand in this district is comparatively great. For example, the volume of the fine soils in the youngest Sabô-stand amounts to about 90% of that in the natural stand. And on the 30-year-old Sabô-stand it amounts to 99%.

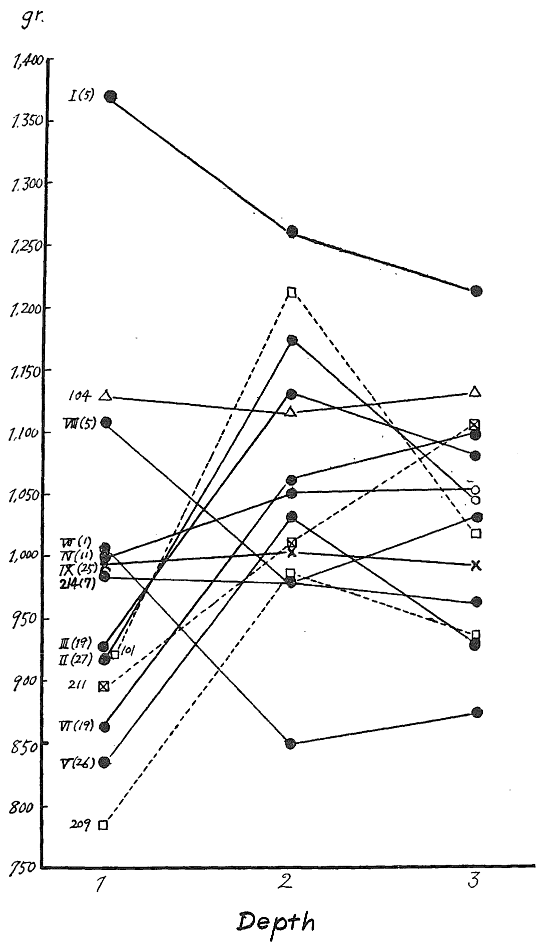

Fig. 25 Vertical distribution of the fine soil weight in the 1,000 cc fresh soil.

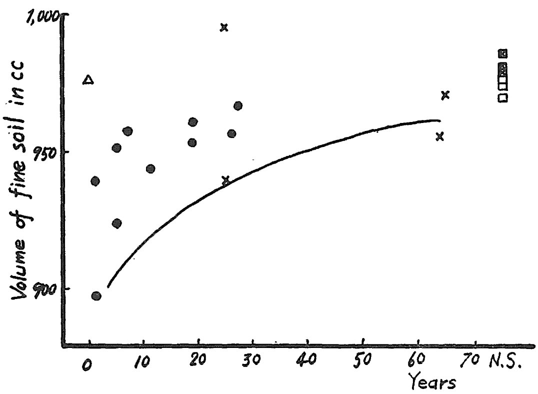

Fig. 26 Volume of fine soils in 1,000 cc of the 1st layer, fresh soil.

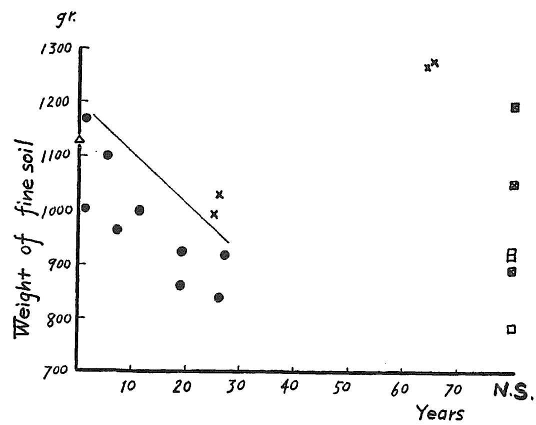

Fig. 27 Weight of fine soils in 1,000 cc of the 1st layer, fresh soil.

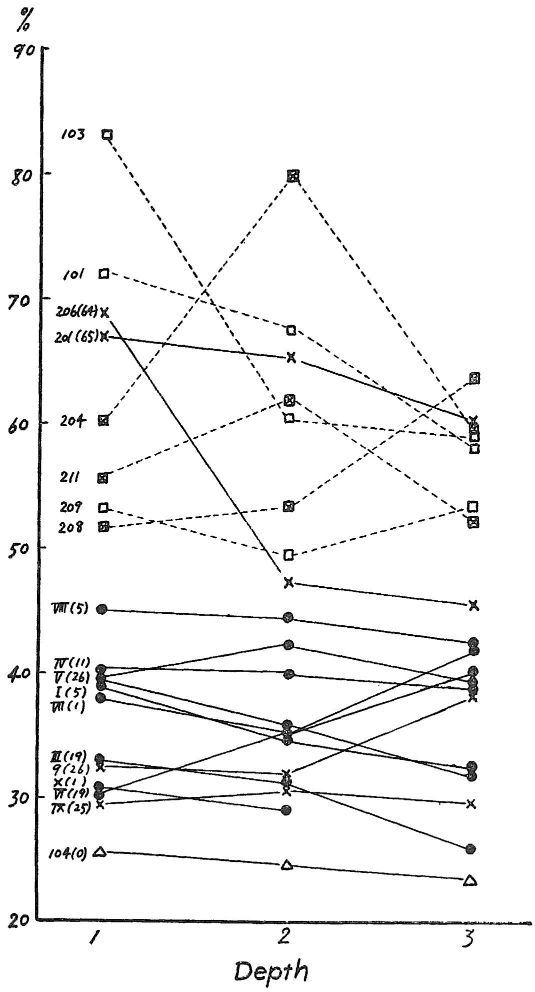

Fig. 28　Vertical distribution of the fraction (<0.2mm) content.

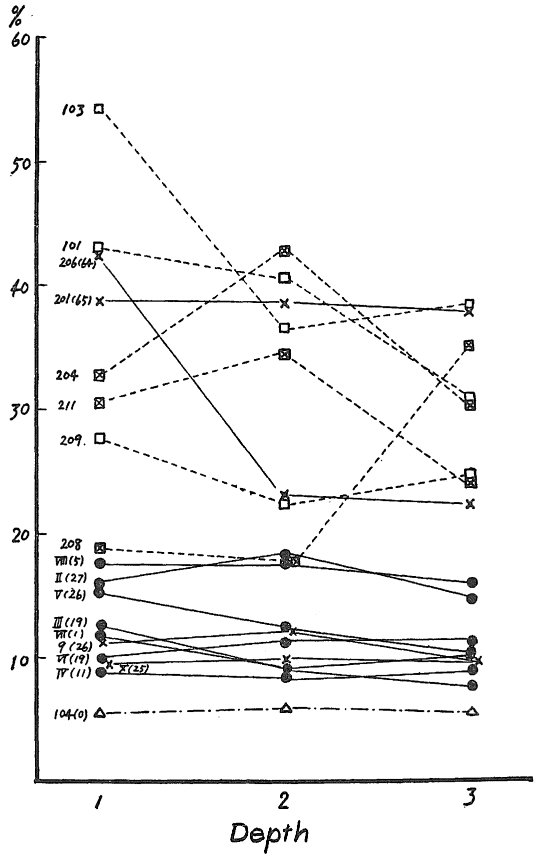

Fig. 29　Vertical distribution of the fraction (<0.02mm) content.

This is due probably to the facts that the granite in this district is of comparatively fine-grained texture, and had been subjected to the deepseated weathering, and consequently has become very brittle. And the elaborate, attentive works on grading or constructing terraces must have strengthened that tendency. Nevertheless, Fig. 28, 29, 30 indicated that there is a great difference in the content of the factions (<0.2mm, <0.02mm 0.002mm) in fine soil between natural stand soil and Sabô-stand soil. For example, the content of the fractions below 0.2mm, 0.02mm, 0.002mm of the old good Sabô-stand soil was 55%, 37%, and 25% of that of the natural stand soil, respectively.

The same may be said of the amount of the each fraction in 1,000 cc fresh soil.

A remarkable fact is that the finer the particle size is, the greater the difference in the amount between Sabô- and natural stand becomes.

This is highly important from the standpoint of plant nutrition and erosion control.

Mohr related that so far as the size of soil particle is concerned, resisting forces which retard soil erosion accelerated by water are caused by (a) friction, and (b) cohesion produced by soil particles.

The former is produced by gravity and ncreases with increasing the diameter of soil particles. And the latter is produced by an annular ring or disc of water at the point of contact of two particles (in moist soils), or by the attraction between the solid particles (in dry soils)[8], and decreases as the diameters of particles increase.

The friction decreases with increasing the degree of slope, whereas the cohesion is independent of that.

Although no detailed quantitative data have been reported, as a general rule, on the steep slopes the small-sized particle seems to be more resistive than large-sized one.

Through the investigated territories, in the young Sabô-stand the terracing has been well preserved and the sod on the side-slope survives, whereas in the old Sabô-stand the shadowiness which resulted from growth of planted seedlings has driven sod to disappear. Consequently, the side-slope in the old stand,

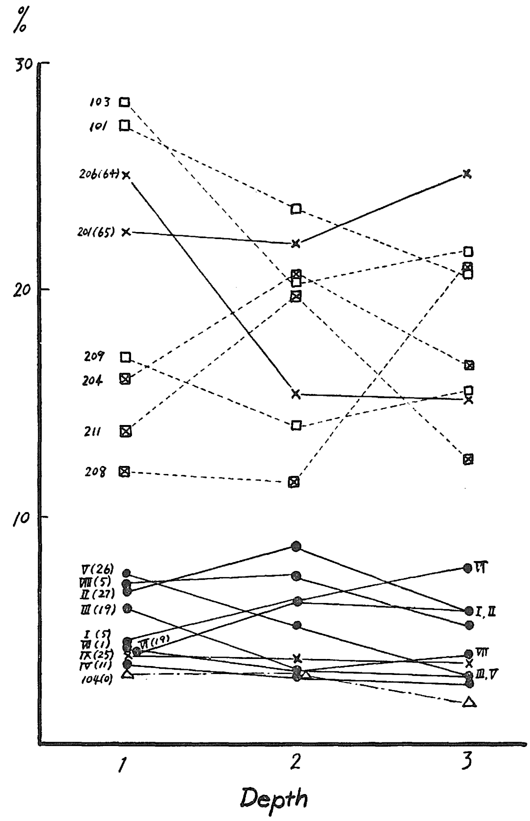

Fig. 30 Vertical distribution of the fraction (<0.002mm) content.

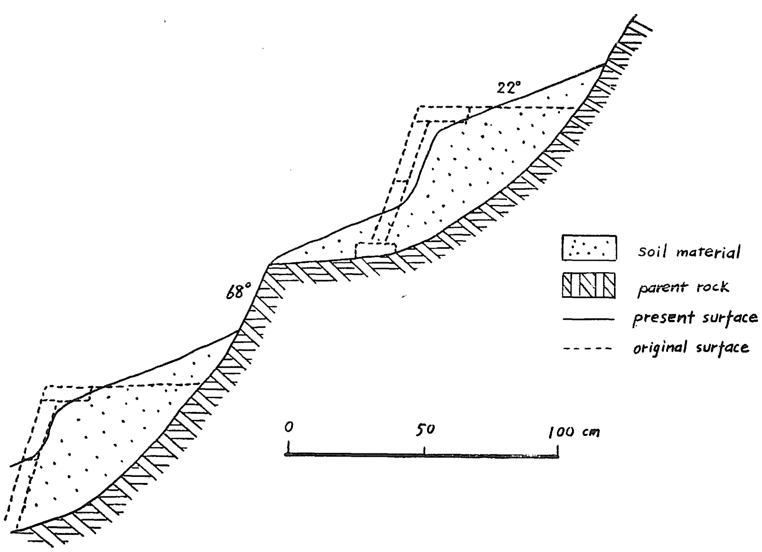

Fig. 31 Typical cross section of the terrace. (Plot No. Ⅲ)

which has a steep inclination, tends to be bare of any vegetative protection.

A considerable amount of removed soil is indicated in Fig. 31 which shows a typical cross section of the terrace in Plot No. Ⅲ.

In general it is likely that the fine-grained soil is less erodible than coarse-grained one in the steep slope, as in most of the forests in Japan. Therefore, in spite of the steady rehabilitation, the Sabô-forest in this district seemed to be not sufficiently safe from the erosion by water.

Data in Table 3 indicate that the amount of each fraction in a given volume of fresh soil was greater in the second or the third layer than in the first layer. That may be readily accepted when one consider the fact that the volume weight of fresh soil was greater in the lower layer than in the upper layer. Noteworthy is, however, that the percentage of each finer particle in fine soil of some stands shown in Fig. 28, 29, 30 and Table 3 was higher in the second layer than in the first layer. This is probably in part due to the downward removal of the finer particles accompanied by rain infiltration, and in part to transportation by surface flowing water. That was assured by the facts that the foregoing phenomenon was observed chiefly in the old stands and disintegration must be more intensive in the upper layer than in the lower layers.

(6) pH

The relationship between thickness of A_0 layer and the pH value is represented in Fig. 32. The pH values were measured in August.

On the assumption of the simplest case in which the acid substance that seems to be produced from litter is one and the most dominant acidifying agent, there would surely exist a linear relationship between the pH value and the logarithm of thickness of A_0 layer, because the amount of hydrogen ions dissociated is proportional to the amount of accumulated organic matter. However, Fig. 32 does not indicate such close relation.

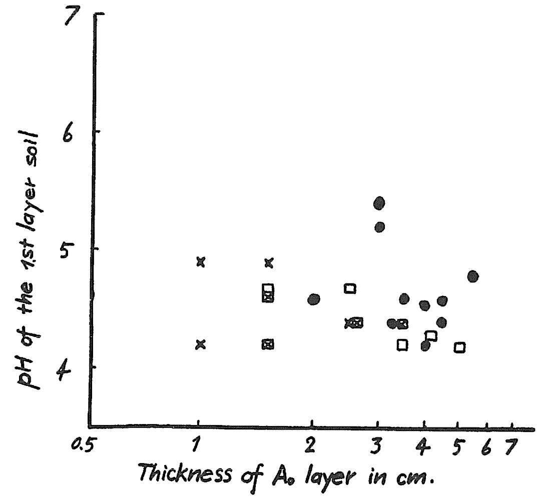

Fig. 32 Relationship between pH value and thickness of A_0 layer.

On the other hand, Fig. 33 which represents the relationship between the pH value and the logarithm of years after afforestation denotes that the young Sabô-stands have rather wide variation of pH values which result from differences in the initial conditions of the plots, and with increasing years the width of the range seems to narrow into about 4.3 of pH value, which most of the soils of the neighboring natural forests show. It might be acknowledged approximately that a linear relationship exists between the two factors.

Those two facts suggest that the most predominant agents which exert an influence on the acidification of soil in this district are dissociation and leaching of cations from the paroent materials.

Under the conditions of appreciable amount of precipitation and great permeability of soils

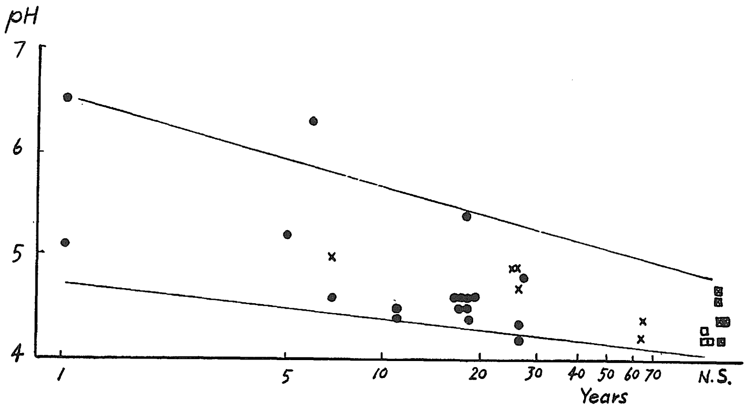

Fig. 33 Change of pH value in the 1st layer with years.

which make removal of the dissociated cations easy, the acidification develops proportionately with years after afforestation.

The acidifying tendency is not so obvious in the lower layers as in the surface layer. As to that matter, the situation is very simiar in Sabô-stands and natural stands. The probable is that the soil-formation agents have been far more drastic in the surface layer than in the lower layers. Those trends are observed not only in the pH values but also in many other soil properties.

Another worker [9] has reported the increasing tendency of the acidity with progressing of soil formation from granite.

(7) Organic carbon

The amount of organic carbon per ha. from the surface to a depth of 30 cm, and in 1,000 cc fresh soil of the first layer, influenced by age of the forest, is presented in Fig. 34 and Fig. 35, respectively.

The increasing tendencies with advancing age are shown in those figures. The similar

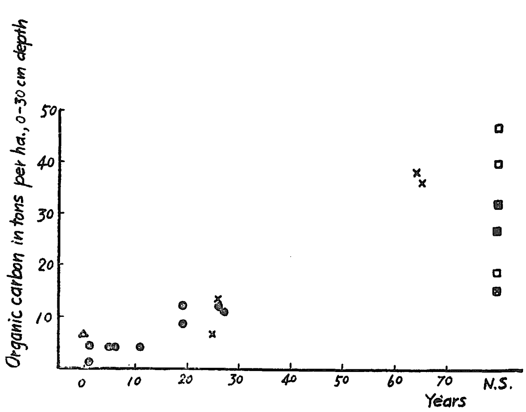

Fig. 34 Amount of organic carbon per ha. to a depth of 30cm.

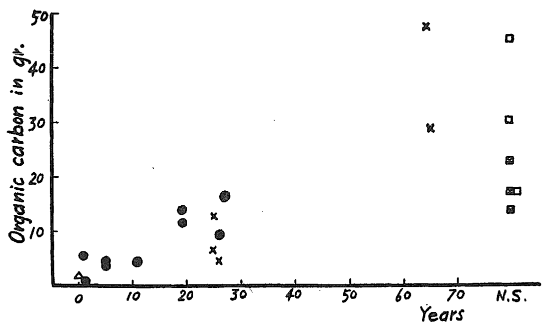

Fig. 35 Amount of organic carbon in 1,000 cc fresh soil of the 1st layer.

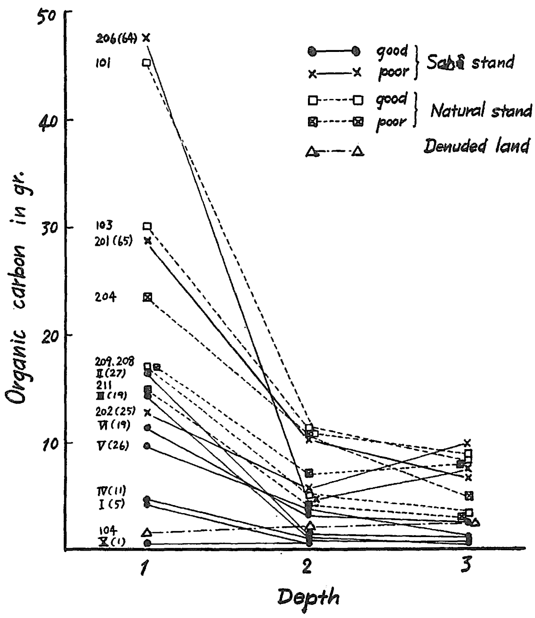

Fig. 36 Vertical distribution of carbon in 1,000 cc fresh soil.

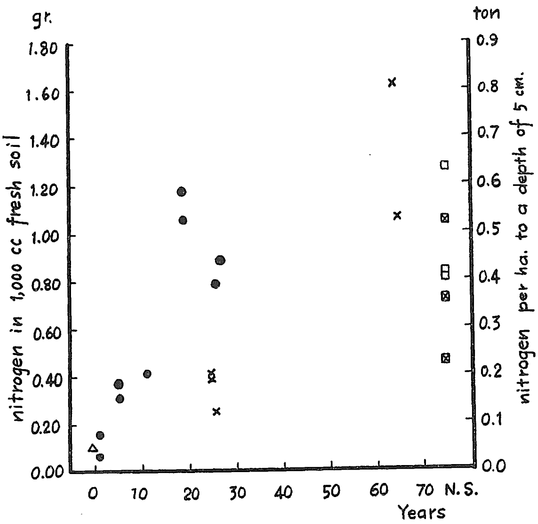

Fig. 37 Amount of nitrogen in surface soil.

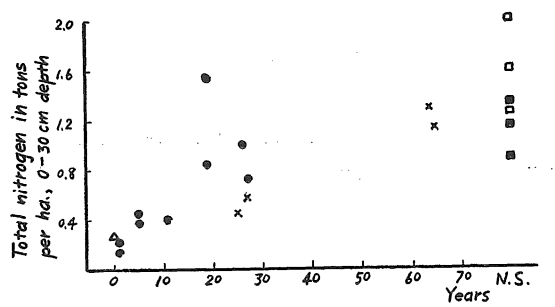

Fig. 38 Amount of total nitrogen per ha. to a depth of 30 cm.

tendencies in two figures seem to be resulted from the fact that the increases occured at the slower rate at the greater depth than at the smaller depth. That is clearly illustrated in Fig. 36, which represents a vertical distribution of the carbon content in 1,000 cc fresh soil.

The natural stands in this vicinity whose soil types belong to B_B also exhibit the similar tendencies.

Minor differences in the value between 64- or 65-year-old poor Sabô-stand and good natural stands are due perhaps to the difference in a rate of annual decomposition of organic matters. An identical amount of carbon in different rapidity of circulation gives a different ecological significance.

(8) Total nitrogen

The amount of nitrogen in 1,000 cc of fresh soil in the surface layer, and per ha. to a depth of 5 cm, influenced by advancing age, is represented in Fig. 37.

Fig. 38 shows the amount of nitrogen per ha. to a depth of 30 cm.

A vertical distribution of the amount of nitrogen in 1,000 cc of fresh soil is illustrated in Fig. 39.

Those figures indicate that the steady increases in nitrogen content has occured with years, whereas no remarkable increases has taken place in the second or the third layer.

Those tendencies are similar to that of the carbon content. However, the nitrogen amount in the soil of the first layer of about 30-year-old Sabô-stands reached to nearly as much as that of the natural stands. It differs much from the case of carbon content.

Following two main reasons are considered for the fact.

(a) The old Sabô-stands consist of broad-leaved trees, whose foliage has high nitrogen content. And the natural stands in this district consist of conifers whose leaves have low nitrogen content.

(b) Due to the slow circulation of nitrogen in the ecosystem, the nitrogen content in soils differ little in the forests occupied by different species.

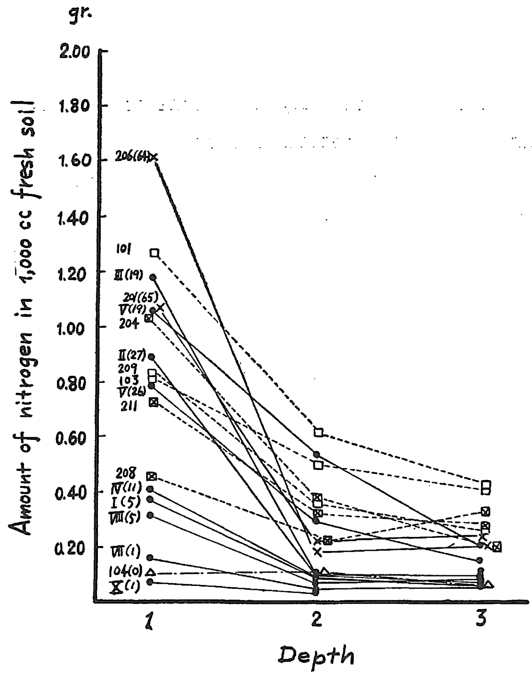

Fig. 39 Vertical distribution of nitrogen amount in fresh soil.

(V) Conclusion

In this paper was investigated the rehabilitation of the soil properties in Sabô-stands situated in Mie Prefecture.

Organic matter supplied from the newly planted trees increases the carbon- and nitrogen content in the mineral soils. Because of the fact that the Sabô-stands consist of broad-leaved species, i. e. nitrogen-rich species, the increase of the nitrogen content is more rapid than that of the carbon content.

Those changes occur in topsoils to a much greater degree than in the subsoils. The improvement in the chemical properties influences soil conditions directly, because it offers favorable nutrients to the plants, and indirectly, because it exercises profound effects on the improvement of physical properties.

Because of a much lower specific gravity value of a humus substance an addition of humus into mineral soils apparently lowers the specific gravity of fine soil and proceeds the development of soil structure by binding together the finer particles produced by disintegration.

The development of soil structure results in the decrease in volume weight, and the increase in pore volume.

In the topsoil of younger Sabô-stands, however, situation is somewhat different. Improvement of soil properties seems to progress reversely in those stands. It is nothing but an exceptional phenomenon which seems to occur in early several years.

During the early thirty years after afforestation the increase in pore volume seemed to be resulted from the increase in $A_{min.}$ and $W_{max.}$. And $A_{min.}$ increased more rapidly than $W_{max.}$. Subsequently, $A_{min.}$ tended to decrease, and only $W_{max.}$ increased.

This tendency somewhat differs from that reported by another worker, due probably to the difference in the initial conditions of the soils.

In this paper I have proposed a tentative explanation which seems to illustrate those apparently opposite results consistently.

Rehabilitation of texture, i. e. production of the finer fractions in the soil, was least progressive. Especially, the contents of clay and silt fraction in Sabô-stands were much lower than that of the natural stands.

It must be added that erosion pavement observed on the surface suggested the removal of considerable amount of the finer fractions by water.

The pH values of the topsoils tend to decrease approximating to the value of the natural stands in this district.

Chief characteristics of soils in poor stands were high volume weight and low pore volume, as compared with good stands of an identical age. However, the contents of the finer particles in the poor forests are not much lesser than that of the good forests. Therefore a supply of appreciable amount of humus would seem to promote the development of soil structure. In Sabô-forests, especially, causality of plants and soil conditions is very close. Sometimes in former years, the stems or the branches of Kuromatsu (Pinus Thunbergii.) in the young Sabô-stand had been cutted by bad merchants who sold them as Kadomatsu (New Year's pine decoration in Japan) resulting the checked growth of the trees and consequently scanty supply of organic matter. It seemed to be probable that those acts had interfered the smooth development of the soils.

There are many factors with which the degree of rehabilitation is estimated. One of them is an appearance or composition of the species in the stand, which was reported recently by Narita and Yasui[10]. Although the report showed that trees in the good Sabô-stands have grown not less abundantly than in natural stands, much attention should be given to the development of soil properties from the standpoint of erosion control. Because the species planted in Sabô-stand require lesser of soil conditions by nature.

Therefore, rehabilitation in plant growth does not immediately mean the corresponding improvement of soils.

In consider the improvements of soils the different factors by which the degree of improvement would be estimated lead to different conclusions.

Some factors approached rather rapidly to the values of the natural stands (volume weight, pore volume), and some factors very slowly (texture). The amounts of changes of some other factors were so small that it was rather difficult to find out the definite tendency (pH, specific gravity).

Changing of another factor takes at first a contrary direction, but afterwards turns toward the value of the natural stand (minimum air capacity).

From the standpoint of erosion control, the most desirable conditions seem likely to be the great amount of organic matter accumulated on the mineral soil, tight fixation of the soil bodies by developed root systems, and developments of soil structure by the finer particles bound with organic colloids. Those conditions have been rehabilitated not so rapidly as those that influence the growth of planted trees. The developement of soil texture serves as an example.

Many proposals have been advanced on the management considered to be fitted for those forests from the point of erosion control.

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要　　約

三重県名張市から伊賀上野市に至る木津川砂防工事事務所管内の砂防林で，土壌性質の復旧過程を調べた．

林分の生立に伴い，新しく有機物が供給されるようになると，表層土においては炭素量，窒素量が増大する．とくに窒素は，砂防林の構成樹種が主として肥料木であるため急速に多くなるが，炭素の増大はそれに較べるとおくれている．

この変化は，しかし，殆んど第1層に限られていて，下層にまでは及びにくい．

これら化学性の変化は，それ自体としても直接，林木の生育に好ましい条件を提供しているが，また同時に，間接的に，土壌の物理性にも影響を与える点で，二重に重要である．

すなわち，鉱物質粒子にくらべて比重の小さい腐植物質の混入は，細土真比重を小さくするが，砂防林の場合，物に重要な作用は，物理風化によってできた微小粒子と結合して構造を発達させることである．

構造の発達は，容積重の減少，孔隙量の増大をもたらす．尤も，施工後，日の浅い林分の表層土では，構造の発達よりも雨水によって締め固められる影響の方が大きいため，復旧とは逆方向に進むことが認められるが，これは，はじめの数年間だけに起る例外的な現象に過ぎない．

孔隙量の増大は，はじめの30年ぐらいまでは，最小容気量と最大容水量の増大の結果であり，しかも前者の増大の速さの方が，後者のそれよりも大きいが，30年以後は最小容気量は減少し，最大容気量だけが増大するようになる．

この点は，堤が栗太地区その他の砂防林で得た測定結果とやゝ違っているが，これは初期条件の違いを反映したものであろう．

最小容気量を増大させる因子のなかで重要と考えられる，比較的大粒径分の細粒化作用と，最大容水量を増大させるのに重要な小粒径分の生成，及びそれによる構造の発達をとりあげてみよう．

50年乃至100年ぐらいの短い期間を考えてみると，前者は土壌生成の全過程を通じて，強さの変動が少いと思われるが，後者は，鉱物粒子の生成は経過年数に無関係にほゞ恒常であるとしても，それらを結びつけて構造を発達させる有機コロイドは，林分の生立に伴って起るであろうから，若い時代には供給量は尠いが，後になるほど高まってくると考えられる．

また毛管孔隙の増大は当然，一部には非毛管孔隙からの転換を伴うから，前者の生成の強さが高まれば，後者は却って減少するようになる．

従って，風化のごく初期には，最小容気量も最大容水量も共に増大し，最小容気量の増大の方が，最大容水量の増大よりも旺盛である時期もあるが，有機物の供給が始まることにより，最大容水量の増大の速さが漸次高まり，両者の増大の相対的な強さが変ってくる．そのため遂には，最大容水量の増大は即ち最少容気量の減少を伴うようになる．

砂防地の土壌がこの全過程のうちのどの点から出発するかは，その母材料の初期条件によってきまることであろう．

以上により，栗太地区その他の測定結果をも総て矛盾なく説明できるので，一つの考え方として提案しておきたい．

粒径組成の回復は最もおくれている．特に，粘土，微砂などの微粒分の量は，付近天然アカマツ林のそれに較べて著しく貧弱である．また，表層土では流亡によって可成りの微粒分が失われ，エロージョン・ペイブメントを形成している．

pH は年数経過と共に漸次減少し，付近天然アカマツ林の示す値に近付く傾向を示している，

不良林は一般に，同令の優良林にくらべて容積重が大きく，孔隙量が小さい．しかし微粒分は多く含まれていて，粒径組成のうえでは好ましい条件を備えているのであるから，適当な腐植の混入があれば構造が発達して，孔隙量の増大が期待出来そうである．林分の成立と土壌性質の間の因果関係は，砂防林では特に密接であり重要である．その点からいって，当地方に曾て屢々みられたように門松用材料としての盗伐で，クロマツが比較的若い時期に主軸及び枝を切りとられると忽ち生長不振に陥り，林地への有機物の供給が衰え，これが発端となって悪循環を繰り返すことはあり得るし，それは他の樹種，他の立地の場合におけるよりも一層深刻であろう．

砂防林の復旧の度合いを測るのには，いろいろの目安がある．林内に出現する樹種及びその配分状態，またはそれらの成長の模様から判断する立場もある．筆者の調査に先だって行われた，成田・安井(10)の報告がそれである．そして，優良砂防林においては既に天然林に劣らない生長をしていることが認められた．

一方，防災的な見地からは，土壌物質そのものゝ改変にも注目しないではおられない．なぜならば，もともと砂防林に植えられる樹種は，環境に対する要求の少いも

のが選ばれている．従って，それらの樹木の生長振りが旧に復したことを以て直ちに防災上からも安全な状態に回復したと看做すことは当を得ていない．

土壌の変化をみる場合でも，とりあげる性質によって，結果はまちまちである．或るものは比較的早く天然林の状態に近付いているし（容積重，孔隙量），また或るものでは非常におそい（粒径組成）．

また，変化量が非常に僅少で，測定誤差や採取地点間のバラツキが相対的に大きいため，判断が困難な場合もある（PH，真比重）．

また，一旦は成熟化とは逆の方向に進み，その後で天然林土壌の値に近付く方向に向きかわるのもある（最小容気量）．

侵蝕防止という点からは，A_0 層の集積，根系の発達による表層土壌の固定のほか，土壌粒子の細粒化およびそれによっておこる耐水性構造の発達などが重要であろうが，それらは決して速くは回復しない．特に，凝集力による土層の安定を期待できる微細粒子の生成が最もおくれていることは重要である．

このことは，たとえ，生立している林木が立派な生長をみせていても，此処に他の普通林におけると同様の施業を行うことが無謀であることを教える．

これらの森林に加えられるべき作業種に関しては，従来とも多くの報告がある．

Table 3—1

Number of Plot	Depth	Age of stand	Volume Weight fresh soil	Volume Weight fine soil	Pore Volume (%) fresh soil	Pore Volume (%) fine soil	Wmax. (%) fresh soil volume	Wmax. (%) fresh soil weight	Wmax. (%) fine soil volume	Wmax. (%) fine soil weight	Amin. (%) fresh soil	Amin. (%) fine soil	Spec. Gravity	pH
I	1	5	149.3	144.0	43.0	45.3	39.1	26.2	41.2	28.6	3.9	4.1	2.63	4.6
	2		143.5	135.2	45.5	48.8	41.7	29.1	44.8	33.1	3.8	4.0	2.64	4.7
	3		134.7	127.8	48.6	51.2	40.5	30.1	42.7	33.4	8.1	8.5	2.62	4.7
II	1	27	95.8	95.1	61.9	64.1	35.6	37.2	36.9	38.8	26.3	27.2	2.65	3.8
	2		122.1	119.6	54.0	55.0	47.8	39.1	48.7	40.7	6.2	6.3	2.66	4.8
	3		109.5	106.5	57.8	59.0	46.4	42.4	47.3	44.4	11.4	11.7	2.60	4.8
III	1	19	102.8	96.4	59.9	62.4	50.9	49.5	53.0	55.0	9.0	9.4	2.56	4.6
	2		127.5	119.7	51.8	54.8	40.7	31.9	43.1	36.0	11.1	11.7	2.65	4.7
	3		121.3	113.8	54.5	57.4	45.4	37.4	47.8	42.0	9.1	9.6	2.67	5.6
IV	1	11	112.6	106.0	57.1	60.6	37.8	33.6	40.1	37.8	19.3	20.5	2.69	4.4
	2		130.0	115.8	51.4	56.6	41.1	31.6	45.4	39.2	10.3	11.2	2.67	4.7
	3		125.0	113.7	52.8	57.1	47.7	38.2	51.5	45.3	5.1	5.6	2.65	4.9
V	1	26	92.9	87.6	63.6	66.6	47.2	50.8	49.5	56.5	16.4	17.1	2.62	4.3
	2		109.9	105.9	58.3	59.9	48.3	44.0	49.6	46.8	10.0	10.3	2.64	4.5
	3		105.5	98.8	59.5	63.2	49.4	46.8	52.5	53.1	10.1	10.7	2.68	4.6
VI	1	19	98.0	90.6	62.0	65.0	51.9	53.0	54.5	60.1	10.1	10.5	2.59	4.6
	2		122.2	113.0	54.2	57.7	42.3	34.6	45.0	39.8	11.9	12.7	2.67	5.4
	3		125.1	116.4	52.6	55.7	44.5	35.6	47.1	40.5	8.1	8.6	2.63	4.6
VII	1	1	128.0	111.8	52.0	58.0	41.9	32.7	46.7	41.8	10.1	11.3	2.66	5.1
	2		117.9	96.8	55.7	63.5	44.2	37.5	50.4	52.1	11.5	13.1	2.65	5.2
	3		120.4	100.0	54.8	62.7	46.7	38.8	53.4	53.4	8.1	9.3	2.68	5.3
VIII	1	5	130.3	119.2	51.6	55.9	48.6	37.3	52.7	44.2	3.0	3.2	2.69	5.2
	2		124.2	108.6	53.7	59.5	48.7	39.2	54.0	49.7	5.0	5.5	2.68	5.5
	3		126.2	112.8	52.6	57.6	48.0	38.0	52.5	46.5	4.6	5.1	2.66	5.1
IX	1	25	114.0	105.8	56.2	59.8	35.7	31.3	38.0	35.9	20.5	21.8	2.63	4.9
	2		113.9	105.9	56.6	59.7	40.9	35.9	43.1	40.7	15.7	16.6	2.63	4.7
	3		115.9	105.9	56.6	60.4	39.3	33.9	41.8	39.5	17.3	18.6	2.67	5.0
X	1	1	132.9	124.4	49.5	52.7	38.5	29.0	40.9	32.9	11.0	11.8	2.63	6.5
	2		131.0	124.7	50.4	52.8	41.2	31.4	43.2	34.6	9.2	9.6	2.64	6.8

In 1,000cc fresh soil								Content of fraction							
gravel		fine soil		root		C	N	In fine soil (%)				In 1,000cc fresh soil (gr.)			
cc	gr.	cc	gr.	cc	gr.	gr.	gr.	2–0.2 mm	0.2–0.02mm	0.02–0.002mm	<0.002 mm	2–0.2 mm	0.2–0.02mm	0.02–0.002mm	<0.002 mm
46.3	122.3	950.8	1369.0	3.0	1.3	4.38	0.37	60.9	30.5	4.2	4.4	833.7	417.6	57.5	60.2
66.0	174.0	932.0	1260.0	2.0	1.0	0.63	0.09	65.1	24.0	4.6	6.3	820.3	302.4	58.0	79.4
51.0	134.0	949.0	1213.0	0	0	0.73	0.12	67.2	25.1	1.9	5.8	815.1	304.5	23.1	70.4
11.3	30.3	965.3	917.5	23.5	10.0	16.42	0.89	60.5	23.6	9.2	6.7	555.1	216.5	84.4	61.5
17.5	46.8	981.3	1174.0	1.3	0.5	1.29	0.11	57.6	24.3	9.5	8.6	676.2	285.3	111.5	101.0
19.0	50.8	979.8	1043.8	1.3	0.5	0.84	0.10	60.4	25.2	8.5	5.9	630.5	263.0	88.7	61.6
38.0	102.0	960.0	925.0	2.0	1.0	13.69	1.18	67.1	20.1	6.8	6.0	620.7	185.9	62.9	55.5
53.0	143.0	945.0	1131.0	2.0	1.0	0.68	0.11	68.7	22.2	5.8	3.3	777.0	251.1	65.6	37.3
49.0	132.0	949.0	1080.0	2.0	1.0	0.65	0.08	73.8	18.4	4.8	3.0	797.1	198.7	51.8	32.4
45.3	122.0	942.5	998.8	12.3	5.8	4.50	0.41	59.7	31.3	5.6	3.4	596.3	312.6	55.9	34.0
92.8	249.8	906.8	1050.0	0.5	0.3	0.74	0.08	60.0	31.5	5.3	3.2	630.0	330.8	55.7	33.6
73.0	197.0	925.0	1052.0	2.0	1.0	0.33	0.06	60.7	30.4	6.1	2.8	638.6	319.8	64.2	29.5
32.5	87.3	955.3	836.5	12.3	5.3	9.62	0.79	60.5	24.0	8.0	7.5	506.1	200.8	66.9	62.7
24.8	66.5	973.5	1031.3	1.8	0.8	3.82	0.30	64.2	23.5	7.0	5.3	662.1	242.4	72.2	54.7
44.3	118.5	941.8	930.3	14.0	6.0	1.77	0.16	68.0	21.3	7.7	2.9	632.6	198.2	71.6	27.0
42.5	114.8	952.8	863.0	4.8	2.0	11.31	1.06	69.7	20.8	5.5	4.0	601.5	179.5	47.5	34.5
59.3	160.3	939.0	1061.3	1.8	0.8	2.76	0.54	64.6	24.2	4.9	6.3	685.6	256.8	52.0	66.9
56.8	153.0	942.8	1097.3	0.5	0.3	2.20	0.21	57.9	31.0	3.3	7.8	635.3	340.2	36.2	85.6
102.8	276.5	896.8	1003.0	0.5	0.3	5.52	0.16	61.9	26.4	7.5	4.3	620.9	264.8	75.2	43.1
122.5	329.8	877.0	849.0	0.5	0.3	0.59	0.05	64.3	26.5	5.9	3.3	545.9	225.0	50.1	28.0
122.0	328.0	874.0	874.0	4.0	1.8	0.52	0.06	59.5	30.2	6.3	4.0	520.0	264.0	55.1	35.0
74.3	200.8	923.5	1100.8	2.3	1.0	3.74	0.31	54.9	27.4	10.7	7.0	604.3	301.6	117.8	77.1
96.8	261.5	902.8	980.0	0.5	0.3	0.78	0.08	55.4	27.2	10.1	7.4	542.9	266.6	99.0	72.5
85.5	231.0	913.3	1030.3	1.3	0.5	0.93	0.09	57.2	29.6	7.9	5.3	589.3	305.0	81.4	54.6
53.5	142.8	939.5	994.0	7.0	3.0	6.66	0.41	70.6	20.2	5.1	4.1	701.8	200.8	50.7	40.8
50.3	134.3	948.0	1003.8	1.8	0.8	1.51	0.10	69.0	21.3	5.9	3.8	692.6	213.8	59.2	38.1
62.0	165.8	937.5	992.8	0.5	0.3	1.09	0.09	70.2	20.8	5.4	3.6	697.0	206.5	53.6	35.7
60.0	160.5	939.5	1168.3	0.5	0.3	0.23	0.07	69.1	23.4	5.2	2.4	807.3	273.4	60.8	28.0
44.3	118.3	955.3	1191.0	0.5	0.3	0.24	0.04	70.7	21.6	5.6	2.2	842.0	257.3	66.7	26.2

Table 3—2

Number of Plot	Depth	Age of Stand	Volume Weight fresh soil	Volume Weight fine soil	Pore Volume (%) fresh soil	Pore Volume (%) fine soil	Wmax. (%) fresh soil volume	Wmax. (%) fresh soil weight	Wmax. (%) fine soil volume	Wmax. (%) fine soil weight	Amin. (%) fresh soil	Amin. (%) fine soil	Spec. Gravity	pH
101	1	N. S.	94.9	94.6	61.4	63.1	54.0	56.8	55.4	58.6	7.4	7.7	2.56	4.2
	2		124.6	122.9	52.1	52.7	49.0	39.8	50.1	40.8	2.6	2.6	2.60	4.6
	3		106.1	103.6	62.1	63.1	48.3	45.5	49.1	47.4	13.8	14.0	2.71	4.9
103	1	N. S.	95.7	96.1	61.0	62.9	50.0	52.3	51.5	53.6	11.0	11.4	2.59	4.2
	2		134.6	129.0	49.2	51.7	46.1	34.3	48.4	37.5	3.1	3.3	2.67	4.6
	3		135.7	128.3	49.0	51.7	46.0	33.9	48.6	37.9	3.0	3.1	2.66	4.8
104	1	D. L.	118.9	115.6	54.7	56.1	46.8	39.4	48.0	41.5	7.9	8.1	2.63	5.5
	2		115.4	113.2	56.0	56.8	52.8	45.8	53.5	47.3	3.2	3.3	2.62	5.3
	3		118.2	115.2	55.7	56.8	51.5	43.6	52.5	45.6	4.2	4.3	2.67	6.9
201	1	65	133.0	132.1	47.9	49.4	39.2	29.4	40.4	30.6	8.7	9.0	2.61	4.4
	2		136.9	134.7	48.2	49.0	38.8	28.3	39.5	29.3	9.4	9.5	2.64	4.8
	3		137.2	134.6	48.6	49.6	40.7	29.7	41.6	30.9	7.9	8.0	2.67	4.7
204	1	N. S.	107.8	107.7	57.5	58.7	47.4	43.9	48.5	45.0	10.1	10.2	2.61	4.6
	2		129.2	129.6	50.6	50.9	46.2	35.7	46.4	35.8	4.4	4.5	2.64	6.8
	3		127.4	125.7	51.7	52.4	44.2	34.7	44.9	35.7	7.5	7.5	2.64	4.9
206	1	64	138.7	133.2	47.0	49.2	33.0	23.8	34.5	25.9	14.0	14.7	2.62	4.2
	2		151.9	137.3	44.0	49.9	31.8	20.9	36.1	26.3	12.2	13.8	2.64	4.5
	3		156.9	141.9	37.9	45.5	32.7	20.9	39.3	27.7	5.2	6.2	2.60	4.4
208	1	N. S.	123.4	122.0	51.8	52.9	42.5	34.5	43.4	35.6	9.3	9.6	2.59	4.2
	2		131.6	131.0	49.8	50.0	40.5	30.8	40.7	31.1	9.3	9.3	2.62	5.0
	3		129.8	129.5	53.0	53.1	41.4	31.9	41.4	32.0	11.6	11.7	2.66	6.8
209	1	N. S.	82.0	80.5	67.4	69.0	46.3	56.5	47.4	58.9	21.1	21.6	2.60	4.3
	2		111.1	103.3	58.3	61.3	46.8	42.1	49.2	47.6	11.5	12.1	2.67	5.0
	3		106.3	98.2	60.2	63.2	51.0	47.9	53.5	54.5	9.2	9.7	2.67	5.0
211	1	N. S.	90.4	90.8	64.5	65.5	44.7	50.0	45.4	50.0	19.8	20.1	2.63	4.4
	2		100.6	100.7	62.2	62.4	44.8	44.5	44.9	44.6	17.4	17.5	2.68	4.8
	3		110.3	110.4	58.9	59.0	45.7	41.4	45.7	41.4	13.2	13.3	2.69	5.6
9	1	26	152.1	126.6	42.1	51.7	29.1	19.1	35.7	28.2	13.0	16.0	2.62	4.7
	2		144.9	122.9	45.1	53.1	33.5	23.1	39.5	32.1	11.6	13.6	2.62	5.0
	3		149.5	128.0	43.4	51.2	34.9	23.4	41.1	32.1	8.5	10.1	2.62	5.3

In 1,000cc fresh soil								Content of fraction							
gravel		fine soil		root		C	N	In fine soil (%)				In 1.000cc fresh soil (gr.)			
cc	gr.	cc	gr.	cc	gr.	gr.	gr.	2−0.2 mm	0.2−0.02mm	0.02−0.002mm	<0.002 mm	2−0.2 mm	0.2−0.02mm	0.02−0.002mm	<0.002 mm
7.5	20.0	974.3	921.5	18.2	7.8	45.15	1.27	27.9	28.9	15.9	27.3	257.1	266.3	146.5	251.6
12.0	32.5	987.5	1213.3	0.5	0.3	10.56	0.62	32.2	27.1	17.2	23.5	390.7	328.8	208.7	285.1
15.8	42.3	983.0	1018.3	1.3	0.5	8.76	0.43	41.7	27.4	10.1	20.8	424.6	279.0	102.9	211.8
5.0	13.8	969.8	932.0	25.3	10.8	30.01	0.81	16.8	29.0	26.0	28.2	156.6	270.3	242.3	262.8
43.0	116.0	952.0	1228.0	5.0	2.0	10.93	0.50	39.5	24.0	16.1	20.4	485.1	294.7	197.7	250.5
53.0	142.0	947.0	1215.0	0	0	8.14	0.43	40.8	21.5	16.0	21.7	495.7	261.2	194.4	263.7
22.0	60.0	976.0	1128.0	2.0	1.0	1.58	0.10	74.5	19.9	2.4	3.2	840.4	224.5	27.1	36.1
14.0	38.0	986.0	1116.0	0	0	2.12	0.11	75.3	18.9	2.7	3.1	840.4	210.9	30.1	34.6
20.0	53.0	980.0	1129.0	0	0	2.60	0.07	76.5	18.1	3.5	1.9	863.7	204.4	39.5	21.5
15.8	42.5	969.5	1281.0	14.8	6.3	28.82	1.06	32.9	28.4	16.2	22.5	421.5	363.8	207.5	288.2
16.8	45.0	982.8	1323.3	0.5	0.3	10.19	0.23	34.6	26.8	16.6	22.0	457.9	354.6	219.7	291.1
19.3	51.8	980.3	1319.5	0.5	0.3	6.47	0.25	39.6	22.5	12.8	25.1	522.5	296.9	168.9	331.2
6.5	17.8	978.3	1053.5	15.3	6.5	23.07	1.05	39.8	27.4	16.8	16.0	419.3	288.7	177.0	168.6
0.5	1.3	994.3	1288.8	5.3	2.3	10.44	0.39	20.0	37.3	22.1	20.6	257.8	480.7	284.8	265.5
12.5	33.5	987.0	1240.3	0.5	0.3	4.84	0.21	40.0	29.9	13.3	16.8	496.1	370.9	165.0	208.4
42.0	113.3	955.0	1272.3	3.0	1.3	47.46	1.62	31.1	26.5	17.4	25.0	395.7	337.2	221.4	318.1
113.5	306.3	881.8	1210.3	4.8	2.0	4.60	0.19	52.7	24.4	7.5	15.4	637.8	295.3	90.8	186.4
139.3	375.8	832.8	1181.3	28.0	12.0	7.32	0.21	54.5	23.1	7.2	15.2	643.8	272.9	85.1	179.6
12.8	34.3	980.3	1196.3	7.0	3.0	16.87	0.46	48.2	33.0	6.8	12.0	576.6	394.8	81.4	143.6
4.8	13.0	994.5	1302.8	0.5	0.3	7.04	0.22	46.4	35.9	6.1	11.5	604.5	467.7	79.5	149.8
1.8	4.5	998.5	1293.0	0	0	7.89	0.34	36.1	28.9	13.9	21.1	466.8	373.7	179.7	272.8
10.3	27.8	976.3	786.0	13.5	5.8	16.90	0.83	46.8	25.5	10.8	17.0	367.9	200.4	84.9	133.6
47.5	128.0	950.8	982.5	1.8	0.8	4.81	0.38	50.5	27.3	8.2	14.0	496.2	268.2	80.6	137.6
47.5	128.3	952.0	934.5	0.5	0.3	2.99	0.26	46.3	29.1	9.2	15.5	432.7	271.9	86.0	144.9
1.5	4.0	985.0	894.3	13.5	5.8	13.33	0.72	44.3	25.3	16.7	13.7	396.2	226.3	149.4	122.5
0.8	1.8	996.3	1003.0	3.0	1.3	3.81	0.33	38.0	27.5	14.7	19.7	381.1	275.8	147.4	197.6
0.3	0.5	998.5	1102.3	1.3	0.5	2.65	0.28	47.7	28.0	11.8	12.5	525.8	308.6	130.1	137.8
180.3	486.8	815.0	1032.0	4.8	2.0	4.54	0.25	67.2	21.6	4.9	6.3	693.5	222.9	50.6	65.0
149.5	403.8	850.0	1044.8	0.5	0.3	3.87	0.06	68.0	19.8	4.4	7.8	710.5	206.9	46.0	81.5
151.2	408.5	848.8	1086.3	0	0	5.11	0.35	61.6	28.7	4.0	5.7	669.2	311.8	43.5	61.9

Photo. 1　Tsuminaekô (terracing with sod)

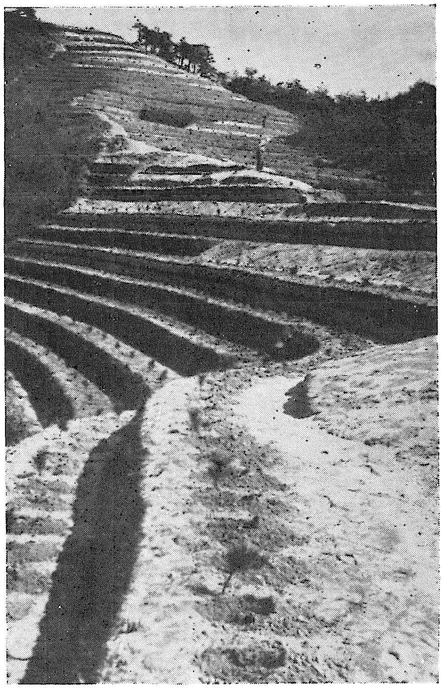

Photo. 3　General view of Sabô-stand. (Survived natural stands are also seen.)

Photo. 2　Sujikô (terracing with fascine.)

Photo. 4　Devastated land.

(Note)

1. Planted species in photo. 1, 2 : Pinus Thunbergii 1 : Alnus firma 2
2. Those photographs were taken in March, immediately after planting.