THE DEVELOPMENT AND PROBLEMS IN THE ANTI-EROSION PLANTATION IN JAPAN

by

Hidehiro Ishibashi
Professor of Forestry
Department of Forestry, Faculty of Agriculture
Iwate University
Ueda 3, 020 MORIOKA, Japan

SUMMARY

Highly intensive anti-erosion plantation project has been put into execution in connection with the erosion control program in the watershed in Japan.

After many experiences of practice a planting system had been developed with a successful result in reforestation with the pioneer trees in a considerable area. At the same time, however, in other instances the attempt met difficulty or failed in rehabilitation of vegetative cover. Moreover, one of the most important problems is the fact that the soil properties in the anti-erosion plantations are, even in the apparently well restored stands, far behind in recovery than the vegetational circumstances.

It is now urgent to develop a new type of forest management which can be applied to this kind of forest in order to stimulate the tree growth and induce the plantation to a desired forest type without disturbing the protective surface characteristics.

Zusammenfassung

In Verbindung mit dem Programm zur Erosionsbekämpfung in japanischen Einzugsgebieten steht ein sehr intensives Anpflanzungsprojekt zur Erosionsbekämpfung in Ausführung.

Nach vielen praktischen Erfahrungen ist ein Planungssystem für die Wiederaufforstung mit Pionier-Holzarten in

einem großen Gebiet mit befriedigtem Erfolg entwickelt worden. Gleichzeitig sind jedoch Versuche zur Wiederherstellung der Vegetationsdecke unter anderen Umständen auf Schwierigkeiten gestoßen oder gar mißlungen. Eines der wichtigsten Probleme ist die Tatsache, daß in den Anpflanzungen zur Erosionsbekämpfung auch in den gelungenen Aufforstungen die Wiederherstellung der Bodeneigenschaften gegenüber den Vegetationszuständen weit zurück liegt.

Es ist nun dringend notwendig, eine neue Type der Waldbewirtschaftung zu entwickeln, die auf diese Art Wälder angewandt werden kann, um das Wachstum der Bäume zu stimulieren und ohne Störung des flächenschützenden Charakters zur gewünschten Waldtype zu gelangen.

1. GENERAL SITUATION OF THE DEVASTATED FOREST LAND IN JAPAN

A considerable area of devastated forest land is distributed on the relatively gentle mountain slope in the central part of Japan(Fig.1). The predominant mechanism of the devastation is a sheet erosion. There is abundant evidence which shows that those areas were in former times covered with well stocked Japanese cedar (Cryptomeria japonica D.Don) and Japanese cypress (Chamaecyparis obtusa S. et Z.). Already in the documents recorded in the 17th century, however, we can find the description of the devastation in those areas and the erosion control law to prevent further deterioration.

Main basic factors of the devastation can be classified in the actions of natural and human agents.

(1) Natural agents

(1)-1. Geology and soil

The base rock of the area is a granite which a deep weathering had taken place in. The parent material of the soil produced from the rock is very brittle. The soil derived from the material is distinguished by

a) sandy texture
b) susceptivity of dryness
c) low adsorption of nutrient
d) low durability against water erosion.

(1)-2. Climate

Precipitation of the devastated area is in general low; 1506mm in UENO, 1367mm in KOOBE and 1218mm in OKAYAMA, which are situated in those area, while the average annual precipitation of Japan amounts 1700mm. Small precipitation is unfavorable for regeneration in cut-over area.

Air temperature is in general mild. The soil temperature in the surface layer of the bare ground, however, reaches up to 50°C in midsummer.

Frost heaving is also observed in some areas.

(2) Human agents

These areas were from old times so thickly inhabited and highly developed that the forests were repeatedly cleared to obtain fuel and construction materials.

Under those unfavorable natural environment, when the forest cover had been seriously disturbed by human agents the soil mantle began to be removed chiefly by a sheet erosion mechanism and parent materials were exposed. Natural recovery can not be expected to occur, and an artificial rehabilitation measures including engineering controls and vegetative measures are required.

In this paper the writer deals with the vegetational rehabilitation measures in connection with degree of recovery in vegetative cover and soil properties.

2. BRIEF REVIEW OF THE DEVELOPMENT OF REHABILITATION WORKS IN JAPAN

2-1. Works in the old feudal days (1686-1867)

Eleven kinds of works are recorded to be carried out. They are classified in

a) stone check dam
b) sodded channel
c) earth dam for fixation of slope base

d) prevention works against slip of mountain slope
e) replanting in the devastated mountains.

The materials for the works were wood, sod, grass, seedling, straw, faggot, soil and stone.
The works had aimed to prevent sediment inflow into river by achievement of afforestation.

2-2. Works at the beginning of Meiji Era (1873-1878)

In this period sixteen kinds of work were devised on the valuable suggestion offered by the European civil engineer who was engaged in river improvement in Japan and emphasized the necessity of erosion control in headwaters basin.
The works were invented in a combination of conventional types of Japanese works and modern European civil engineering techniques. They comprise dam, stone wall, foot protection, terracing with sod, revetment, and tree planting.

The desirable effects which could be expected by the works were a) rain water storage in mountain slope, b) stream bank fixation by deposited sediment, c) prevention of stream bed scour, d) fixation of mountain slope, e) inhibition of gully erosion, and f) check of soil removal on the mountain slope.

2-3. Present works

Present works are basically nearly the same as those developed in the Meiji Era. Several improvements have been introduced in materials, planting species, and execution measures, with the development of civil engineering, knowledge of ecology and other related fields.

2-4. Typical type of the anti-erosion plantation

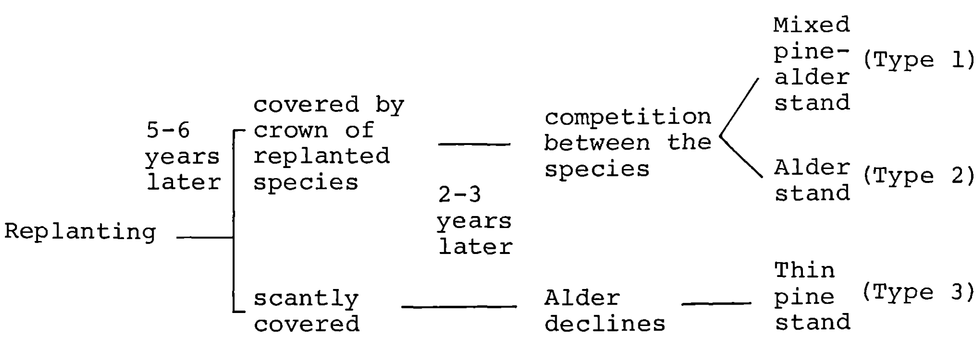
Fig.2 shows the cross section of the present anti-erosion plantation in denuded mountain slope. On the upper part of slope the face of terraces are protected by straw, while on the lower part by sod or concrete plate which exert much constructive resistibility. In some areas the terrace and slope are completely covered with straw to prevent frost heaving.

Afforestation on the terrace is carried out by a mixed planting of Japanese black pine (Pinus Thunbergii Parl.) and Alder (Alnus pendula Matsum) in the 1 to 2 number ratio with planting density of 6000-10000 seedlings to a hectare. The combination of black pine and alder has been adopted after repeated trial and error. The black pine has an advantage of greater increment in early stage of growing than the red pine. The alder produces a litter which contains much nitrogen provided by root nodule bacteria. The red pine (Pinus densiflora S.et Z.) is the dominant species in the adjacent natural stand. However, besides retarded growth in early stage of growing, its root is susceptible to transplanting, and we can hardly get successful result in artificial regeneration.

3. RECOVERY OF THE FOREST LAND BY THE ANTI-EROSION PLANTATION

3-1. Types of forest establishment

The replanted areas develop in three ways as shown in the following diagram(2).



The stand of the Type 1 is most desirable both in the land protective effect and in commercial value. The stands of the Type 2 and Type 3 cover considerable area in the replanted mountains. In KIZUGAWA Basin about 40% of the replanted land were occupied by the Type 2 and Type 3 stand(2). In TANAKAMI area almost all the stands which were replanted before 1935 belong to the Type 3 (5). The Type 2 and Type 3 of stand can not develop into the desirable ones which exert a erosion control effects. The land will be subject to recycle of erosion if any cultural treatments are not taken to revive the pine trees.

3-2. Growth of planted trees

Some examples of the composition and the growth of the anti-erosion plantations are shown in Tab.1, compared with those of pine natural stands. Fig.3 shows the productivity of the anti-erosion plantation expressed in height curve.

The pine-alder mixed stand which belongs to the Type 1 shows a steady growth which is by no means inferior to the well established natural pine stand. On the other hand the poorly established plantation which belongs to the Type 3 shows only one-tenth of mean increment of the well established natural stand.

It is striking that the red pines which were regenerated by natural seeding after the execution of anti-erosion plantation showed remarkable growth.

3-3. Recovery of soil properties

For understanding the extreme environment of the areas some informations about the change of soil properties after the replanting will be shown in this section.

3-3-1. Development of floor cover on the terrace of the plantation

After finishing the execution of the anti-erosion plantation the terrace begins to be covered with leaf-litter. In most favorable circumstances the terrace is completely covered with litter in five or six years, while just then in the unfavorable conditions the cover degree reaches only 50%.

Amount of litter, carbon content, and nitrogen content for different ages of the replanted stand are shown in Fig.4,Fig.5, and Fig.6. Assuming the linear increasing trend to apply, amount of carbon as a litter increased 120-510 kg/ha.year in the well-established stand, while only 20-40 kg/ha.year in the poor stand. Similar inclination was found in the increase of nitrogen; 2-21 kg/ha.year in the well-established stands, while 0.4 kg/ha.year in the poor stand.

3-3-2. Particle size distribution

Although the soil of the terrace tends to produce finer particles as the time proceeds, the tendency is not so pronounced as indicated in Fig.7. The clay contents in surface soil layer of the replanted stand are lower by far than those of the adjacent natural stands (Fig.8).

Other several soil properties, such as acidity(4), pore size distribution(4), erodibility potential(3) were also determined. From those results it may be concluded that the soils in the anti-erosion plantations are, even after 30 years, insufficient in restoration to the stable state of forest land. Particular attention must be given to the fact that the soil properties are far behind in recovery compared with vegetation.

4. TENDING WORKS AGAINST POORLY ESTABLISHED ANTI-EROSION PLANTATION

The stands of Type 2 and Type 3 are, as mentioned above, in re-devastation danger. The Construction Office has begun to carry out the tending works against them.

4-1. Tending work for the plantation of Type 2

The Type 2 of the plantation is composed of the well-grown alders and the dominated black pines.

Although the alder has the advantage of growing rapidly during the first few years and providing a plenty of leaf litter rich in nitrogen, it is subject to insect damage (by "Anoplophora malasiaca Thomson"). According to the investigation in TANAKAMI area, 30 to 70% of the alder tree in the anti-erosion plantation aged over 5 years had suffered from the insect damage (5). Therefore, we can not expect this type of plantation to be a long-lived stable stand.

The tending work for this type of stand consists of

(1) topping of alders, and
(2) fertilization with the aim of control of growth of alders and stimulation of growth of the released pine trees.

As a rule four years after the planting the alders are cut at the height of 30-50cm, and 1 ton/ha. of fertilizer, with nutrient content of N:13%, P:17%, K:12%, are spread by a helicopter. The treatment, named "The Tending Work A", is repeated also seven and ten years after the replanting.

4-2. Tending work for the plantation of Type 3

The stand of Type 3 consists of underdeveloped pine trees in very thin density. The leading cause of the decline of the planted tree is a fertilizer exhaustion.

The nutritious substances which were absorbed in the tree are restored on the forest land in the form of litter. On the immature granite-derived soils in the anti-erosion plantation the accumulation of organic matter is predominant in the early stage of reforestation. In this period a rate of mineralization of organic matter in soil is far less than that of accumulation of litter on the ground. It takes a long period of time before a dynamic equilibrium is re-established between the amount of nutrient supplied and that mineralized. Therefore, when we expect to maintain the considerable increment only by fertilization, we must continue it till the nutrient circulations reach their equilibrium states. The tending work for the declining pine tree was designed based on this idea.

Main points in the work are the following three:

(1) fertilization
(2) provide soil material to improve full development of root
(3) put organic materials (straw or compost) into the ground to maintain the soil moisture, fertilizer, and loosened state of soil compactness.

Typical cross section of the tending work is shown in Fig. 9 with the specifications. The work is named The Tending Work B

4-3. Effects of The Tending Work B

Since 1967 the above-mentioned tending works have been carried out as a government undertaking in TANAKAMI area. They both had produced striking effects on the establishment of the desirable stand type and on the growth of the under-developed pine trees. In this section the determination on the improvement of increment produced by the experimental Tending Work B which was carried out in 1964 prior to the practice will be explained.

TSUTSUMI(5) had determined an average annual height growth of the declining pine trees in the sampled plots composed of two degrees of excavation depth (60 and 30cm), two kinds of buried organic material(rice straw and compost), and four kinds of fertilization amount.

Increase in the tree height growth stimulated by The Tending Work was found in the whole plot. Some typical instances are shown in Fig.10.

One year after the execution of The Tending Work the trees scarcely attained greater height growth in the whole plot. It took about three years before the treated trees attained a distinctively greater height increment than the control ones whose annual height increments are less than 10cm.

Same tendency was found in the diameter growth.

4-4. Further problems to be solved

Further determination must be pursued on durability of the effectiveness of The Tending Work in connection with the transition of soil properties. Unfortunately we don't have yet a definite knowledge about the management plan which is appiicable to this kind of reforested area. Recovery degree of anti-erodibility of soil and of equilibrium state in the nutrient circulation might be the leading criteria in deciding the treatment method of the plantation.

The possibility of the dominant tree species transfer from the black pine to the red pine or other more valuable species must be also examined.

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3. Ishibashi,H.,1968: Potential Erodibility of the soil in the anti-erosion plantation. Trans. 20th Ann. Meet. TOOHOKU Branch, Jap. For. Soc.
4. Ishibashi,H.,1972: Recovery of soil properties in anti-erosion plantations. Bulletin of the Iwate University Forests, No.4
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Table 1. Composition and increment of the stand in KIZUGAWA Basin, per ha.

Stand No.	Develop-ment	Stand age	Tree species	Av. tree height (m)	Av. diameter (cm)	Number of tree	Volume (m^3)	Mean increment (m^3)	Cur. ann. incr. (m^3)	Type of stand	Remarks
			(The anti-erosion plantation)								
X	well	1	Pinus Thunbergii	0.23		3500					
			Alnus pendula	0.51		7500					
			Total			11000					
IV	well	10	Pinus Thunbergii	2.6	2.0	1543	1.93	0.19	0.72		* nat. regeneration
			Pinus densiflora*	3.2	1.5	686	0.37	0.04	0.18		
			Br. leav. tree			15588	45.15	4.51	11.27		
			Total			17817	47.45	4.74	12.17		
VI	well	19	Alnus pendula	2.6	3.7	8500	18.23	0.96	7.84	2	
			Robinia p.-acacia	4.9	5.7	1200	17.57	0.92	2.52		
			Alnus Sieboldiana	10.3	9.3	300	11.72	0.62	1.54		
			Total			10000	47.52	2.50	11.90		
II	well	27	Pinus Thunbergii	10.0	13.4	1019	85.38	3.16	8.32	1	
			Pinus densiflora*	11.0	12.8	895	107.44	3.98	9.11		
			Alnus pendula	5.4	4.8	6821	42.95	1.60	6.04		
			Alnus Sieboldiana	9.5	10.0	62	2.05	0.07	0.43		
			Total			8797	237.82	8.81	23.90		
IX	poor	26	Pinus Thunbergii	5.0	5.5	1900	21.18	0.81		3	
			(The natural stand)								
101	well	50	Pinus densiflora	12.9	15.1	2200	175.45	3.51	7.82		
103	well	60	Pinus densiflora	24.0	28.2	600	415.90	6.93	7.67		
204	poor	40	Pinus densiflora	2.5	3.6	4200	10.23	0.26	1.24		

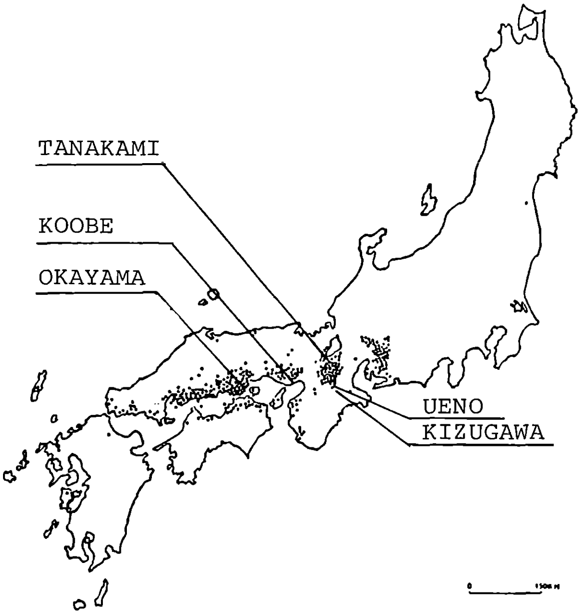


Fig.1 Distribution of devastated forest land in Japan.
One dot indicates 100ha.
by CHIBA,T.(1)

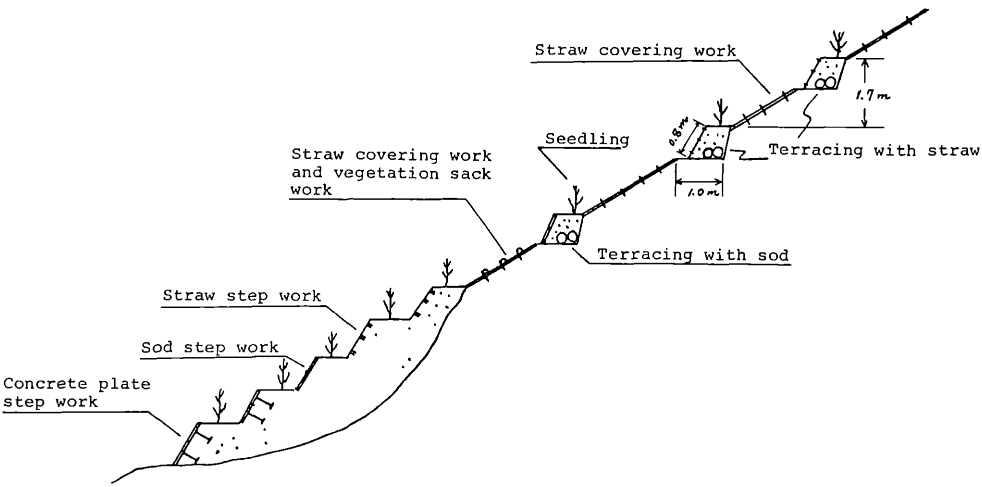
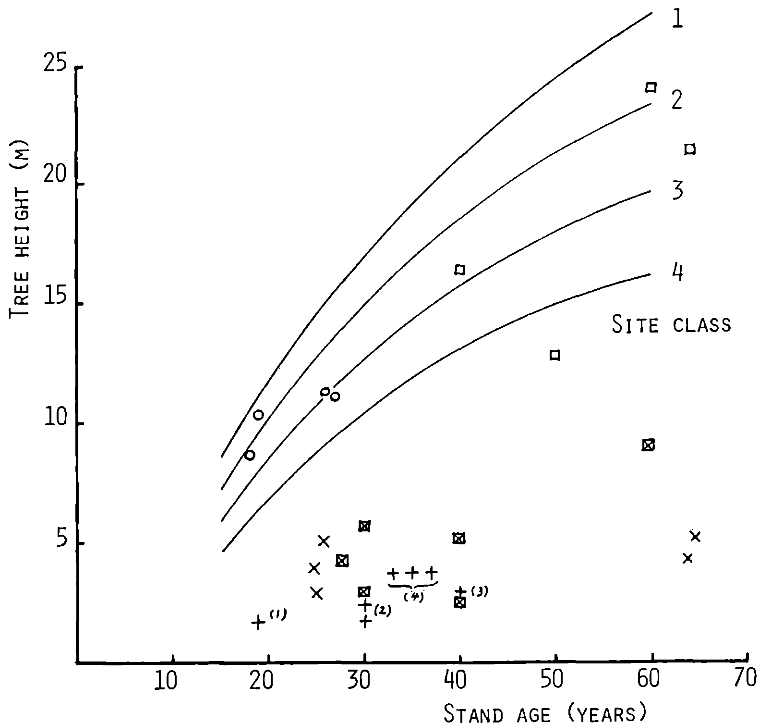


Fig.2 Cross section of the typical anti-erosion plantation. (Based on a figure in BIWAKO Construction Office pamphlet.)



o Well established	Anti-erosion	plantation	KIZUGAWA Basin
× Poor			
◻ Well established	Natural	stand	
⊠ Poor			

\+ Extreme infertile forest
(1) KURODANI National Forest
(2) BENZAITEN National Forest
(3) OKUYAMA National Forest
(4) OOYAMA National Forest

Fig.3 Site class of the anti-erosion plantation, compared with the red pine forest in KINKI District.

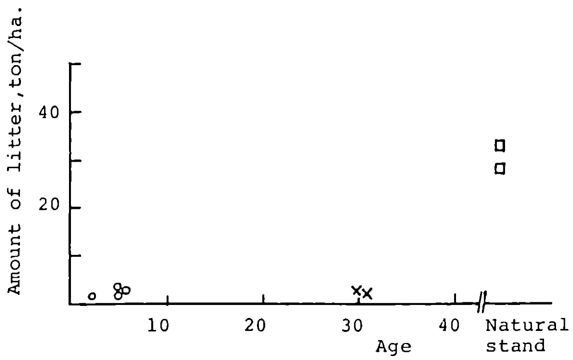


Fig.4 Amount of litter for different ages of the anti-erosion plantation and the natural stand, KIZUGAWA Basin.

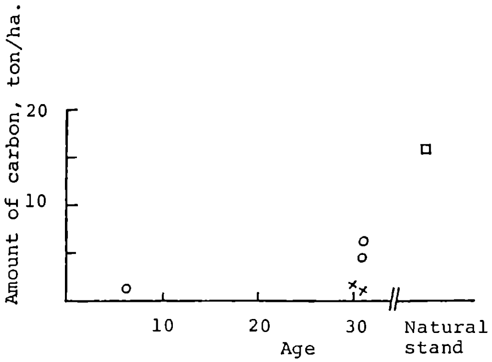


Fig.5 Amount of carbon in litter for different ages of the anti-erosion plantation and the natural stand, KIZUGAWA Basin.

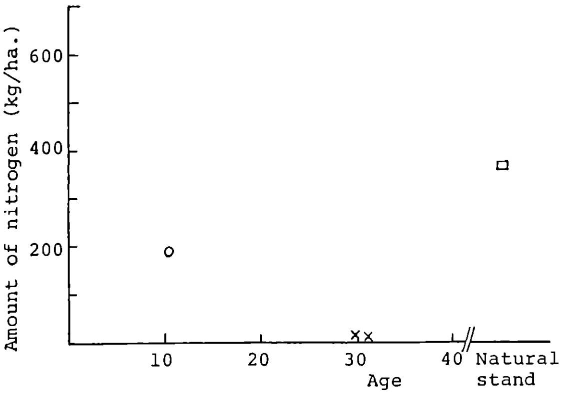
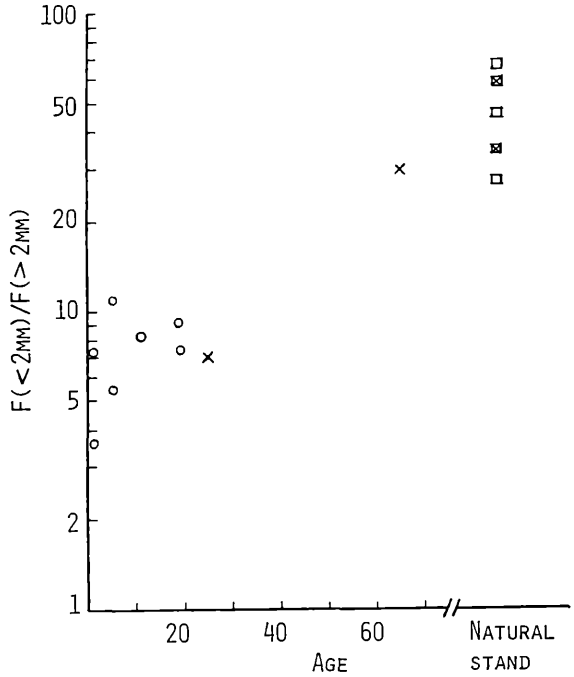


Fig.6 Amount of nitrogen in litter for different ages of the anti-erosion plantation and the natural stand, KIZUGAWA Basin.



F(< 2mm) Amount of particle finer than 2mm
F(> 2mm) Amount of particle coarser than 2mm

Fig.7 Ratio of the fine fraction to the coarse frction of soil in the surface layer, KIZUGAWA Basin.

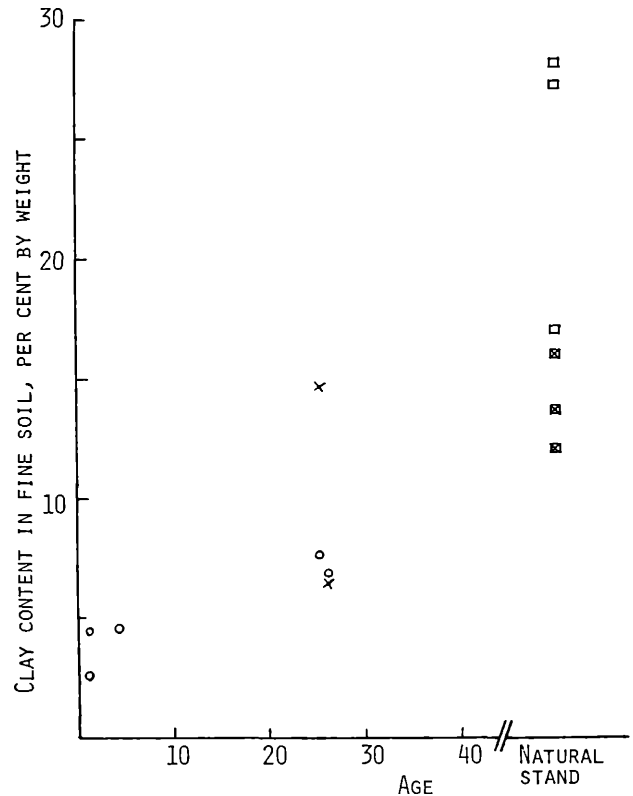


Fig.8 Clay contents of surface soil layer for different ages of anti-erosion plantation and natural stand, KIZUGAWA Basin.

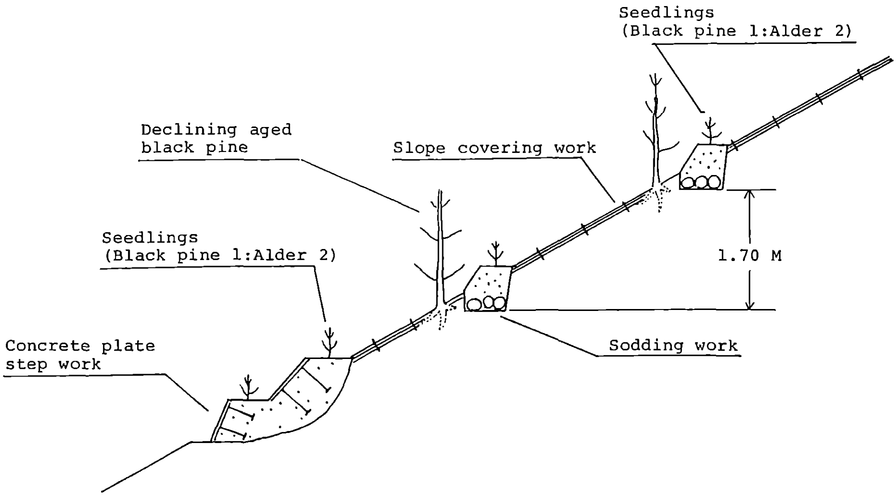
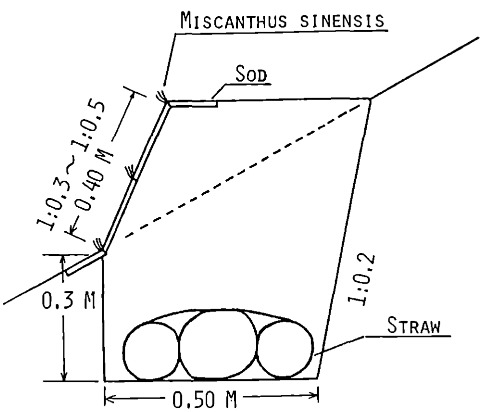


Fig.9-1 Cross section of The Tending Work B.
(Based on same source as Fig.2.)



Material list for the sodding work (per 10m)

sod (20× 20× 4cm)	6 m^2
rice straw	40 kg
Miscanthus sinensis	1 bundle
Fertilizer (N:P:K=13:17:12)	6 kg

Fig.9-2 Detail of the sodding work in The Tending Work B.
(Based on same source as Fig.2.)

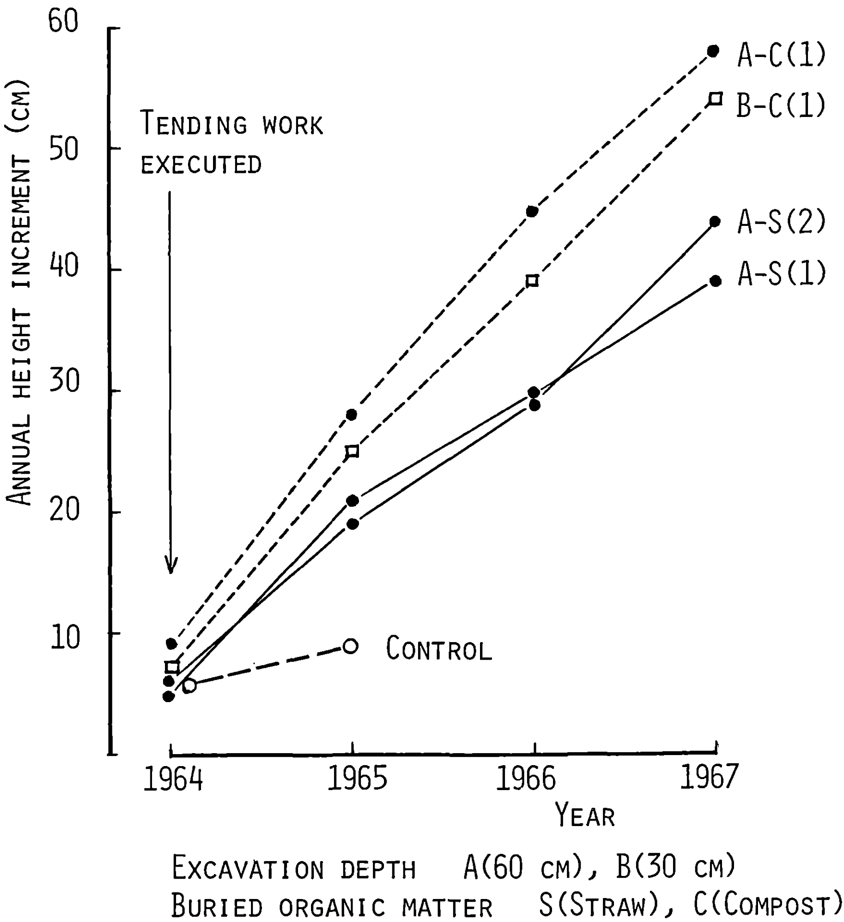


Fig.10 Increase of annual height growth of Pinus Thunbergii resulted from the Tending Work B in TANAKAMI Area.
Drawn from the data by TSUTSUMI(5).

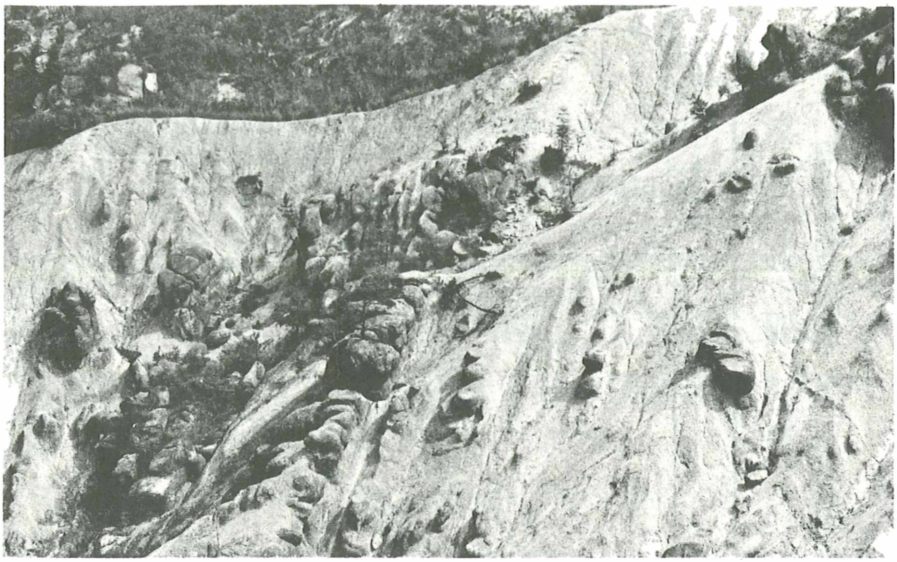


Fig.11 Typical appearance of the devastated slope in granite-derived mountain due to sheet erosion, TANAKAMI area.

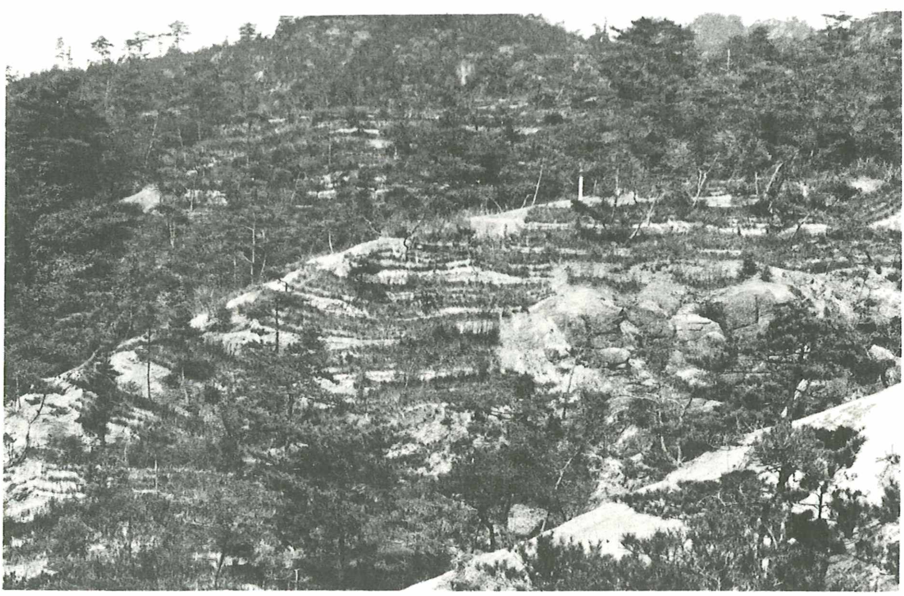


Fig.12 Just after execution of the anti-erosion plantation.

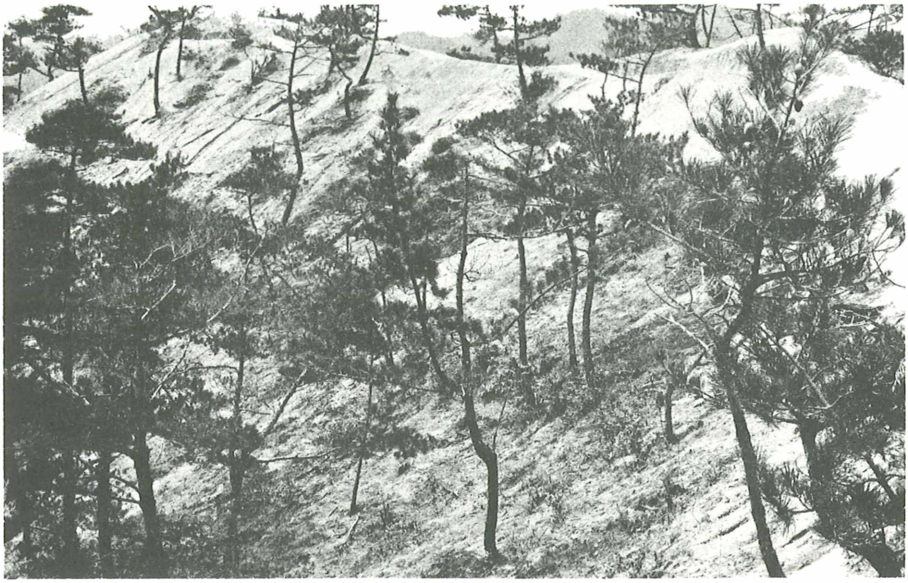


Fig.13 Poorly rehabilitated anti-erosion plantation. The land is in danger of re-devastation.

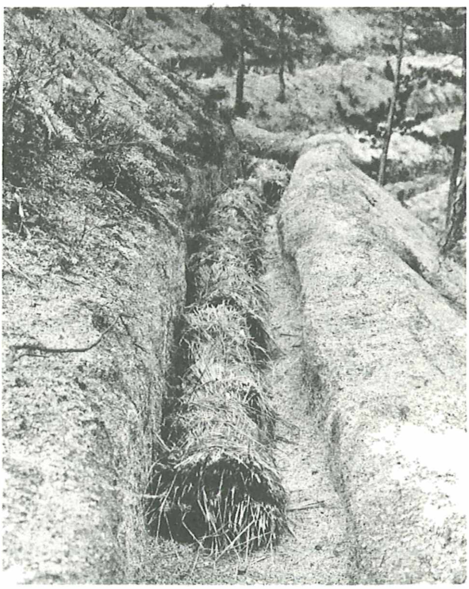


Fig.14 Under execution of the Tending Work B in the declining forest. Straw is put into the excavated trench.