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Restoration of living environment based on vegetation ecology: Theory and practice

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The foundation of ecological restoration is how to preserve biocoenoses (i.e. functional ecosystems) and how to restore and reconstruct them where they were destroyed. One of the most important challenges is the restoration of complex, multilayer forests representing the potential natural vegetation. Native forests have functions in disaster mitigation and environmental protection, as well as providing the basis of existence for local people and maintaining gene pools for the future. Through vegetation surveys in Japan and South-east Asia, we have established basic principles in vegetation-ecological restoration of forests. We have been restoring expected disaster-mitigation and environmental protection forests, as experimental reforestation projects, since the 1970s at more than 750 sites throughout the 3000 km long Japanese Archipelago, and since the 1980s in parts of South-east Asia, China and South America. The restoration movement has spread from a local activity to a global movement. We aim for the sustainable development of human society through ecological restoration of living environments.

Key words: chinju-no-mori; ecological restoration; native forest by native trees; potential natural vegetation; restoration practice.

Introduction

Natural environments have been devastated and destroyed worldwide by recent rapid development, urbanization and industrialization. It is no exaggeration to say that the basis of human life is now threatened (Miyawaki 1982a,b).

We ecologists have been giving warnings against the devastation of nature through study results, and have produced some good effects. Besides criticism, however, we should contribute to the wholesome development of human society by active concern for nature restoration and reconstruction (Miyawaki 1975, 1981). Species and taxa that have already become extinct because of the destruction of nature are impossible to restore. Plant communities that have been destroyed are also generally quite difficult or sometimes impossible to restore (Miyawaki 2001). Therefore, it is fundamental that existing species and communities are protected and preserved and those that have been destroyed by human impact should be restored and reconstructed. However, the mere deceptive appearance of vegetation restoration should be avoided. It is essential to restore natural vegetation of combined native species in accordance with the potential abilities of the habitat, and to try to restore the whole ecosystem specific to a region (Miyawaki 1992).

Vegetation, a basic component of ecosystems, can often be restored after ecological research and adequate vegetation field surveys, although some systems, like raised bogs, are quite difficult to restore once they are destroyed (Miyawaki & Fujiwara 1970).

Vegetation-ecological restoration has various methods according to its purpose and the objects treated, for example, grassland and shrub vegetation. So-called 'Satoyama' – seral secondary forests or substitute forests – should be restored, and lawn areas can also be constructed for the recreation and refreshment of citizens. However, it is most important to restore and reconstruct natural or quasi-natural multilayer forests, which save the lives of local people, the cultures originating in each district, and gene pools for following generations. They also have diverse functions in disaster mitigation and environmental protection (Miyawaki 1999).

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This paper is about restoration of these natural or quasi-natural forests. We aim at sustainable development of human society and ecological restoration of living environments through reforestation based on field investigations, where we understand the structures and systems of indigenous forests.

Methods

A thorough vegetation field survey is carried out on the objective site. We determine the phytosociological community units of many plant communities in the region from our investigation of the remaining natural vegetation and substitute vegetation. We then represent them onto a map of the actual vegetation. We determine the potential natural vegetation (Tüxen 1956) of the region from the remaining natural vegetation and its relationship to the substitute vegetation there, and draw this onto a potential natural vegetation map. Each unit of potential natural vegetation consists of species combinations. From this we are able to find the main tree species of the native plant communities of the region (Miyawaki 1999; Fig. 1).

We collect and germinate seeds of these tree species. Bare seedlings from the potential natural vegetation are difficult to transplant because they are deep- and tap-rooted. We grow them in pots until their root systems

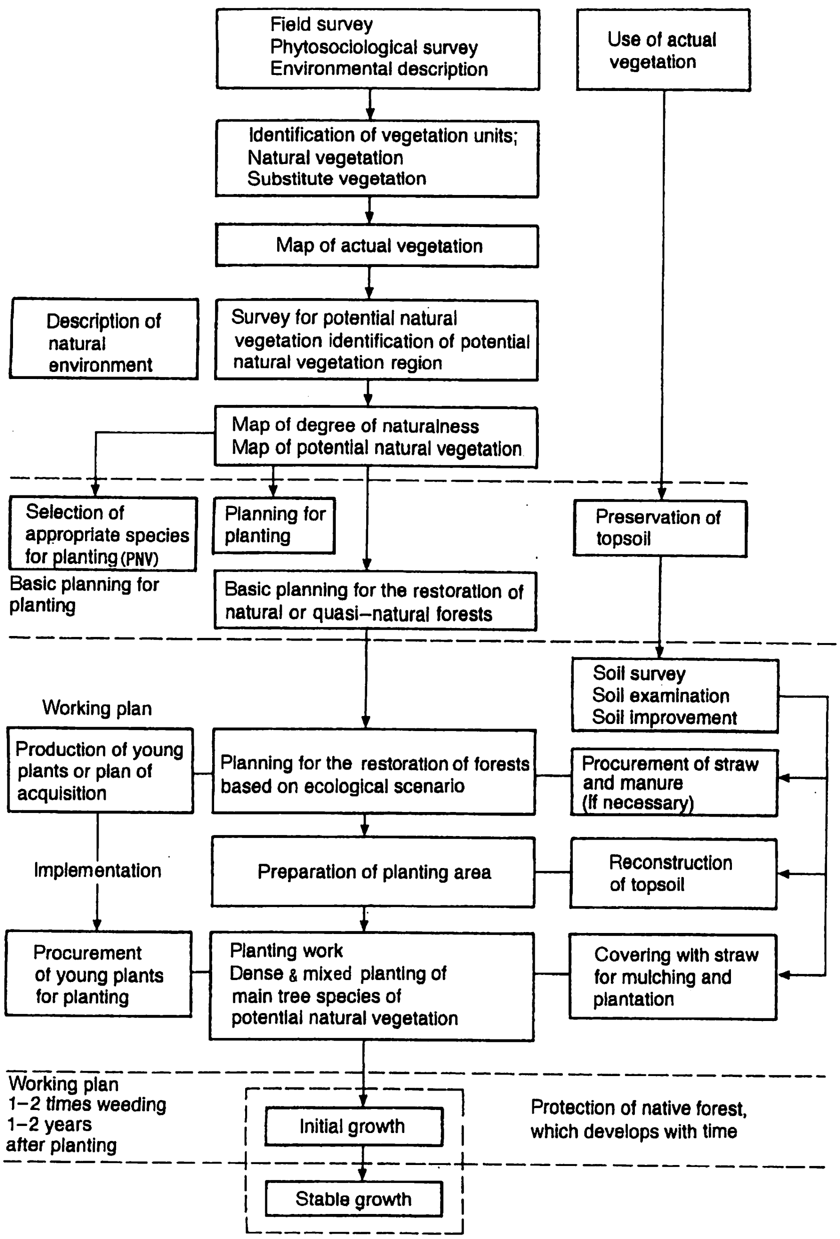

Fig. 1. Flow chart from field survey to restoration of native forests.

fully develop in containers. We prepare as many kinds of potted seedlings of the main and companion species as possible, then mix and plant them densely according to the system of natural forests. After planting we mulch with rice straw and other organic materials. Mulching prevents soil dryness even if it doesn't rain for a month. It prevents soil erosion on steep slopes and even under heavy rainfall. It prevents weed growth. It protects seedlings against cold. It works as manure after materials get decomposed.

In many cases of ecological planting weeding is needed for the first 3 years. Weeded grass should be laid on the forest floor as added mulching. After that there is generally no need for maintenance. Young trees grow steadily through natural selection as time goes by (Miyawaki *et al.* 1993).

Results

Japan

With the field investigation of laurel forests on Amami Island in 1963 (Miyawaki & Ohba 1963), we started field investigations in every vegetation type of Japan, from natural vegetation of remaining forests to farmland and grassland impacted most by humans, with the assistance of Ministry of Education, farsighted local governments and private companies. From the data of investigations we drew actual vegetation maps to show the distribution of local vegetation, and potential natural vegetation maps (Miyawaki 1979, 1990).

For 10 years from 1980, through further field investigations all over Japan, we determined community units of Japan's vegetation, systematized them, and represented them onto actual vegetation and potential natural vegetation maps (Miyawaki *et al.* 1980, 1981, 1982, 1983, 1984, 1985, 1986, 1987, 1988, 1989).

Utilizing actual vegetation maps for diagnosis of the present green environments and potential natural vegetation maps for the scenario of reforestation, we tried to reconstruct forests where native forests were lost. The first company that asked us to reconstruct green environments was Nippon Steel Corporation. We made field surveys around their nine ironworks, determined the potential natural vegetation of each region and restored native forests. Since then we have grappled with the restoration of green environments based on ecological knowledge (Miyawaki 1975).

The number of ecological plantations until February 2003 is 769. The plantation sites range from Hokkaido to Okinawa, from reclaimed land along the sea to a collapsed highway site 1900 m a.s.l. and from the laurel forest (*Camellietea japonicae*) zone to the summergreen broad-leaved forest (*Fagetea crenatae*) zone (Miyawaki 1996, 1998; Fig. 2).

For example, Aeon Group (one of the biggest shopping center developers in Japan) held planting festivals around their 349 new shopping centers all over Japan from 1989 to 2002. The citizens planted 4 257 000 seedlings during these festivals. On the average one person planted 20 seedlings in 1 h. The results of these ecological plantations based on a vegetation-scientific scenario are quite good. Seedlings that were only 30–50 cm high when planted grew to 7 m high after 10 years, higher than 10 m after 15 years, and form so-called antidisaster environment protection forests (Miyawaki 1989a; Miyawaki & Golley 1993).

According to our research, the main tree species of the potential natural vegetation in the *C. japonicae* region are *Persea thunbergii* in coastal areas, *Castanopsis cuspidata* var. *sieboldii* on ridges, evergreen *Quercus* (*Cyclobalanopsis*) spp. including *Q. myrsinaefolia, Q. glauca, Q. salicina and Q. acuta* in inland areas. *Q. gilva* and *Q. sessilifolia* are also the potential natural vegetation south of the Chubu district, Honshu, *Q. miyagii, Q. glauca* var. *amamiana* on Amami, Okinawa, and *Bischofia javanica, Beilschmiedia erythrophloia* in coastal areas of the subtropical zone (Miyawaki *et al.* 1980, 89).

As mantle communities at the forest edge, *Pittosporum tobira, Rhaphiolepis umbellata, Q. phillyraeoides* and others are planted in coastal areas, and *Camellia sasanqua* var. *hiemalis, Gardenia jasminoides* f. *grandiflora* and *Rhododendron* spp. in inland areas. The function of a mantle community along the forest edge is preservation of the forest and beautification by seasonal flowers between the forest and the open landscape (Miyawaki *et al.* 1979; Miyawaki *et al.* 1983; Miyawaki 1997, 1998).

Dense, mixed planting of 30–50 species of the potential natural vegetation is in accordance with the system of natural forests, and enables a multilayer forest to grow after 15–20 years by the peculiarity of planted species. At some planting sites, however, even after ecological dense, mixed planting, adequate natural selection is not seen until 10–15 years after planting and some tall trees have thin stems compared to their height. This problem will be solved in time.

South-east Asia

Since 1978 we have been researching in the tropical rainforest zone of Malaysia, Thailand and Indonesia. The study results show that natural forests were completely destroyed in many areas because of slash-and-burn farming, felling trees and oil palm farming. Slash-and-burn farming over a large area has destroyed every tree within a forest and it takes quite a long time to see a forest naturally restored. Sometimes it is nearly impossible (Miyawaki 1982c, 1989b, 1993).

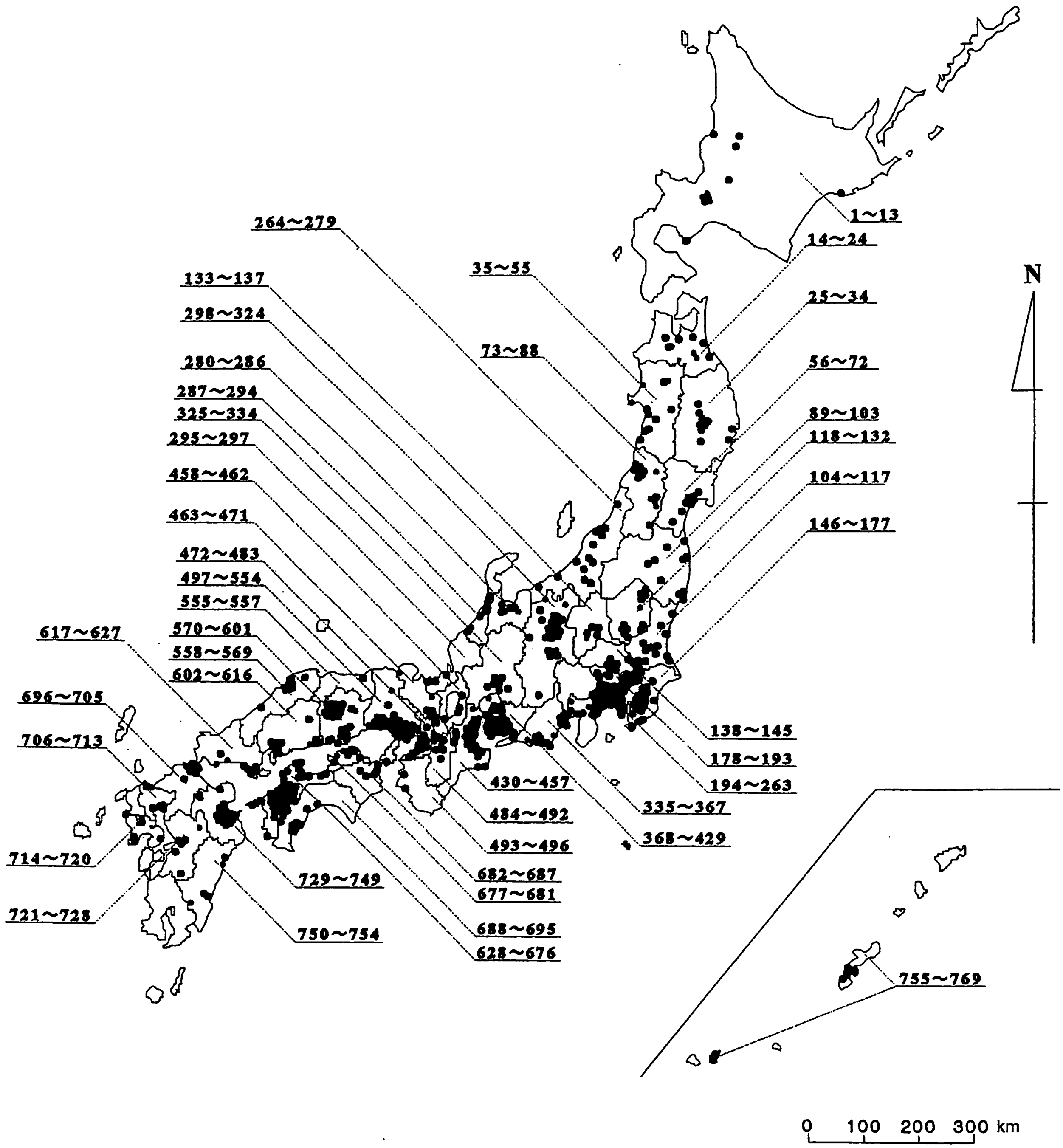

Fig. 2. Location of constructed environment protection, disaster mitigation forests in Japan as of 1 February 2003. Numbers shows each planting spot.

For reforestation on bare land at Bintulu, Sarawak, on Borneo Island, we chose *Hopea* spp. and *Shorea* spp. from the potential natural vegetation, not exotic species, such as, *Eucalyptus* spp. and *Acacia mangium*.

For 10 years we collected seeds of 92 species from the potential natural vegetation including 41 species from *Dipterocarpacea*, cultivated potted seedlings with fully developed root systems, and mixed and planted them ecologically (Miyawaki 1991). Twelve years have passed since the first planting. Through weeding for the first 3 years and solid natural selection after that, seedlings grew steadily into a splendid quasi-natural forest (Miyawaki & Meguro 2000; Fig. 3). Ecological planting is carried out every year with the help of volunteers from Japan and local students and citizens. At present several phases of tree growth can be seen at the sites of 50 ha.

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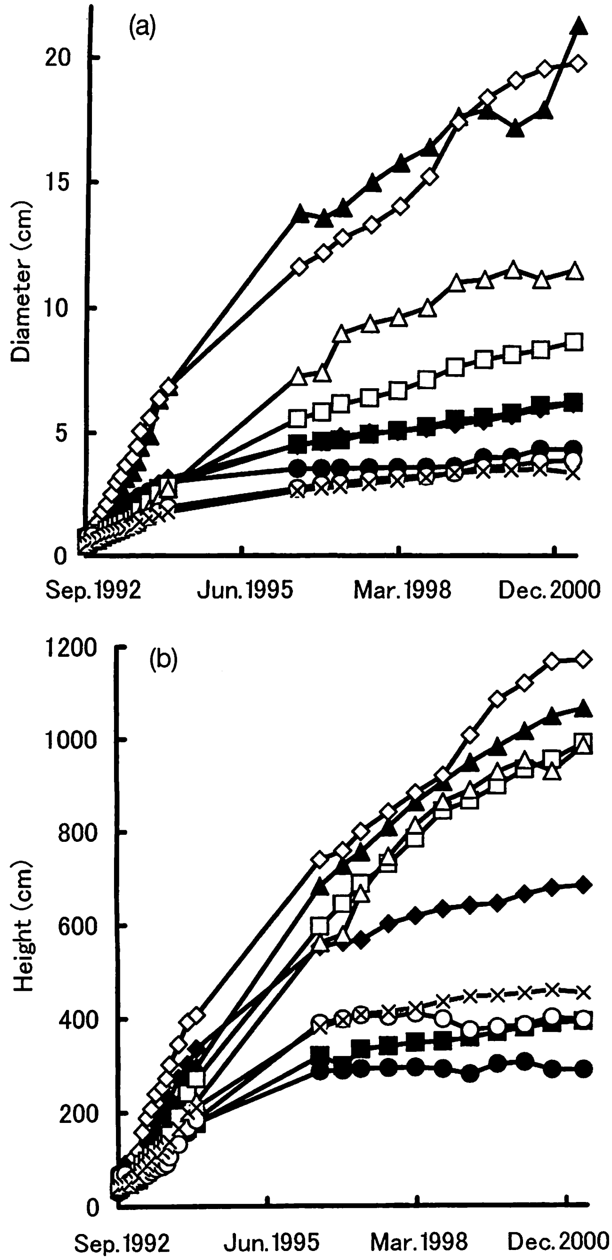

Fig. 3. Growth behavior of (a) tree height and (b) diameter of planted seedlings at Bintulu reforestation site, Sarawak, Malaysia, based on vegetaion surveys (◆). *Baccaurea lanceolata* (4); (■) *Baccaurea macrocarpa* (12); (▲) *Dracontomelon dao* (20); (●) *Eurycoma longifolia* (10); (◇) *Sandoricum koetjape* (20); (□) *Shorea dasyphylla* (92); (△) *Shorea leprosula* (59); (○) *Shorea mecistopteryx* (77); (×) *Shorea ovata* (170). The numbers in paranthesis are those of investigated trees.

South America

For restoration of Amazonian lowland tropical forest, we began field investigations in 1991 around Belêm, Brazil. This area is called 'the green lung of the earth'. We held the first planting festival in May 1992. Every year since then we have been planting seedlings in cooperation with citizens.

Discussion

According to Clements' succession theory it will take 150–200 years in Japan to restore a native forest from barren land and many scientists presume it will take more than 300 years in tropical zones like Borneo and the Amazon (Clements 1916). But a period of more than 100 years is too long for us. Nature restoration in a shorter period is required. We should not stick to the secondary progressive succession.

Field surveys have told us it is not climate conditions but soil conditions that matter. At sites with poor soil, we make retaining walls on slopes to lay soil, organic material and fallen leaves. Bare lands should be covered with as much topsoil as possible. Many planted seedlings are the main components and companions of the potential natural vegetation (i.e. terminal vegetation) not pioneer or intermediate species. We make potted seedlings of these species, with well-developed root systems, and mix and plant them densely following the system of natural forests (Miyawaki 1999; Fig. 4).

In this way we have succeeded in restoring quasi-natural forests in 15–20 years in every region of Japan.

One example of reforestation in South-east Asia is an experimental greening project at Bintulu, Sarawak in Malaysia. Planted seedlings have now grown into a 12–14 m high forest in 10 years. We calculated the wood volume and the amount of carbon dioxide sequestered per year per hectare in the reconstructed forest. We also compared the figures with those of a restored forest on a man-made island, Ohgishima, Japan. The result was that the figures at Bintulu were much higher than in Japan (Miyawaki & Meguro 2000; Fig. 5). Restoration of tropical rainforests is most effective for conservation of the global environment (Miyawaki & Abe 2002).

In Belêm in the Brazilian Amazon, we began field investigations in 1991 and held the first tree-planting festival in May 1992, when the Earth Summit was held in Rio de Janeiro. We planted fast-growing and intermediate species in addition to *Virola surinamensis, Tabebuia serratifolia* and other main tree species of the potential natural vegetation for two reasons. One is that we couldn't carry out adequate vegetation surveys because of a limited preparatory period. The other is that it is an established theory that planting pioneer species is the key to a successful reforestation from bare land. The number of planted tree species was 50 (finally 92).

Fast-growing species like *Balsa; Ochroma pyramidale* and *Boleira; Joannesia princeps* , were 6 m high in 1994, 2 years after planting; 10 m high in 1996, 4 years after planting; and 15 m high in 1998, 6 years after planting. d.b.h. measured up to 20–30 cm. The trees had grown magnificently, and the physiognomy was a quasi-natural forest. However, in the field investigation of

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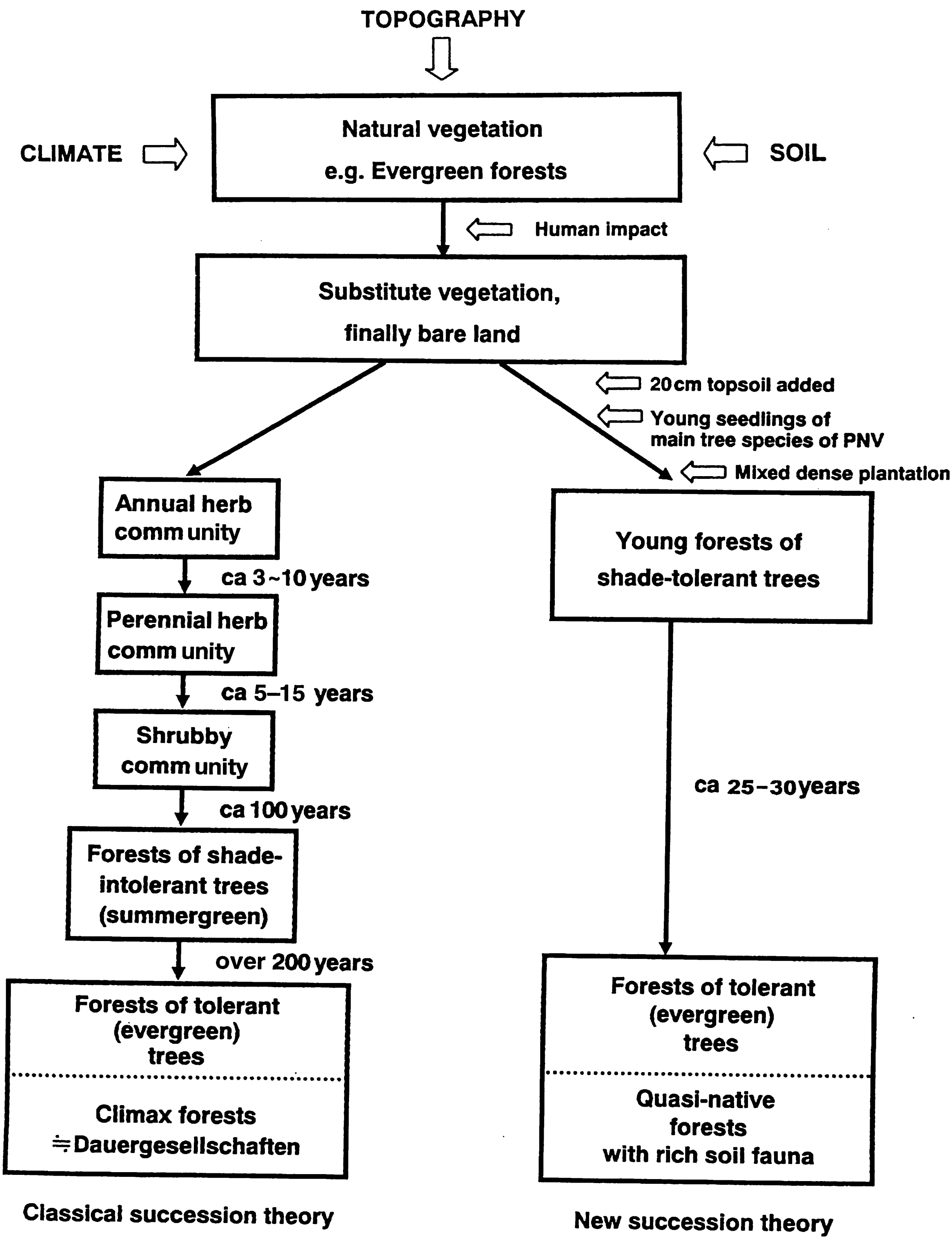

Fig. 4. Comparison between new and classical succession theory in laurel forest area of Japan.

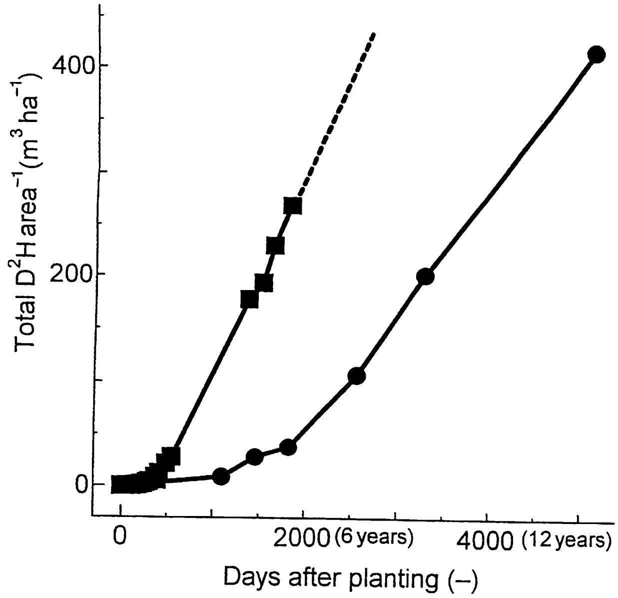

Fig. 5. Volume indicator "D^2H" at a tropical rainforest zone in Malaysia and a laurel forest zone in Japan. (■) Bintulu/Borneo (27.3 t ha^{-1}.y); (●) Ohgishima/Tokyo Bay (16.6 t ha^{-1}.y). $W_S = 0.0396(D^2H)^{0.933}$(kg, cm^2m); $W_B = 0.0060(D^2H)^{1.027}$ (kg, cm^2m); W_S, dry weight of stem; W_B, dry weight of branches; D, d.b.h.; H, tree height.

2000 and 2001, we found that most of them had fallen down although they had not experienced very strong wind. Fast-growing species are shallow-rooted and short-lived. The fallen trees prevented the growth of *Virola* spp. and the other main component species of the potential natural vegetation in the forest. Unfortunately biodiversity there cannot be said to be adequate (Miyawaki & Abe 2002).

For comparison studies we had planted potted seedlings of 14 species only from the potential natural vegetation, including *Virola* spp., on Breves Island, Brazil. They have grown steadily and reached 8–10 m to form a quasi-natural forest in 10 years. We saw great differences in growth between the two sites, Belém and Breves (Miyawaki & Abe in press). As a result, it can be said that restoration of diverse quasi-natural forests in a shorter period is attained from dense, mixed planting of main and companion tree species from the potential natural vegetation, following the system of natural forests with much care for soil conditions. It takes 15–20 years in Japan and 30–40 years in the Torrid Zone (Miyawaki 1999). In 1928, English forest engineers planted trees by trial and error at an experimental forestry site in Ipoh, on the Malay Peninsula. Among the trees they included some main tree species from the potential natural vegetation. Now there is a forest of *Hopea* and *Shorea*. They have succeeded in restoring a quasi-natural forest. This is one example showing that correct selection of tree species is essential.

There may be criticism that planting potted seedlings in a vast area is costly. The solution to this problem is getting local citizens to collect seeds, to make potted seedlings and to plant them as leading participants. We ecologists write scientific scenarios for reforestation. Administrative institutions and private companies work as behind-the-scene directors. This is how we have restored quasi-natural forests in Japan, Asia and South America.

These forests of complex multilayer communities have disaster-mitigation and environmental protection functions in each region. In the Great Hanshin Earthquake, which hit the Kobe district, western Japan in January 1995, there was no damage to trees in Japanese traditional temple forests, the potential natural vegetation, however, huge structures made of non-living materials collapsed, including elevated railways, highways and tall buildings (Miyawaki 1998). On a global scale, natural forests help to avoid global warming by absorbing carbon dioxide. Restoration and regeneration of ecologically diverse forests is inevitable for citizens in every region to survive in the next century, and the next millennium.

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