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Maintenance and Rehabilitation of the Mixed Conifer-Broadleaf Forests in Hokkaido, Northern Japan

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Abstract

Over the last 100 years, a number of forestry and ecological studies have been carried out on the regeneration mechanism of mixed conifer-deciduous broadleaf forests in Hokkaido, northern Japan. We reviewed several studies on the mixed forests concerned with physiological ecology and ecosystem management in relation to the process analysis of natural regeneration. Based on these results, we proposed methods for rehabilitation practices for the disturbed and degraded mixed forests where we cannot expect natural regeneration. In order to rehabilitate those mixed conifer broadleaf forests, a bulldozer with fitted rakes was used to eliminate culm and rhizome of dwarf bamboo (such as *Sasa senanensis* or *S. klirensis*). In order to make plantations, we would also use wildlings of gap phase species regenerated after scarification. However, it is still unclear how many seedlings and what species would be best suited for rehabilitation. A new practical system for restoring disturbed and degraded mixed forests should be established. To ensure the availability of the system, we should analyze the growth characteristics of individual species within the mixed forests as well as the interactions among species in forests of Hokkaido.

Key words: Practical forestry, forest regeneration, sustainable management, growth characteristics, mixed conifer-broadleaf forests

Introduction

Degradation of natural forests in Hokkaido, located in northern Japan, has been accelerating annually, which may be due to anthropogenic activities, such as over-harvesting, air pollution, etc. in addition to the harsh natural environment (e.g. Ito 1987, Matsuda 1993). Despite our advancements in the area of forestry science (Sato 1929, Taniguchi *et al.* 1968, Matsuda and Yajima 1979, Matsuda and Takikawa 1985, Matsuda 1985, 1993, Koike 1991, Shibuya *et al.* 2000), the quality and quantity of our precious natural forests are decreasing.

Many studies have been conducted on the transition from natural mixed conifer-deciduous broadleaf forests to production forests specifically for timber since the 1950s (hereafter, we will call deciduous broadleaf trees, as "broadleaf trees"). However, many man-made forests could not be established because of the harsh physical environment as well as biological problems (Taniguchi *et al.* 1968, Matsuda and Takikawa 1985, Matsuda *et al.* 1999). They need some care if they are to establish themselves. In 1997, the Japanese government signed the International Agreement of Bio-diversity Conservation Program. To achieve this program, we have been establishing species-rich deciduous broadleaf forests in abandoned larch and pine plantations, as well as monitoring the changes in species richness and productivity accompanied by physical environmental changes (Hiura 2001).

From a commercial point of view, market prices of conifers have been lower than those of broadleaf trees, such as ash, oak, Caster aralia (*kalopanax*), Monarch birch and elm (Matsuda and Yajima 1979). We can keep the relatively high commercial value of broadleaf trees, but it is still difficult to produce these broadleaf trees from commercial plantations. Instead, they still come from the natural mixed conifer-broadleaf forests (e.g. Shibuya *et al.* 2000). In an attempt to preserve the mixed forests as a viable natural resource, we should seek reasonable methods of forest management, which encourage biodiversity and forest productivity.

Ecological studies have revealed that mosaic and patch structures are major components of mixed forests (Pickett and White 1985). However, how can we evaluate the contribution of pattern and degree of disturbance on the recycling processes in mixed conifer-broadleaf forests?

To answer this question, we should first look at the community or population approach and lastly the ecophysiological characteristics approach (Bazzaz 1979, Mooney and Gulmon 1983) in relation to tree forms (e.g. Fujimoto 1993). Moreover, we need a reasonable regime of disturbances for assessing the building phase of natural forests after such events. Both natural and anthropogenic disturbances can be defined as a sudden change in the resource base of a unit of the landscape that is expressed as a readily detectable change in population response (Bazzaz

1983).

Naturally, we should more pay attention to conserve our precious natural forests and to rehabilitate the degradation of natural forests by way of practical forestry techniques (e.g. Kikuzawa 1983, Samejima 1985, Sakagami and Ishida 1987, Matsuda 1993, Watanabe and Sasaki 1994, Shibuya *et al.* 2000). Based on these advanced studies, we should improve forestry technology in Hokkaido, aiming at the conservation of mixed conifer-broadleaf forests.

In this report, we try to summarize the methods for rehabilitating natural forests after several types of disturbances and to propose practical methods for conservation of the mixed forests. We followed the nomenclature of Latin names of both tree species and disease names established by Ohwi (1978) and Hayashi *et al.* (1985), respectively.

Mixed conifer-broadleaf forests in Hokkaido

Natural mixed conifer-broadleaf forests in Hokkaido were named by the late Prof. Misao Tatewaki (1955-1957, 1958) as the Pan-Mixed Conifer-Broadleaved Forest that located between the Kuromatsunai-lowland, located in southern Hokkaido, and the southern limit of the Schmidt Line placed on Sakhalin Island and on northeast China (Fig. 1). The Pan Mixed Conifer-Broadleaf Forest is regarded as the transition zone between cool temperate broadleaf forests and sub-arctic coniferous forests. This transition has also been recognized in Western Europe and northeast America (Tatewaki 1958). The mixed forests are considered to be the frontier for broadleaf forest invasion of the coniferous forests after the glacial period (Matsuda 1991).

However, under the global warming situation, it is hard to imagine that the coniferous forest would once

again invade the area dominated by broadleaf trees in temperate regions (Matsuda 1993). We should consider the mixed forests as a transient "climax" (but not the meaning of Tansley's climax) between coniferous forests and broadleaf forest. Because a floristic mosaic created by a variety of disturbances and natural regeneration (Pickett and White 1985, Shibuya *et al.* 1987, Matsuda 1993, 1997, Hiura *et al.* 1998), we should recognize the instability and vulnerability of the mixed forest.

Maintenance and rehabilitation of the mixed forests

Before the immigration of people from southern Japan to the island of Hokkaido, mixed forests maintained a high level of biodiversity and functional activities (e.g. Tatewaki 1958, Ito 1987). In fact, Matsuda and Yajima (1979) revealed that the natural forests of northern Hokkaido were composed of several kinds of trees with specific characteristics of growth, especially their shade tolerance capacity, through an analysis of annual rings and growth pattern of harvested timbers in wood yards. However, settlement activities changed many of the natural mixed forests into plantation or secondary stands.

Selective cuttings have been employed as an acceptable method of non-destructive forest management. After several small harvests, the creation of plantations was attempted but resulted in many poor even aged uniform stands. Unfortunately, those stands are not adequately managed (e.g. improper timing of thinning and pruning) which was partly due to the rapid increase in labor costs and decrease in commercial value of timber.

Interactions among species (e.g. oak-birch, birch-maple, fir-oak-maple, etc.) have been studied from

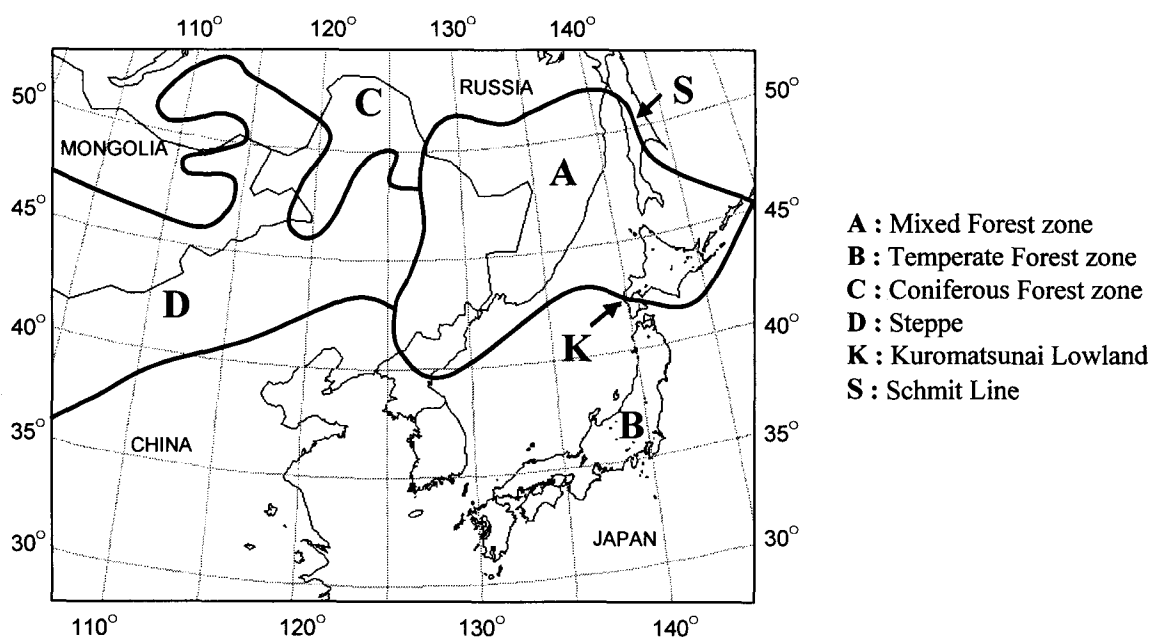


Fig. 1. Location of the Pan Mixed Conifer broadleaved forest named after Prof. Misao Tatewaki (after Ito 1987).

the viewpoint of community ecology (Shibuya *et al.* 1995, Shibuya and Igarashi 1996, Hiura *et al.* 1998). The mixed forests are characterized by a mosaic structure in space, time and species composition (e.g. Matsuda and Yajima 1979, Shibuya *et al.* 1995, Matsuda 1993, Hiura *et al.* 1996, 1998). If we want to construct methods to rehabilitate the disturbed forests, we should know more about the mechanisms of forest succession (Bazzaz 1979, 1983, Mooney and Gulmon 1983) as well as interactions among species, with references to the existence of dwarf bamboo (Hiura *et al.* 1996) and different shade tolerance traits (Shibuya *et al.* 1987, 1996). For example, the growth rate of fir or oak is influenced not by density effect but by the existence of other broadleaf trees or conifers, respectively.

In contrast, the growth rate of maple is independent of guilds of conifers and broadleaf species (Hiura *et al.* 1998). The Maple species (*Acer mono* and *A. mono* var. *mayrii*) is usually accompanied by several other species and sometimes form the middle layer in mixed forests (Shibuya and Igarashi 1996). Shibuya *et al.* (1996) suggested that the co-existence of species might be regulated not only by density dependent interactions but also by chemical interaction among species. To effectively predict the growth of each species, we should know the responses of species in the mixed forests to the timing and severity of natural and anthropogenic disturbances (Bazzaz 1979, Mooney and Gulmon

1983, Higo 1994). Moreover, the ecological role of birds and mammals on reproduction (e.g. Hayashida 1989, Mizui 1993) and seed dispersals in natural forests (Yagihashi 2001) should be analyzed to maintain the mixed forests.

Even though people's expectations of multiple aspects of forest resources are large, the quality and quantity of mixed forests are declining (e.g. Matsuda 1993). We are afraid that our precious forests will be completely destroyed by anthropogenic activities before we can develop adequate technology for forest management. This is our proposal to better understand the condition of mixed forests, and through this knowledge to develop methods to manage or rehabilitate the decaying mixed forests (Fig. 2).

1) Harvesting of mixed forests

It is quite important for us to harvest timber while maintaining secondary forests. While it is true that harvested forests will return to their original condition (Photo. 1) after an extended period of time, it is important to keep some secondary forest activity as close to normal as possible. Furthermore, we need to remember that natural forests are destroyed by anthropogenic activities and over-harvesting. Before we can discuss and propose methods for improving harvested forests, we first need to consider the balance between growth capacity and the harvest amount by selective cutting.

SILVICULTURAL SYSTEMS IN HOKKAIDO UNIVERSITY FORESTS

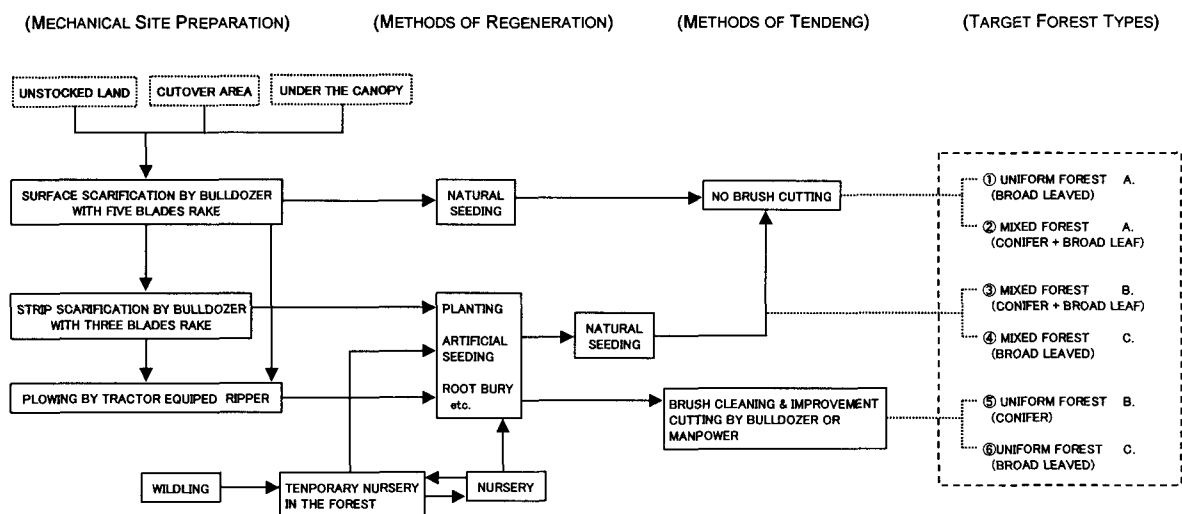


Fig. 2. Silviculture system in Hokkaido University Forests.

Notes: We employ a bulldozer with rakes for site preparation to eliminating *Sasa* bamboo. Between lines of planted firs, bulldozers are again used to press roots and sprouts of invading birch and brush to reduce competition between species. Before plants *P. glehnii* reach the height of surrounding plants, we expect the recovery of small dwarf bamboo to avoid invasion brushes.

It is very hard for us to estimate the true growth rate or increment of mixed forests because of the complexity in space and time (e.g. Matsuda 1993). Even though we have several permanent plots in our Experimental Forests for estimating the growth increment of mixed forests, we still cannot obtain a reliable value. We can, however, harvest a small quantity of timber within the growth volume of the mixed forests. For this purpose, there are several methods for evaluating the growth of natural or secondary forests in central Hokkaido (Shibata 1988,

Yamamoto 1990, Watanabe and Sasaki 1994). Despite this fact, we cannot directly apply these methods to forests in northern Hokkaido because of the differences in topographic, edaphic and biotic conditions.

Generally speaking, the forest floor in heavy snow regions of Japan is usually covered by dwarf bamboo (*Sasa* sp.) (e.g. Ito 1987, Koike et al. 2001). The successful growth of trees in these areas will surely increase after the selective cutting or natural disturbance on the dwarf bamboo (Matsuda and

Table 1. Target forest type with afforestation methods of regeneration and tending.

Target forest type	Mixed forests A	Mixed forests B	Mixed broadleaf forests	Uniform Conifer forests	Uniform Broadleaf forests A	Uniform Broadleaf forests B
Representative species	Fir & oak	Fir & birch	Oak & birch	Spruce	Birch	Kalopanax
Site	Gap phase & under the canopy	Unstocked land 0.1ha>	Unstocked land <0.1ha>	Unstocked land 0.1ha>	Unstocked land 0.1ha>	Unstocked land 0.1ha>
Regeneration methods	Natural regeneration (compensatory planting with seedlings or planting with nursery stock)	Planting with nursery stock (seedlings) and wildlings, seeding, buried roots, natural regeneration	Planting with nursery stock and wildlings, seeding, bury roots, natural regeneration	Planting with nursery stock	Natural regeneration with seedlings	Planting with nursery stock and wildlings, seeding, buried roots
Target species	Fir, spruce, oak & birches	Fir & spruce (nursery stock), oak (seeding), kalopanax (buried roots), magnolia, basswood, Amur cork tree (wildlings),	Oak (seeding), kalopanax (buried roots), magnolia, basswood, Amur cork tree (wildlings), birches (natural regeneration)	Spruce, larch, Norway spruce	Birches at mesic site, willow, alder & oak at valley	Elm & ash (nursery stock), kalopanax (buried roots), oak (seeding)
Method of regeneration		Density of plantation; 800-2000/ha for fir and kalopanax, 800/ha for oak; planting each other	Density of plantation; 800-2000/ha for fir and kalopanax, 800/ha for oak; planting each other	Distance between rows=5m (for bulldozer), planting spruce at 2m, 800/ha, regenerated birch for wild shelter.		Distance between lines=5m (for bulldozer), planting spruce at 2m, 800/ha
Tending methods	No brush cutting, Improvement cuttings or cutting overstory trees	No brush cutting, salvage cutting of birches	No brush cutting, salvage cutting of birches or regulation	Brush cutting, pressing root of invading birch and weeds and expect recovery of dwarf bamboo. One time thinning	No brush cutting, density control with bulldozers after 10-20 years of plantation	Brush cutting, pressing roots of invading birch and weeds and expect recovery of dwarf bamboo
Notes	Oak and conifers will be mixed together under slightly shaded conditions. In contrast, birches usually will dominate at exposed sites. In principle, natural thinning can be expected in birch stands.	Planted fir should be mixed with the other species. Todo-fir will avoid from Scleroderris canker by broadleaf trees.	Mixing with several species with time. Density regulation should depend on natural thinning.	This method applies to shade intolerant species. Less labor required with low density planting. Invading birches will act as wild shelter and protect planted trees with shallow root systems.	Density control will be needed for regenerated mountain birch. However, cutting seedlings will have no effect because of suckering. Pressing on roots of invaded species with bulldozer to regulate density.	Mosaic forest type is ideal. If stand size is large enough large, we plant several species. Brush cutting will be carried out depending on the recovering of dwarf bamboo or brush.

Species

Common name	Latin name	Common name	Latin name
Fir, Todo-fir	<i>Abies sachalinensis</i>	Elm	<i>Ulmus davidiana</i> var. <i>japonica</i>
Spruce	<i>Picea glehnii</i>	Ash	<i>Fraxinus mandshurica</i> var. <i>japonica</i>
Norway spruce	<i>Picea abies</i>	Kalopanax	<i>Kalopanax pictus</i> = <i>K. septemlobus</i>
Birches	<i>Betula platyphylla</i> var. <i>japonica</i> , <i>B. ermanii</i>	Basswood	<i>Tilia japonica</i> , <i>T. maximowicziana</i>
Alder	<i>Alnus hirsuta</i> , <i>A. japonica</i>	Magnolia	<i>Magnolia obovata</i> = <i>M. hyporeuca</i>
Willow	<i>Salix</i> spp.	Amur cork tree	<i>Phellodendron amurense</i>
Oak	<i>Quercus mongolica</i> var. <i>grosseserrata</i>		

Yajima 1979, Pickett and White 1985, Yoshida 2002). However, if the light conditions of the harvested area are advantageous for the growth of dwarf bamboo, the area will be immediately occupied by dwarf bamboo (e.g. Koike *et al.* 2001). As a result, the number of regenerated seedlings does not increase rapidly because the natural regeneration on the forest floor is inhibited by the invasion of dwarf bamboo (Photo. 2). Therefore, practices of only selective cutting do not promote the conservation of natural forests.

2) Forest rehabilitation for several species of trees

The key points of forest management for the conservation of mixed forests are how many trees can be harvested, the interval between harvests and finally how we can manage the forests. If we wish to keep the mixed forest on Hokkaido, we should introduce practical methods for accelerating natural regeneration of trees. Based on our field studies, we propose a system for accelerating natural regeneration in the mixed forests, as shown in Figure 2. This system is characterized by the presentation of a target forest type in northern Hokkaido, Japan.

At first, we introduced big forestry machines in anticipation of the expected natural regeneration (Matsuda 1993, Shibuya *et al.* 2000). It is quite effective to use a bulldozer fitted with upward-warped rakes to eliminate rhizomes and culms of dwarf bamboo, i.e. *Sasa* sp. Using bulldozers in forests drastically help reduce the labor of site preparation and scarification (Photo. 2,7). The depth of soil layer with organic matters under dwarf bamboo is deeper than other sites (Ujiie 1985), which may allow us to use bulldozers into the *Sasa* sp. dominant forests. However, this technique has not been established because we still cannot overcome the danger of erosion caused by using a bulldozer on steep slopes. At present, we apply this technique for site preparation at sites where are either flat or only gentle slopes.

In forests facing the Sea of Japan (or East Sea), we are faced with a different problem. During winter the heavy snowfall, as much as 2.0-5.0 m, causes the bending of tree trunks, as well as the induction of fungi of *Rhacodium* sp. or *Phascidium* sp., which causes "damping off" disease in seedlings (Hayashi *et al.* 1985) (Photo. 3). However, we usually harvest trees at the end of a heavy snow season (snow changes to "compact snow") because we can protect regenerated seedlings under the snow against disturbances caused by cutting and harvesting trees. We have also introduced an unique method of using a bulldozer to create seedbeds on relatively steep slopes to aid natural regeneration (Takahata *et al.* 1989). Since the one track of the bulldozer runs on snow, the amount of soil eliminated by the blade of a bulldozer is small (Photo. 4a, 4b), which helps to conserve the forest floor.

It is also important to consider the methods used in

scarification. The question is how much soil shall we eliminate by using a bulldozer for promoting natural regeneration? The successful regeneration of the birch species requires the scaring of only the topsoil, while others species require a different level of scarification. It is therefore very important to decide the degree of scarification in regards to the target tree species (Takahata *et al.* 1989, Watanabe and Sasaki 1994). Matsuda (1993) proposed a forest management system for managing the mixed forests that can be seen in Table 1. For the successful regeneration of forests, we need to know more about the regeneration and growth characteristics of representative tree species.

Regeneration and tending methods of representative species

Fir (*Abies sachalinensis*):

The natural distribution of the fir is located on the southern tip of Hokkaido to the north (Ito 1987). This species makes up a large percentage of the mixed forest and shows a large shade tolerance on the forest floor (Matsuda and Yajima 1979, Sakagami and Fujimura 1981, Matsuda and Takikawa 1985) and relatively well in the success of natural regeneration at uprooted mound under hydric sites. For more than 60 years we have been using this fir as major plantations species (Taniguchi *et al.* 1968) because the fir is endemic to Hokkaido and the surrounding area. Additionally nursery practices are relatively better for producing seedlings when compared with the production of seedlings of *Picea jezoensis*, a major conifer species in Hokkaido. The genetic background of the fir was studied in relation to its geographical differentiation, timing of bud sprout and structure (Okada *et al.* 1973), and it was found that we cannot use the fir seeds originated from heavy snow areas in eastern Hokkaido where they have little snow with winter desiccation. Moreover, wood of fir contains high moisture in xylem, which usually induces crack during winter below ca. -20°C (Ishida 1986). The cracked parts will be covered by the cured tissue as if its shape were "snake" (Photo. 5).

We have planted this fir with enough growing space and have created even aged stands. However, the fir should be mixed with other species because of its high shade tolerance capacity (Shibuya *et al.* 1987, Matsuda 1993, Hiura *et al.* 1996). For example, we firstly plant fir, and then birch species (*Betula ermanii*, *B. platyphylla* var. *japonica*) will invade into the open space between line-planted firs, and will form mixed stands of the two species. The diameter growth of a fir in this type of stand was slightly smaller than that of a fir plantation with continuous tending or brush cutting. This fir has a relatively high susceptibility to *Scleroderris* canker (caused by *Scleroderris lagerbergii*) (Hayashi *et al.* 1985) (Photo. 6). However, when the fir was mixed with mountain birch (*Betula ermanii*), the occurrence of this disease

was minimized (Fukuta *et al.* 1990).

Spruce (*Picea glehnii*)

Akaezo-spruce (*P. glehnii*; hereafter we call this as spruce) plantation areas have increased in recent times, this may be a result of improved nursery production compared to that of Ezo-spruce (*P. jezoensis*) (Matsuda 1989). It is difficult for us to produce seedlings of Ezo-spruce in nurseries because the aphid (*Cimara bogdanowi*) usually attacks and forms galls on the shoots of this species (Hayashi *et al.* 1985). Ezo-spruce can regenerate with highly use of micro-topography (mound and pit) in natural forests (Natsume 1985). The pit may be act as a safe site for regeneration without *Racodium* sp. (Photo. 3a).

The buds of the spruce sprout 2 to 3 weeks later than those of the fir (*A. sachalinensis*). Based on the phenological trait of several kinds of spruce collected through the world, we usually employ the spruce as an afforestation species in areas where spring frost damage usually occurs in plantations of the fir. The spruce is classified as a light-demanding conifer, especially in its younger stages (Sakagami and Fujimura 1981, Matsuda 1989, Kayama *et al.* 2002). This spruce can grow in wetland areas, rocky areas, serpentine soil etc. and can sometimes form a uniform stand (Matsuda 1989, Kayama *et al.* 2002). It is therefore possible to make a plantation with even aged trees using this spruce.

With the increasing age of man-made spruce (*P. glehnii*) forests, we need to pay special attention to the damages caused by strong winds, as well as the period after an outbreak of insects, which may be related to the shallow root system of the spruce (Matsuda 1989, 1993). Moreover, bark beetle (*Ips typographus japonicus*) usually attacks damaged spruce caused by strong wind or suppressed by bulldozer at harvesting timbers and tending forests. Therefore, we plant spruce seedlings with enough growing space (5m between lines and 2m intervals of seedlings, at least) in order to promote the developing of root system. We employ a bulldozer with upward-warped rakes for site preparation to partly eliminate dwarf bamboo (Photo. 7a, b). Between the lines of planted spruces, bulldozers are again used to press the roots and sprouts of invading birch and weeds for reducing interspecific competition. Before planted seedlings of the spruce reach the height of surrounding plants, we expect the return of dwarf bamboo because we wish to avoid the invasion of birches and big herbaceous plants. But at the same time, we also need the invading birch to act as shelter against wind damage. Optimum density of the plantation of this spruce is estimated to be ca.800 ha⁻¹ with a little thinning.

Birch species (*Betula platyphylla* var. *japonica* and *B. ermanii*)

With the exception of Monarch birch (*B.*

maximowicziana), the two birch species, i.e. white birch (*B. platyphylla* var. *japonica*) and mountain birch (*B. ermanii*) are typically light demanding pioneers whose commercial value is low (Koike 1988, Mori 1991). Although Monarch birch is also a light demanding species, the commercial important species, the birch usually lives to be 200-300 years old and is one the composers of the mixed forest and produces high quality timber (Matsuda and Yajima 1979, Yamamoto 1990, Mori 1991). Recently, white birch has become a candidate species for producing tree sap for drinking, which is expected to be a management method of non-destructive forest use (e.g. Terazawa 2000, Shi *et al.* 2001).

However, once the birch species has invaded an open area (Photo. 2, 8), like the dwarf bamboo, the natural regeneration of commercially important species, such as oak, elm, kalopanax, ash and Ezo-spruce will be hardly expected. Therefore, we should manage and control the density of birches (Shibuya 1994, Shibuya *et al.* 2000) by using bulldozers with a blade or rakes to promote the regeneration of trees other than birch (Matsuda 1993).

Representative species (*Quercus mongolica* var. *grosseserrata*, *Kalopanax pictus*, *Fraxinus mandshurica* var. *japonica*, etc.)

How can we promote the successful regeneration of commercially important species? We should pay attention to their growth traits, such as reproductive characteristics, light demanding traits, competitive abilities etc. based on both field surveys (e.g. Taniguchi *et al.* 1968, Matsuda and Takikawa 1983, Higo 1994, Matsuda 1993, Kurahashi *et al.* 1997, Takahashi 1997) and experimental studies (Sakagami and Fujimura 1981, Takahashi 1981, Koike 1988, 1990, Seiwa 1994).

We successfully obtained seeds from candidate elite trees in the Uryu Experiment Forest of Hokkaido University using a truck crane (Matsuda 1985). We will be able to obtain seeds of commercially important species using this method (Photo. 9). Our partial understanding of the role of bird-mediate seed dispersal system in the regeneration process allows us to propose a method of forest management (Yagihashi 2001).

The following notes outline the silviculture method for establishing plantations of each species:

4.1 Oak: We can create a plantation of oak (*Quercus mongolica* var. *grosseserrata* = *Q. mongolica* var. *crispula* or *Q. crispula*) by planting acorns. However, depending on the oak species the amount of acorn production can vary greatly from year to year, i.e. the masting year (Sano 1988, Mori 1991). Moreover, the germination capacity of the acorn is very sensitive to its moisture content, and the critical value is around 40% of the oak acorn's dry mass (Tamari 1980, Mori 1991). How can we store the acorns of the masting year to keep their high survival rate and germination

capacity? We have been testing several methods to preserve acorns of the oak (Mizui 1993). Coating the acorn with wax is one of the reliable methods for keeping its vitality. We also examine the methods for creating mixed stands of the oak with *A. sachalinensis* and other broadleaf tree species in nature.

4.2) Kalopanax: The germination capacity of kalopanax (*Kalopanax pictus* = *K. septemlobus*) is relatively low. Seed dispersal of this species is tightly dependent on the activity of birds (Mori 1991, Yagihashi 2001). On the other hand, propagation of *K. pictus* is easily carried out by its roots. In order to assist propagation, we obtain seedlings 30-40cm tall from forests and cut their roots in ca. 10cm, then we bury the cut roots in soil. Using this method the nursery will obtain many seedlings. However, we still have little information on the suitable site for making plantations with *K. pictus* obtained from root propagation (Matsuda 1993). We also expect this species to be utilized for medical purposes in the future (Lee *et al.* this volume).

4.3) Ash, elm, magnolia, Amur cork tree and basswoods: We can successfully produce seedlings of ash (*Fraxinus mandshurica* var. *japonica*) and elm (*Ulmus davidiana* var. *japonica*) in a nursery and use them for creating plantations. However, seedlings of magnolia (*Magnolia obovata* = *M. hyporeuca*), basswood (*Tilia japonica*, and *T. maximowicziana*) and Amur cork tree (*Phellodendron amurense*) are obtained from wildings cultivated in a nursery to develop their roots because of wide variations in the masting year (Sugata and Kamata 1988).

Further considerations

Natural forests are generally characterized by their heterogeneous canopy structure and species composition (Bazzaz 1983, Pickett and White 1985). Regenerated seedlings will grow and survive under shady conditions for a long time, especially fir (*A. sachalinensis*) that can last more than 30 years (Matsuda and Yajima 1979, Yajima 1982). Regenerated seedlings would be suppressed by two factors; the overstory or middle layered shrubs and the low branches of the overstory trees. Once the canopy-gap has formed, seedlings will begin to grow after some lag. The reason may be partly understood by the poor root system caused by shady conditions, and the reliance of leaves in the bud state on light (Koike *et al.* 1997).

According to photosynthetic responses of seedlings and saplings to light flux (Koike 1988), a similar pattern was detected in both typical early successional and late successional species. High flexibility in photosynthetic traits was found in early successional species (Bazzaz 1983). However, gap phase species, such as ash, kalopanax and magnolia, change their photosynthetic responses to light flux from the low light utilization in the seedling stage to the high light utilization in the sapling stage (Koike

1991, Koike *et al.* 1998). Therefore, we should create open space for the regenerated seedlings of gap phase species before they reach the bottom of the big branches of the canopy trees (Yajima 1982, Ishizuka *et al.* 1989, Ishizuka and Kanazawa 1989). Light demanding type species usually show conical shape while shade tolerant species have mono-layered crown (Fujimoto 1993). We can distinguish successional traits of trees by their tree form.

Of course, we should make forests from the viewpoint of conservation biology, especially pay attention to the activities of all living lives (e.g. Hayashida 1989, Mori 1991, Mizui 1993, Hiura 2001, Yagihashi 2001).

In conclusion, disturbed mixed forests cannot usually rehabilitate themselves through natural regeneration (Matsuda 1993). If we wish to recreate mixed forests, we should use wildings regenerated after scarification to create plantations. However, it is still unclear how many seedlings and what kinds of species we shall use for rehabilitating disturbed forests. We should establish a new practical system for restoring disturbed and degraded mixed forests. In order to make this system as efficient as possible, it is important to analyze the growth characteristics of individual species of the mixed forests as well as the interactions between them.

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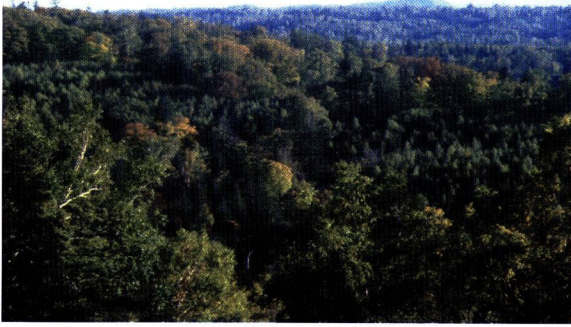


Photo. 1. A view of natural mixed conifer-broadleaf forest as an original condition (at Uryu Exp. Forest).

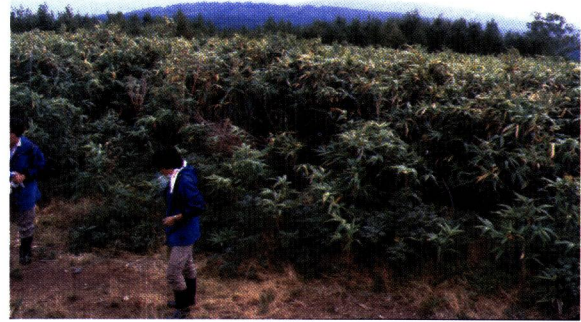


Photo. 2. Dense of dwarf bamboo vegetation invaded into forest floor after intensive logging. Height of men is ca. 170cm.



a

Photo. 3. *Rhacodium* sp. or *Phascidium* sp., which causes “damping off” disease in seedlings

a: *Picea jezoensis* in nursery, (photo by K. Tanaka)

b: *Abies sachalinensis* in new plantation

(photo by Y. Sakamoto)



b



Photo. 4. Making seedbeds on mountainous slopes during snow season. The amount of soil eliminated by bulldozer is small which helps to conserve forest floor.



Photo. 5. The cracked parts of a fir will be covered by the cured tissue as if its shape were “snake”



a



b

Photo. 6. Scleroderris canker caused by *Scleroderris lagerbergii* in snow (a). (photo by S. Matsuzaki)
A view of damaged seedlings after snow melt (b).

a



b



Photo. 7. We employ a bulldozer with upward-warped rakes (a) for site preparation to partly eliminate dwarf bamboo and litter with microorganisms (b).



Photo. 8. Birch species has invaded an open area like the dwarf bamboo.



Photo. 9. Collection of seeds of commercially important species using a crane car.