Possibilities for Adaptation of Japanese Revegetation Techniques in Afghanistan*

By

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アフガニスタンにおける日本の森林復元技術の適用*

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Introduction

Land devastation is caused by destruction and removal of vegetation cover of an area by such human activities as misuse of land and neglect of conservation measures, which are further exacerbated by environmental and climatic factors. In Afghanistan land devastation was mainly attributed to unsystematic forest cutting for fuel and timber, forest fire, overgrazing, dry farming and soil erosion. Destruction of plant cover was followed by severe soil erosion, heavy flooding, siltation and land denudation.[3,10]

The aim of this report is to present an overall image of land devastation, to discuss revegetation and soil erosion control works applied in semi-arid parts of Afghanistan. Also, despite the fact that revegetation works were developed and

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practised according to the natural and social conditions of each country, the possibilities of adapting Japanese revegetation techniques in Afghanistan will be explored.

I. Natural conditions in Afghanistan

1. Location and climate

Afghanistan, with an area of 635,000 km² and a population of fifteen million is located in south-west Asia between latitude 29°30′ and 38°31′N, and longitude 60°45′ and 74°51′E (Fig. 1).

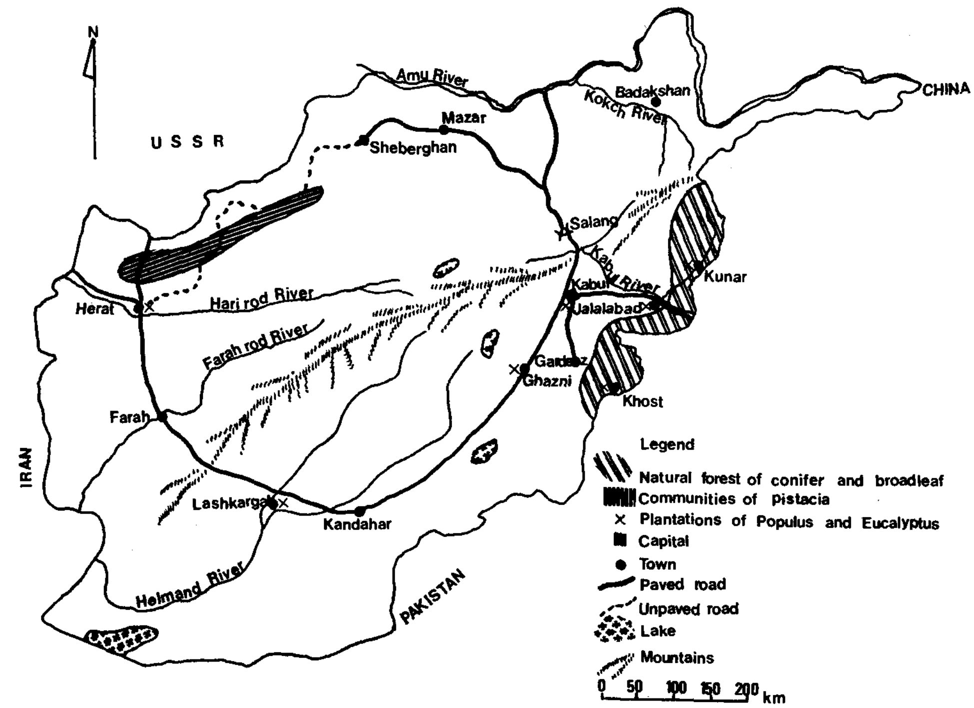


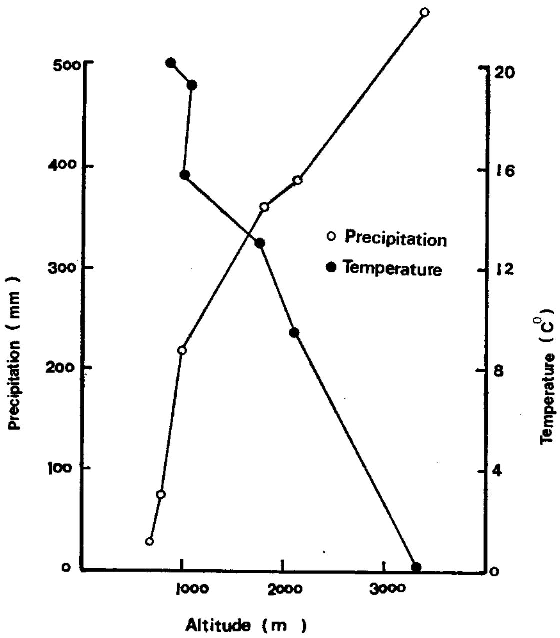
Fig. 1. A map of Afghanistan.

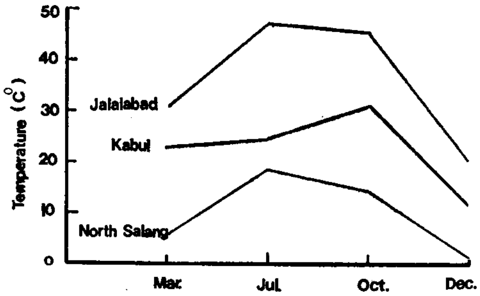
Due to mountainous topography of the country, Afghanistan's climate is mainly under the influence of altitude. North and southern aspects of high mountains have different temperature and precipitation (Fig. 2); while the former decreases, the latter increases with an increase in altitude.[2,7)]

Due to the distance from the ocean and the presence of subtropical high pressure zone the climate is dry, with warm summer, cold winter and big differences in seasonal temperatures (Fig. 3).

In mountainous areas, precipitations is mostly in the form of snow. Snow from the Hindukush mountains which lie in the middle of the country melts in summer and supplies water for rivers.

South and south-east are under the influence of Indian monsoons. Annual





↑ **Fig. 3.** Seasonal changes of temperature in Afghanistan.

← **Fig. 2.** Changes in annual temperature and precipitation due to altitude in Afghanistan.

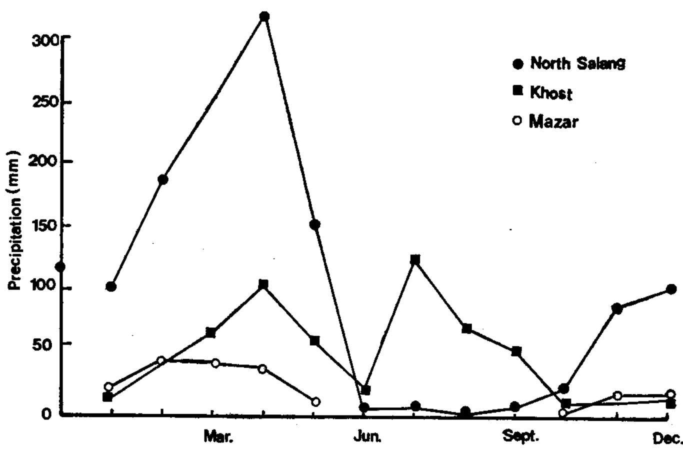


Fig. 4. Monthly average precipitation (mm) (Recorded years; 8)

North Salang: Altitude 3350 m, annual average precipitation and temperature are 1,236.9 mm (mostly snow) and 0.2°C respectively. The Salangs are located in the center of Afghanistan and the precipitation of this area is the main source of water for rivers of the country.

Khost: Altitude 1185 m, annual average precipitation and temperature are 600 mm and 15.9°C respectively. It is located in the south-east of the country and is under the influence of Indian Monsoons. Precipitation is high during plant growing season and therefore most of the coniferous and broadleaf forests of the country are located in this area.

Mazar-i-sharif: Altitude 378 m, annual average precipitation and temperature are 199 mm and 17.1°C respectively. Mazar is located in north Afghanistan, where dry farming is being practiced extensively.

average precipitation of the country is not more than 350 mm while precipitation of this area is around 600 mm coming mainly as rain during the spring and summer (Fig. 4).[2] Broad leaf and coniferous natural forests of the country are therefore located in this area (Table 1).

Table 1. Distribution of natural forests in Afghanistan

Location and composition	Area in ha.
Coniferous forest of Paktia (south)	450,000
Coniferous and broad leaf forest of Kunar (east)	444,000
Coniferous and broad leaf, communities of *Pistacia vera*, *Juniperus* and etc. scattered all over the country	1,084,000
Total	1,978,000

2. Geology and soil

The central and north-eastern mountains of Afghanistan consist of Preordovician phyllite, Paleozoic schist, slate, gneiss, granite, granodiorite and diorite, and Cretaceous, Jurassic and Cenozoic limestone, sandy marls and shales. Outcrops of volcanic materials are scattered throughout most of the mountainous areas. The northern, southern, and eastern lowlands are occupied primarily by Quaternary deposits including alluvial fans, shallow temporary lakes and sand dunes.[2,6,7]

Desert saline and alkali soils have developed from both alluvium and sedimentary rocks. Major river valley soils are initially formed mainly of glacio-fluvial, alluvial and Eolian sediments. Soils of steppe and rolling hilly areas of lower latitude are formed from loess derived from glacial and alluvial materials. Mountain soils have formed from a complex of residual, colluvial, alluvial and eolian materials. Soils of the alluvial plains constitute forty percent of the cultivated areas and are scattered throughout the country. The remaining twenty percent is in high mountain lands and forty percent is in arid waste land.[7]

3. Topography and vegetation

(1) Northern, eastern and south-western areas have extensive plains (600 m altitude) where the major features are sand dunes, salty marshes and shallow temporary lakes. In sandy places, *Citrullus colocynthis* and *Haloxylon ammodendron* (Saxaul communities) are very common.[7] In eastern area (elevation 500 m) large shrubs of *Acacia modesta* and *Calotropis procera* are characteristic. *Artemisia maritima* is widely distributed in this zone (although it can be found even in alpine zones), and is usually growing on saline soils, forming 1$\sim$2 m apart in pure communities.

In places where water is available, *Vitis vinifera*, *Morus alba*, *Salix* spp., *Platanus orientalis*, *Pinus halepensis*, *Cupressus sempervirens*, *Thuja orientalis* etc. are planted mainly as avenue and garden trees.

(2) Steppes (600$\sim$2000 m): This zone is characterized by rolling hills, semiarid flat lands, broad river valleys and terraces, sand dunes, range lands and crop

lands. In the rolling hills and flat areas where there is adequate moisture, dry farming is being practised. *Populus* spp. are mainly cultivated by irrigation for timber. Composition of avenue and garden trees has marked similarities to what was described in zone one.[2,7]

In most of the lower areas of this zone, the number of species is very few while, in higher elevations the vegetation becomes gradually richer, and where there is more moisture due to topographical reasons natural forests of *Pistacia vera* which are of commerical value are being formed, although the trees are low (3~5 m in height). *Tamarix pentandra* and *T. leptostachys* often forms large open associations along rivers or on grounds with underlying water.

(3) Mountain Ranges (2000~3500 m): This is the zone of deciduous and coniferous forests. Deciduous trees are dominant in the lower parts while, the coniferous forests dominate the upper parts. *Quercus baloot* is found mixed with *Olea cuspidata, Pistacia kinjuk* and *P. cabulica.*

From an altitude of about 2200 m, *Quercus* disappears and *Cedrus deodara* and *Pinus excelsa* are dominant. Higher up *Picea smithiana* are mixed in some places with deciduous trees mainly *Fraxinus* spp. and *Ulmus campestris,* forming dense forests. *Cedrus deodara* diminishes slowly from elevation of 2500 m while, *P. gerardiana* becomes dominant, and so the forest becomes less dense. The timber lies generally at about 3500 m.

(4) Alpine zone (3500 m upward): In the lower parts of this zone *Juniperus* communities are rather tall (2~3 m), while, in drier places *J. seravschanica* is depressed and covering the ground with it's branches. Table 2 shows the comparison between Afghan and Japanese flora.[6]

Table 2. Comparison between Afghan flora and Japanese flora (number of species of composed)

	Afghanistan	Japan
Gymnospermae	14	39
Monocotyledoneae	397	1140
(*Gramineae*)	(165)	(231)
Choripetalae	1254	1839
(*Cruciferae*)	(188)	(65)
(*Leguminosae*)	(346)	(97)
Sympetalae	1015	629
(*Compositae*)	(432)	(360)
(*Labiatae*)	(160)	(86)
Total	2680	3647

II. Land devastation and revegetation works in Afghanistan

1. Factors of land devastation

In Afghanistan the problem of land devastation has a long history. Transhuman migrations, pastoralism and concentration of population around water resources leads to over exploitation of the land resources.

For hundreds of years these factors have been contributing to land devastation, although in small scale and at a slow pace. Recently due to the growth of population, there has been an increase in demand for wood both for fuel and timber; meat and wheat and other cereals for the staple diet. Thus the pressure has increased on natual renewable resources such as forests, range lands and dry farming areas for the production of the above mentioned items. In general, unwise use of land together with harsh climatic and environmental conditions caused land devastation.

Although sufficient data is not available at present individual factors of devastation will be explained as follows;

(1) Overgrazing: Overgrazing has long been known to exist in Afghanistan. Rangelands are of great economic significance. Sixty two percent or 393,700 square kilometer area of the country is currently considered to be ranges. They are stocked with a maximum of 30 million animals of which over 80 percent are sheep.[10]

Improved pastures are nonexistant, and there has been no evaluation of the capacity of the natural grazing areas. Platable species of plants are being overgrazed leaving the area as a bare land. Areas around watersources also are being overgrazed due to presence of animals for long periods of time. In this way large portion of rangelands changes to barren and devastated areas.

(2) Dry farming: Out of total of 2,350,000 ha under wheat in 1978, 1,050,000 ha were planted unirrigated or by dry farming, mainly in the northern steppes.[10] Large areas of former rangelands have been taken over for the practice of dry farming during the last two decades. An increase in the number of tractors in the countryside facilitated dry farming.

Due to topography and rain pattern soil erosion is a severe problem in the area

Table 3. Exploitation of natural forests in Afghanistan

1.	Standing stock of timber	15,000,000	(m^3)
2.	Wood suitable for fuel	14,000,000	
3.	Annual growth of timber	126,500	
4.	Quantity exploitable	70,600	
5.	Annual exploitation of timber	635,400	
6.	Firewood capacity	60,000	
7.	Actual exploitation of firewood	120,000	
8.	Total capacity for exploitation per year (4+6)	130,600	
9.	Total actual exploitation per year (5+7)	755,400	

of dry farming. Where this has occurred it is likely that productivity will fall off after the first year or two of cultivation and the land will be abandoned.

(3) Deforestation: As it can be clearly seen from Table 3 the process of deforestation is going on very fast. Annual exploitation of wood is 5.8 times more than the exploitable capacity of forests. Moreover, the wood is cut unsystematically and with no provision for reforestation. Occasional forest fire adds to the problem. In this way large areas of forested lands are being changed to bare lands annually.

(4) Soil erosion: Soil erosion process is very active in all of the three mentioned areas. Sporadic high intensity rainfall measuring 30～40 mm in a few minutes, especially during the time when the land is bare and with no vegetation cover causes severe soil erosion and flooding.

Deprived of it's protective cover of vegetation and exposed to wind and runoff, the soil starts to erode. Erosion features such as sheet, rill and gully are quite visible, almost everywhere in the above mentioned devastated areas.

2. Types of revegetation works, mainly in the greenbelt around the Kabul City

Due to semi-arid climate in most parts of the country, the main problem for plant growth in Afghanistan is lack of water. Therefore, methods and species used for revegetation works have water retention and drought resistant characteristics respectively.[1] The purpose of these works, however, are water and wind erosion control, greenization, and fuel wood and timber production. Following is a brief explanation of three main types of revegetation works in Afghanistan.

(1) Sand dune fixation: Sand dune movement is a problem in north and south-west of the country where the average annual precipitation is less than 150 mm. Summer winds of up to 80 km/hr moves these dunes, with subsequent encroachment on agricultural lands, irrigation canals and human settlements.

Vegetation works are the only measures taken so far for dune stabilization. For this purpose cutting of *Haloxylon ammodendron* is planted together with locally grown reeds. However little is known about the results of revegetation works in this area.

(2) Plantations of fast growing trees: Species of *Populus*, *Salix* and *Eucalyptus* are being planted on flat areas, farm boundaries and along the river banks where irrigation is possible. Among these *Populus* are grown in semi-arid areas with an average annual precipitation of 400 mm which is mostly in form of snow, while *Eucalyptus* spp. are planted in areas under the influence of Indian monsoons. *Salix* can be planted in all climatic regions of the country.

For the establishment of these plantations cutting of *Populus nigra*, *P. alba*, *P. euphratica* etc. and *Salix alba* are being planted in late winter and irrigated frequently during summer. *Eucalyptus* spp., however, are propagated by seeds, raised in plastic containers and then transfered to the planting site.

(3) Hillside afforestation: Water retention terracing and trenching method are currently being used for hillside afforestation, while the former is applied in

semi-arid areas with less rainfall, the latter is mostly practiced in clear cut areas of natural forests.[1)]

One of the areas where water retention terraces are extensively at use is the greenbelt around the Kabul City (Fig. 5). This project consists of eleven units, with a total area of 300 hectare. The landscape is hilly with soil ranging from gravelly to gravelly loam.

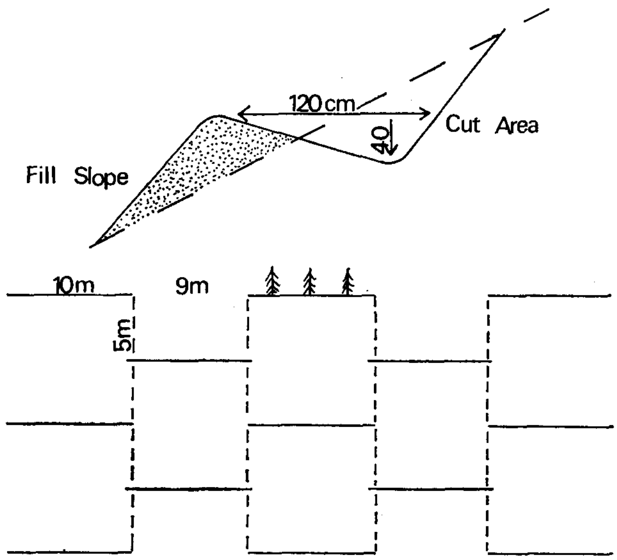


Fig. 5. Schematic drawing of a cross-section (above) and an alternate shape plane figure (below) of water retention terrace practiced in the greenbelt area in Kabul City.

Factors of widespread devastation in this area are mainly overgrazing, cutting and uprooting of herbs and shrubs for fuel and stone extraction.

Some of the nomads travelling to cooler parts of the country during spring and summer seasons, stay in this area from early April to late August, and it is this season when plants start to grow. Travelling sheep, goats, camels and other domesticated animals graze over newly grown plants. Since livestock grazing capacity is not taken in consideration, overgrazing is usually the result. What is left after grazing is being cut and uprooted during autumn for winter fuel by nearby villagers.

Also due to its location in the vicinity of the capital, stone extraction for construction purposes is a common practice. Quarries of up to 20 m in depth and several tens of meters in width can be found almost everywhere in this area.

Revegetation works in this area have a rather long history. Eighty years ago 20 hectares in the west side were planted with *Vitis vinifera*. In the early sixties more than 50 hectares were planted with different species of pine and broadleaf. These works were carried out mainly on bench terraces.

Recently this area was designated as greenbelt zone, and so rather large scale revegetation works were carried out by constructing water retention terraces and by planting the following plant species ; *Robinia pseudo-acacia, Ailanthus glandulosa Cersis griffithii, Cedrus deodara, Picea morinda, Pinus excelsa, P. gerardiana, P. nigra, P. ponderosa* etc.. Planted seedling in most cases are being watered manually 5 to 7 times a year, using 8 and 10 liter buckets. Water is transported from long distances by tankers. Continued watering for up to 5 years proved to be very useful in increasing the survival rate of seedlings. However due to fuel and labor costs, it is being practised only for the first two or three years.

III. Land devastation and revegetation works in Ashio, Japan

Land devastation and revegetation works in Ashio and Tanakamiyama will be cited as two typical examples in Japan.

(1) Ashio district has an area of 185 km^2, and is located at the extreme western edge of Tochigi prefecture. Average yearly precipitation and temperature is 1600 mm and 11.8°C respectively. The maximum daily rainfall recorded so far is 407 mm. Most of the rain falls during the growing season from May to August, and is under the influence of typhoons during the month of August to September (Fig. 6).[4,8,9] Average wind speed is 1.7 m/sec which causes plant damage during winter.[8]

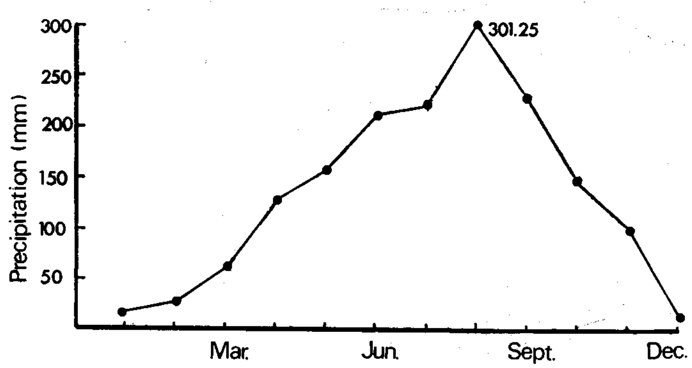


Fig. 6. Ten years monthly average precipitation in Ashio (1973–1982).

Frost heaving displaces planted seedlings, and is severe in area of loamy soils. As data from 1968 to 1972 Table 4 shows, early frost heaving occurs mainly during the month of October before snowfall.

Sulfur dioxide (SO_2) gas emissions from the copper smelting, indiscriminate forest cutting as fuel for smelting and mine timber, and forest fire were the main causes of land devastation. As it can be seen from the following brief chronology of main events, the processes of devastation occurred over a long period of time.

— 1610 — Discovery of copper mine.

— 1884 — Indiscriminate cutting of nearby natural forest as fuel for smelting and for mine timber, and occurrence of big forest fires.
— 1893 — Adoption of a new copper smelting method which increased the quantity of SO_2 emissions to a considerable extent, and resulted in large scale devastation.
— 1956 — Installation of self-cleaning smelting equipment.[4,8]

However, until 1956 the SO_2 gas emission continued and spread to the surrounding areas following the direction of the wind (Fig. 7). As a result, in the

Table 4. Snow fall and frost heaving occurrence in Ashio

year	First snow fall		Last snow fall		First frost	
	Day	Month	Day	Month	Day	Month
1967	14	Dec.	16	Apr.	—	—
1968	5	Dec.	26	Mar.	30	Oct.
1969	28	Oct.	16	Apr.	13	Oct.
1970	15	Nov.	—	—	21	Oct.
1971	28	Oct.	—	—	8	Oct.
1972	21	Nov.	10	Apr.	23	Oct.
1973	6	Nov.	—	—	—	—
1974	—	—	15	Apr.	—	—

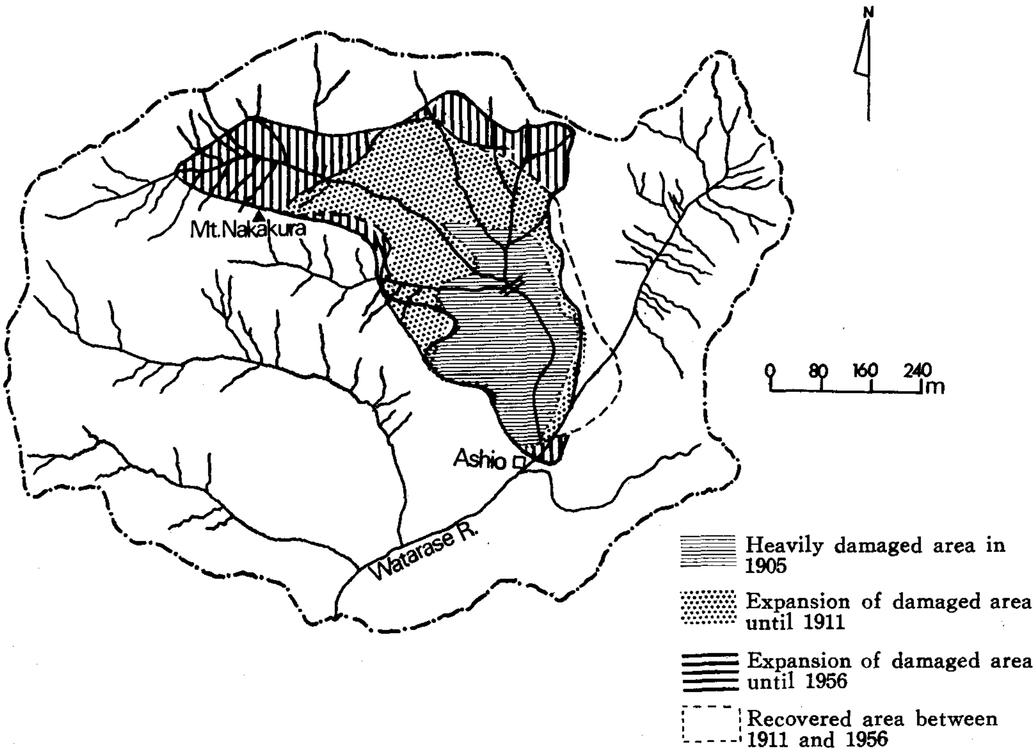


Fig. 7. Changes in heavily damaged area from 1905 to 1956.

area such as Honzan, both woody and herbaceous plants were not only destroyed, but for some time they were unable to grow. Consequently the area was turned bare as rocky mountain slopes with shallow soil cover.

After the installation of self-cleaning smelting equipment, the devastated mountains of Ashio were classified into three categories according to the degree of damage.[4,8,9]

(i) Area of light damage 7,860 ha, almost recovered
(ii) Area of medium damage 3,840 ha, partly recovered
(iii) Area of heavy damage 3,155 ha, hardly recovered

In November 1982 a photointerpretation was carried out using two ran panchromatic airphotographs of the scale 1/10,000 in the year 1957 and five ran airphotos of the scale 1/20,000 in the year 1976. Those were to determine the

Table 5. Results of the photointerpretation of the heavily damaged part of the Ashio devastated area (in ha.), Nov. 1982

Year	Heavy damage (H)	Medium damage (M)		Light damage (S)	Settlements	Total
		(M1)	(M2)			
1950	2,532	—	—	—	11.8	2,544
1957	1,988.6	35	500	8.6	11.8	2,544
1976	1,321.6	205.9	331	673.7	11.8	2,544

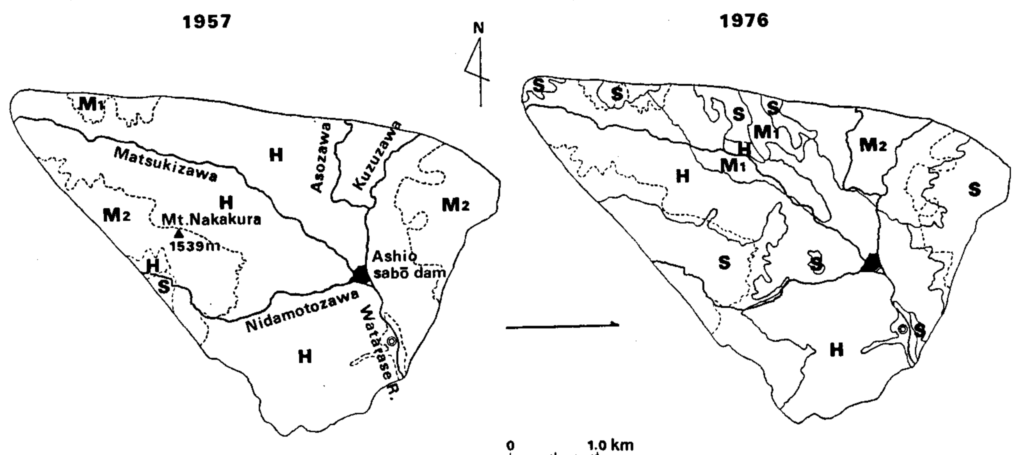


Fig. 8. A photointerpretation map of the heavily damaged area in 1957 and 1976.

H: Area of no vegetation (moderately to steep slope, strongly eroded)
M: Area of sparse vegetation (moderately to steep slope, moderately eroded)
 M1: Area of sparse vegetation, herbs.
 M2: Area of sparse vegetation, herbs and a few trees.
S: Area of dense vegetation (moderately to steep slope, slightly to moderately eroded).
◎: Copper smelting factory (source of SO_2 smoke)
⁝: 1957 mapping unit boundaries
≀: 1976 mapping unit boundaries

effectiveness of revegetation works and to measure the changes in the recovery of vegetation in the area over a period of 19 years.

The airphotographs covered 2,544 ha of the area which in the fifties was delineated as heavily damaged. This covers 14.2 percent of the 17,827 ha total forested land of the Ashio district, and was divided into three mapping units of H area of no vegetation, M area of sparse vegetation and S area of dense vegetation (Table 5). A photo-interpretation map of the scale 1/25,000 was drawn (Fig. 8). It can be clearly seen from maps and Table 5 that even in heavily devastated part there has been a continuing tendency toward recovery due to revegetation works and natural invasion of plants.

At present, revegetation works follow basic works, such as check dams, concrete plates, and vegetation works such as vegetation matting, sack, terracing and air seeding. The tree species used for revegetation works are mainly *Robinia pseudo-acacia, Alnus pendula, Pinus thunbergii, Clethra barbinervis* etc.. However, in Ashio devastated areas, revegetation works have a rather long history. Moreover different kinds of techniques were tried for hillside afforestation in the area. Table 6 shows the works carried out from 1956 to 1974, and Fig. 9 shows the designs of some of the works.

(2) Tanakamiyama: Tanakami mountain is located in south-eastern part of Shiga prefecture, in the basin of Seta River. It has an average annual precipitation

Table 6. Revegetation works from 1956 to 1974, in Ashio

	Kind of work	Years	Amount of work
1.	Grading and steps	1956–1974	2,581,571.5 m
2.	Vegetation plates	1961–1974	147,670 m
3.	Vegetation bags	1963–1974	175,983.5 m
4.	Direct sowing by local grasses	1957	89,037.3 m
5.	Slope sodding work with vegetation blocks of uniform shape	1957–1960 and 1970	40,845.3 m
6.	Terrace work with planting	1956 and 1974	1,187.8 m
7.	Vegetation blocks of different shape (Shape changes are according to slope and other factors)	1957–1958	1,183.6 m²
8.	Point seeding	1958	26,500 Pieces
9.	Straw matted	1967–1969	6,260 m²
10.	Vegetation bag one line	1966–1967	7,923 m
11.	Line seeding (without excavation)	1957–1960	89,648.6 m
12.	Linear sodding (without excavation)	1967	275 m
13.	Step work with straw bundle	1956–1958	120,894.1 m
14.	Vegetation bags and channel work	1965	282.7 m²
15.	Iron net	1969–1970	3,500 m²
16.	Wicker work	1958–1969	14,542.8 m
17.	Step work with stone	1958–1963	3,776 m
18.	Wire cylinder work	1967 and 1971–1973	844 m
19.	Seeding (by sprayers, helicopter etc.)	1970–1973	92,169 m²

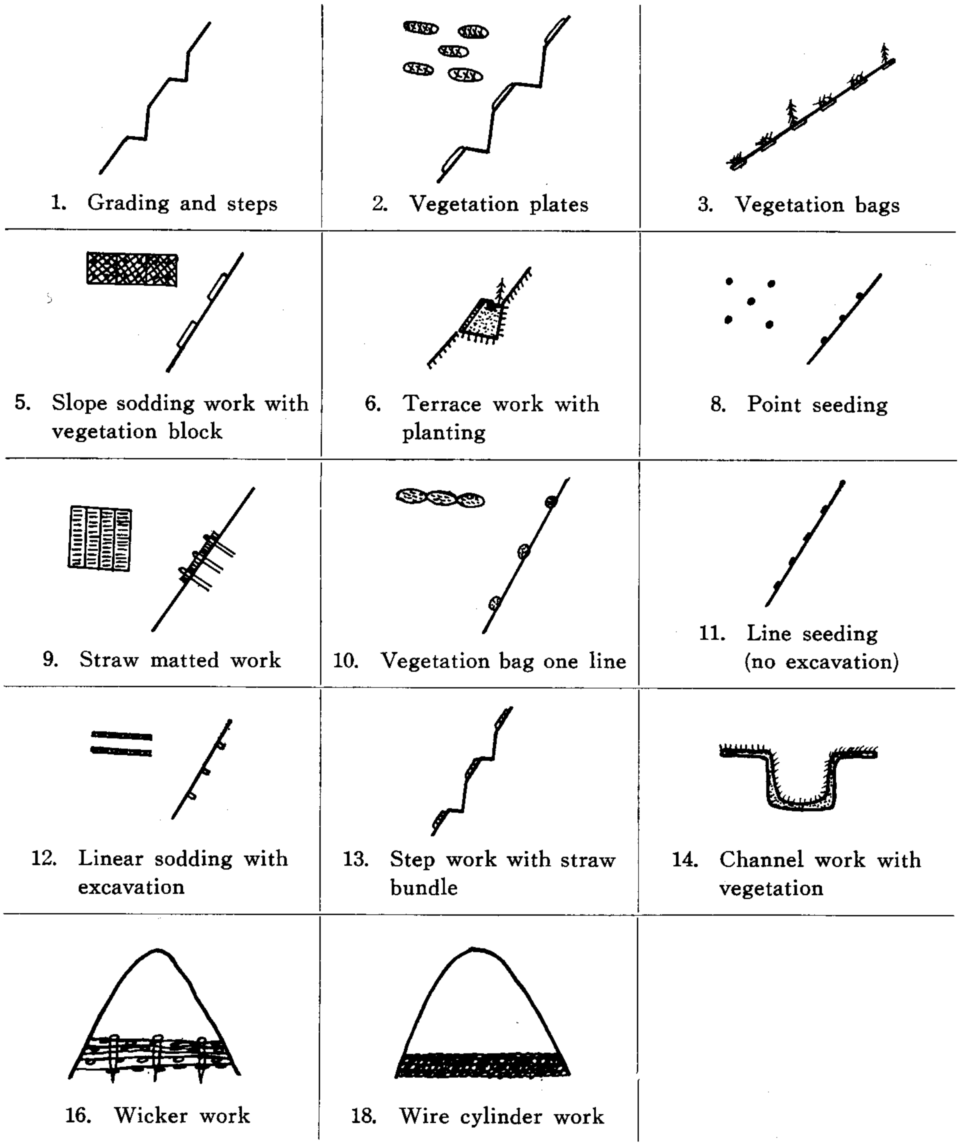
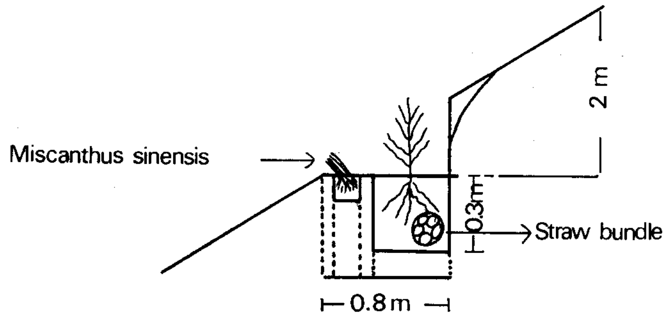


Fig. 9. Hillside works in Ashio.

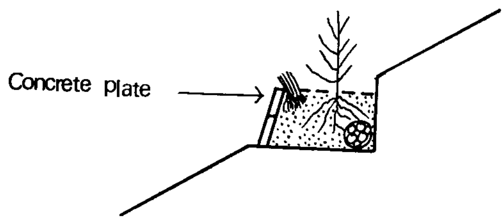
of 1,500 mm, mostly as rain. The bed rock is granite where weathering is very active. Natural vegetation prior to devastation were mainly *Cryptomeria japonica*, *Chamaecyparis obtusa* and *Quercus* spp..

The area was devastated due to the digging of potter's clay, tree cutting for fuel, construction of temples, shrines and palaces in Kyoto and Nara prefectures.

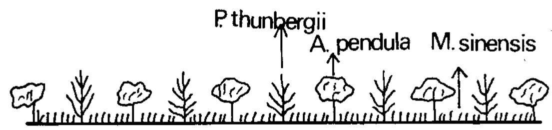
Revegetation works follow terracing along the contours (Fig. 10), with species such as *Pinus thunbergii* and *Alnus pendula* used for planting. *Pinus thunbergii* was chosen due to it's relative fast growth and high survival rate characteristics, while *alder* was selected for adding organic matter to the soil.



A cross-section of terrace constructed in moderately sloping hillsides.



A cross-section of terrace constructed in steep hillsides.



A horizontal diagram of terrace.

Fig. 10. Design of terrace and planting works in Tanakamiyama.

IV. Possibilities for adaptation of Japanese revegetation techniques in Afghanistan

In arid and semi-arid parts of Afghanistan with it's previously mentioned little amount of rain fall and dry summer, planted seeds of grasses, trees and seedling, can not survive without watering. Considering this fact, revegetation works such as seeding by helicopter or sprayers, direct sowing by local grasses, point and line seeding will not give good results.

Foundation works for stabilization of land surface and planting site such as grading and steps, terracing works with planting, step work with stone, wicker work, and wire cylinder works, can be applied in semi-arid and areas under the influence of Indian monsoons where strong wind erosion and surface water erosion take place. However, they may need some minor changes to fit the local conditions.

In most parts of Afghanistan, plants grown from direct seeding in terraces have good growth only for the first few months. Because rain water is available and the soil is moist during this time. Keeping moisture around the newly grown roots for longer periods of time is vital to the survival of these seedlings. Also protecting seeds and seedlings from the direct impact of incoming solar radiation is considered to be very important. To achieve this, vegetation bag method presently at use in Ashio can be practiced for revegetation works in Afghanistan. In this case, organic matter content of the bag should be increased, and also should be supported with straw mat in both sides and beneath (Fig. 11).

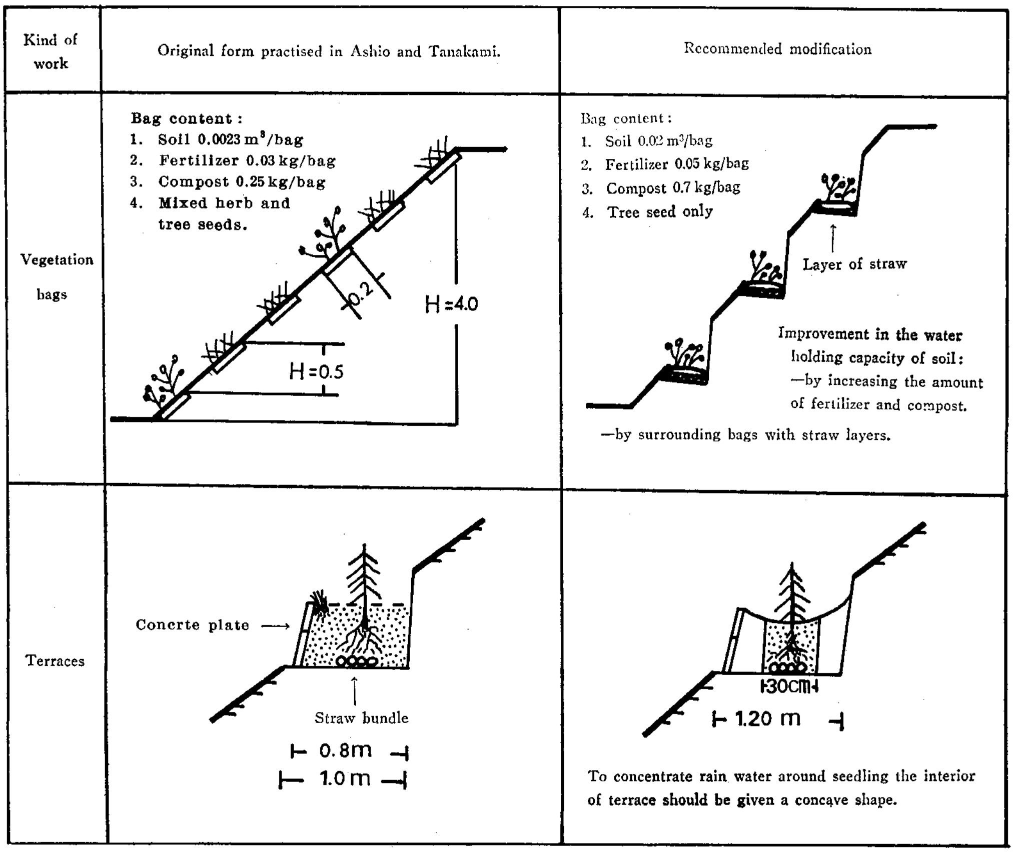


Fig. 11. Recommended modification of some planting works practised in Ashio and Tanakamiyama for use in semi-arid and forested regions of Afghanistan.

This will considerably enhance the moisture holding capacity of the bags, prevent excessive evaporation and increase the survival of seedlings.

To increase the water holding capacity of soil in water retention bench terraces, straw bundles can be embedded in the bottom of the pit near the root zone, in the same way it was practiced in Tanakamiyama. This will increase the moisture availability, and after decaying will provide organic matter for the soil. For soil and hillside stabilization in steep slopes, concrete plates can be constructed in the same manner as in Ashio.

Conclusion

In Afghanistan, land devastation leads to desertification. Every year tens of hectares of range and arable lands are being transformed into desert. Amount and timing of precipitation is a limiting factor in rehabilitation of devastated areas. Wind erosion is a problem in sandy areas, where sand dunes moving by seasonal winds are encroaching on arable lands and villagers.

Land devastation is mainly caused by human misuse of land, negligence of conservation measures and severe climatic conditions. Accelerated soil erosion, flooding and siltation are the common results.

The problem in Afghanistan is to find scientific ways and the proper technology to revegetate the devastated areas and combat the process of land devastation. In this connection, some of the revegetation methods and techniques used in Japan, especially in Ashio and Tanakamiyama can be applied for revegetation works in Afghanistan.

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摘　　要

森林の荒廃と国土の砂漠化は，現在世界的規模で進行しており，人類の生存を脅かす基本的問題となっている。中央アジアに位置するアフガニスタンでも，無計画な伐採，過放牧等による国土の荒廃は著しく，森林復元の必要性が強く叫ばれている。

本論文は，日本とアフガニスタンの森林荒廃の成因を比較検討し，日本の森林復元技術のアフガニスタンへの適用について考察することを目的とした。

① アフガニスタン (国土面積 63 万 5 千 km^2，人口 1,500 万人) は，北緯 29°30′～38°31′，東経 60°45′～74°51′ に位置している (Fig. 1)。気候は，山岳地域においては主として標高によっ

て変化するが，海洋からの距離が遠いことおよび亜熱帯高気圧等の影響のため全般に乾燥しており，また，季節による温度変化も激しい (Fg. 2～4)。

② アフガニスタンの地質状況を概観すると，中部・北東部の山脈はプレオルドビス紀の千枚岩，古生代の結晶片岩，粘板岩，花崗岩，そして中生代，新生代の石灰岩，頁岩等から，また，北部・南部・東部の低地は主として，第四紀堆積物からなっている。砂漠の塩分を含んだアルカリ土壌は，沖積層と水成岩の地域に発達しており，渓谷内の土壌は，おもに氷河，河川，風による堆積物によって形成されている。そして，ステップ地帯と起伏のある地域は氷河，沖積堆積物からなるレスによって形成され，山岳地帯の土壌は，残土，沖積土，風積土が複雑にからみあって形成されている。

③ アフガニスタンの植生 (Table 1, 2) は，地形的には4つの区域に分割される。標高600 m までの平地では，砂丘，湿地，一時的な浅い湖が存在し，*Citrullus colocynthis*, *Haloxylon ammodendron* 等の樹木が生育している。標高600～2000 m のステップは，起伏のある丘，半乾燥気候の平地，河川，放牧地で特徴づけられ *Pistacia vera*, *Tamarix pentandra* 等が生育している。標高 2000～35000 m の山岳地帯は針広混交林を呈し，低標高地で広葉樹 (*Quercus baloot* 等) が，高標高地で針葉樹 (*Pinus excelsa* 等) が優占している。さらに 3500 m を越える高山帯では *Juniperus* 等が生育している。

④ アフガニスタンにおける森林荒廃の歴史は古く，長年月にわたって，遊牧民による水源周辺の開拓と人口集中が続けられてきたことによるが，もっとも問題となるのは，近年の人口増加にともなう主要穀物，肉，木材等の需要拡大である。こうした現状は，過放牧，乾地農業による地位の低下，無計画な伐採 (Table 3) による森林破壊を招き，さらに侵食されやすい気候，地質条件とあいまって，国土の砂漠化に拍車をかけたといえる。

⑤ 半乾燥地帯に位置するアフガニスタンにおいては，森林復元の上でもっとも障害となるのは水不足である。このため，工法，導入樹種の選択にあたっては，水分保持耐乾燥性が要求される。アフガニスタンにおける森林復元技術は，その地域性から北部・南西部で行なわれている砂丘固定，かんがい可能な平地，農地，河岸堤防で行なわれている林帯造成，さらに山腹斜面における階段工，溝工等の緑化工 (Fig. 5) の三つのタイプに大別することができる。もちろん各地域における導入樹種はそれぞれの地域に応じて異なっている。

⑥ 一方，日本の代表的な荒廃地として知られる足尾煙害地は，栃木県の西方に位置し，年降水量 1600 mm，年平均気温 11.8°C，年平均風速 1.7 m/sec である。10月から降雪までの期間に起こる凍上は，ローム質土壌のため激しく，苗木の定着を阻害している (Table 4)。

⑦ 足尾における森林荒廃の原因は，銅製錬による亜硫酸ガス (SO_2) の放出が第一因としてあげられるが，この他にも燃料，鉱山用資材の需要激増に対応した無計画伐採，さらには山火事等が原因となっている (Fig. 7)。近年の植生復元工事の拡大は，自然侵入をももたらし，着実にその成果をあげている。すなわち，1957年と1976年の航空写真判読によって，山腹工

事施工以前の激甚被害地 (H: 2,532 ha) は，1957年には中 (M)・軽 (S) 被害地がそれぞれ増大していることが確認された (Fig. 8, Table 5)。

⑧ 足尾における植生復元技術は，砂防ダム，土留工等の基礎工が，植生盤・植生袋・航空実播等の植生工と有機的に結びついている点が特徴である。導入樹種としては，ニセアカシア，ヒメヤシャブシ，クロマツ，リョウブ等が採用されている (Table 6, Fig. 9)。

⑨ 田上山 (滋賀県南東部，年降水量 1500 mm，花崗岩) における荒廃の原因としては陶土採掘，さらにその燃料としての伐採，また京都・奈良の寺院，神社建設のための用材伐採等があげられる。田上山の植生復元技術は，等高線に沿った階段工が主で，導入樹種としては，クロマツ，ヤシャブシ等があげられる (Fig. 10)。

⑪ 日本の植生復元技術のなかで，航空実播工と吹付土は，アフガニスタンの半乾燥性気候から考えて導入は難しいと推測される。しかし，階段工，編さく工，土留工等の土壌表面を安定化する基礎工は，多少の改良を加えるならば，アフガニスタンにおいても充分その効果を期待できると考える。たとえば，足尾で実施されていた植生袋工法は，種子・苗木を直接日光から防ぎ，湿気を保持できる点で有用であり，田上山で行なわれていた束わらを埋設する工法を併用することにより，さらに水分保持効果が期待される (Fig. 11)。