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Articles

Article

Analysis of Present Situation and Issues on Management Types of Suburban Forests in China -A Case Study in Shenyang- *1

Qingwei Guan*2, Shiquan Li*3, Mark Ryan*4, Masato Katoh*4 and Tatsuhito Ueki*4

ABSTRACT

The Forest Classification Management Policy (FCMP), which is one of the most important policies in China, has been implemented for several years, but some problems related to the policy have not been solved yet. In order to provide some available forest management practices for the implementation of FCMP in China, especially in the metropolises, Forest Resources Survey data and plot investigation data were employed to analyze the forest resources change and stand structure of the different management types in Shenyang city. The results showed Laoshigou Forestry Farm are managed as environmental conservation type, Qipanshan Scenic Forest are recreational forests type and artificial forests of Magang town are employed to produce timber, of which they are located in Shenyang suburbs. The results also showed that the composition of stand age class, dominant trees, coniferales and broadleaf and growth of stand area and stock are different, because different management measures were implemented, though the three investigation sites were at approximate growth and site index 30 years ago, the forest cutting and pasture were banned in Laoshigou Forestry Farm, the secondary forests were recovered by natural regeneration, multi-storied and mixed forests were brought out. This provides strong supports for the management of Public Welfare Forests in Shenyang according to the FCMP. Stand densities in Qipanshan Scenic Forest are very high, because they were transferred from timber forests to recreational forests. The effective scenic thinning for transformation from artificial forests to recreational forests should be employed in Qipanshan Scenic Forest in order to improve forest amenity. Timber forest management in Magang town was characterized with short-term cutting. We suggest that the intensive thinning, which had been identified effectively for increasing wood production in Japan, be introduced to Magang town.

Keywords: China, conservation forest, recreational forest, suburban forest, timber forest

INTRODUCTION

Accompanying economic system reform, especially in light of the implementation of the new market economy system, the Chinese economy has enjoyed outstanding growth. According to the National Statistics Bureau, the GDP had exceeded 1,000 billion USD in 2002, the average GDP growth rate in recent years is over 7%, which is the highest worldwide. (National Statistics Bureau P.R. China, 2003). Due to this rapid economic growth, wood consumption has also been on the increase. In 2002, Chinese domestic wood consumption was about 140 million m^3 including 20 million m^3 of imported material. Consequently, due to this increase in domestic cutting, a number of environmental problems have come about. A large scale flood that happened in the China in summer 1998, which were amplified by over cutting. Since then, cutting in natural forest has been forbidden, and

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correspondingly, timber production has decreased by 20% in recent years (STATE FORESTRY ADMINISTRATION of P.R. CHINA (SFA), 2003). This implies the gap between timber demand and timer production has been widening. The problem of how to balance the increasing wood need and decreasing wood production become an important challenge for the Chinese government. However, the Chinese 5th Forests Resources Census data showed that the Chinese forest cover is only 16.6% of the which is much less than 27% of the world average level. Forest area and stock per capita are also less than the world average level. Further more, the young forest stands, which are below 40 years old in age, make up about 75% of total forest stand. (SFA, 2003). Forest areas those are available for cutting become less and less. Present forest resources are not adequate to serve necessary environmental function and timber production. This situation is more than adequate argument for government to take a pro-active policy approach to increase and conserve forest resources in an effort to quell difficulties brought about by the current situation.

In order to maintain the ecological and social function of forests and to improve wood production, the Chinese government instated rule making called the Forest Classification Management Policy (FCMP) in 1998. Under this policy, forests were to be designated as either of two types: Public Welfare Forests (PWF) and Commercial Forests (CF). The PWF is mainly used for water conservation, combating desert, protection of designated heritage areas and so on. The central and local governments manage and invest in the PWF. Its cutting is strictly limited and even prohibited in some natural forests areas such as the upper reaches of Changjiang River and Huanghe River, etc. The CF is utilized for raising timber, fruit and other forest products. Its investment mainly comes from individuals and corporations, and managed by the same.

As to theoretical base of FCMP, policies makers believed that forests can support production of tangible items like wood products as well as intangible products such as oxygen production and water conservation benefit. According to the policy, forests should be divided into 2 categories based on their major management purposes. But some people thought this theory was contradictory with forests sustainable management theory because it failed to consider the forest as a whole. The theory heavily weighted timber production yet neglected that forests are multi-functional in nature and had ecological, economic social benefits (CHINESE SOCIETY of FORESTRY, 1999). Under the system categorization was over-simplified, and did not address the idea that forests need to maintain their functions and services.

Some foreign experiences had provided support for FCMP, such as that of New Zealand. There, forests were classified into 2 categories, commercial forests and public benefit forest. The commercial forests, which include 18% of all forest area, was not only able to produce enough timber to meet all national needs, but also to be exported to the other countries. Regardless of these positive indications, it is necessary to evaluate if the system of forest categorization used in New Zealand is applicable to the situation in China or not. (JIANG, 2002).

Up to the present, forest classification management of 14 prefectures has been completed in 32 municipalities and autonomous regions of China. The results regarding Liaoning and 3 other prefectures showed variation between prefectures for both categories. The average percentages of PWF and CF took up 46% and 54% of all forest respectively. However, according to category criteria of Forest Law, the area of shelter forest and special use forest, which were managed similarly as PWF, took up just 16% of all forest area, much less than the percentage of PWF. On the contrary, the area of timber forest, economic forest and fuel forest, which were managed similarly to that of CF, accounted for 84% of all forests. This implies that 10.7 million ha of timber forest, economical forest and fuel forest should be transferred to PWF in the 4 prefectures under the FCMP. The results of forest classification management in Shenyang were showed the same trend as above 4 prefectures, in which 61.5 thousand ha of timber forest and economic forest should be transferred to the PWF. (GUAN *et al.*, 2004)

Though this policy was implemented for several years in China, there are some problems need to be solved, such as how to guarantee the investment for the management of PWF, the most important issue is how to transfer timber forests to PWF by appropriate management practices, especially in the metropolises in which the people have strong needs for the PWF.

The objective of this paper is to provide some available forest management measures for implementation of the FCMP in the metropolises. Forest Resources Survey data and plot investigation data were employed to analyze the forest resources change and stand structure of the different management types in Shenyang city, China.

STUDY SITES AND METHODS

Shenyang is the largest metropolis in the northeastern China with a total population of 6.8 million including 4.8 million urban residents. It is located in the south of northeast of China between the east longitude 122°25'-123°48' and north latitude 41°11'-43°2', covering an area of 12,980km² that include 3,498km² urban area. The annual precipitation in Shenyang is 561mm, making it an arid or semi-arid climate zone. It is situated between the Changbai Mountain and Bohai, on the alluvial plains of the Liaohe and Hunhe Rivers, mostly covered by plain, mountains and hills are centered in the southeastern portion. Its average altitude is about 50m above sea level. Shenyang government controls Shenhe etc. 5 districts that are located in the proper, Xinchengzi etc. 4 districts that located in the suburbs and Xinmin etc. 4 counties that are situated in the rural areas.

The study sites are Laoshigou Forestry Farm, Qipanshan

Scenic Forest and Magang Town, all of which are neighboring and located in the Xinchengzi district, Shenyang city (Fig. 1), and all of which consist of a majority of artificial forests with the similar growth and site index. Most of them are hills, the highest altitude is 447m above sea level, which is located Laoshigou Forestry Farm. The annual average precipitation in this area is 600mm, which is higher than that of Shenyang' average level.

In order to understand the change of forest resources, Forest Resources Survey was conducted for every 10 years in Shenyang. About 60,000 compartments were divided in Shenyang including about 1,200 compartments in the study sites according to the growth and site index and administrative division etc. During the Forest Resources Survey, forest type, tree species, tree height, diameter at breast height, forest age, gradient, soil type, vegetation type and others were investigated in each compartment using one plot of 25m×25m in area that was decided in each compartment. The stand stock, composition of tree species and age class etc. of each compartment were calculated according to the data got from the plots.

The Forest Resources Survey data conducted in 1993 and 2002 in Shenyang were used to analyze changes and present situation in forest resources, and to identify the available management practices for the implementation of the FCMP in the study sites in which different management practices were implemented with different management purposes. As the proportion of artificial forests in area is much higher than that of the secondary forests, and some of artificial forests will be transferred PWF according to the FCMP, plot investigations of stand densities in the artificial forests between different age classes were employed to explain stand structure and to identify the thinning strength in the study sites.

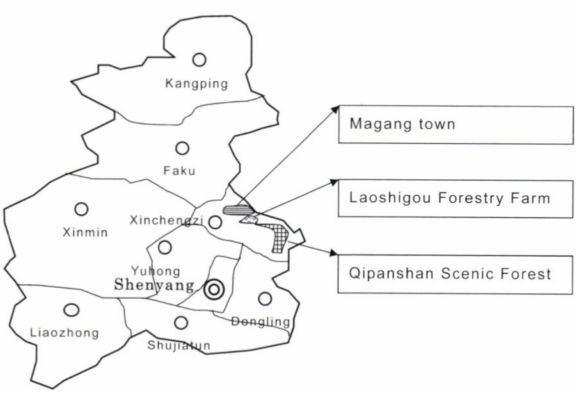

Fig. 1 The investigation sites in Shenyang

RESULTS AND DISCUSSION

The Management Purpose of Study Sites

Forty years ago, the 3 study sites were public forests and administered by the Xinchengzhi District Government of Shenyang City. In 1970, 740ha of forestland of Magang Town were put under the administration of the Committee of Communist Party of Shenyang, and the Laoshigou Forestry Farm was built. After that time, forest cutting and pasture were banned. As a result, forests were recovered to a near natural condition, which is similar to forests management approach that is named the Regenerate Forests by Closing Mountains (RFCM) in China. Now it had become conservative areas for biodiversity in Shenyang, of which the forests have been managed as conservation forest type.

In 1980, sections of forests of Magang and 3 other neighboring towns were put under the administration of the Qipanshan Management Committee with the goal of realizing recreational opportunities in the newly formed Qipanshan Scenic Forest, in which forestland areas reached to 3,698ha. After that time, the forests of Qipanshan had been managed as recreational forest type.

With the change of forestland ownership, the forestland areas of Magang Town were only 1,857ha by 2002, they were managed to produce timber continuously, of which about 3,000m^3 of timber was cut annually, considered as timber forest type.

The basic information of 3 study sites was showed in Table 1.

Forest Management and Resources Change in Laoshigou Forestry Farm

Since the Laoshigou Forestry Farm was founded in 1970, most forests were the secondary forest with low stand stock

Table 1 The basic information of 3 investigation sites

District	Area (ha)	Population (person)	Forest land (ha)	Forest area (ha)	Stand area (ha)			Forest cover (%)
					sub-total	artificial forest	secondary forest	
Laoshigou Forestry Farm	981	60	740	695	658	410	248	71
Qipanshan Scenic Forest	4,242	64,000	3,698	3,411	3,411	3,284	127	81
Magang Town	4,809	15,000	1,857	1,409	1,409	1,409		37

Note: Forest land means that land is ultilized as forests according to the national land ultilization planning. Forest area means that the area of forest land had been covered with forests and density. Forest management hardly employed before 1980's but forest fire protection and banning pasture and forest cutting including fuel forest cutting. After 1990, the artificial forests were implemented at a scale of 10ha in a year, the major tree species is Japanese larch (*Larix leptolepis* GORD.). The artificial forest density is from 2,500 trees/ha to 3,000 trees/ha. Some decayed trees were eliminated in order to avoid the occurrences of forest pests and disease. It can be thought the forests were recovered by natural regeneration without any artificial interference.

Now the forests stand is very similar to natural mixed forests with many kinds of trees including native coniferales, such as Chinese pine (*Pinus tabulaeformis* CARR.), and broadleaf trees, such as Mongolian oak (*Quercus mongolica* FISCH.), Amur linden (*Tilia amurensis* RUPR.), Korean ash (*Fraxinus rhynchophylla* Hance), Manchurican linden (*Tilia mandshuria* RUPR.), Chinese hawthorn (*Crataegus pinnatifida* BUNGE), Amur grape (*Vitis amurensis* RUPR.), Siberian Filbert (*Corylus heterophylla* FISCH.), European birdcherry (*Prunus padus* L.) etc. The plot investigation data showed the basal area at breast height of Mogolian oak took up about 79% of all plot basal area, while the amount of trees of Mongolian oak were 61, which made up 41% of all trees in the plot. It was obvious that the Mongolian oak was the dominant species in the Laoshigou Forestry Farm.

The data of diameter distribution of Laoshigou Forestry Farm showed a typical L type distribution (Fig. 2), same as the diameter distribution of multi-storied and mixed forests. But as to the dominant species of the natural mixed forests, Mongolian oak, their young trees' proportion, which diameter at breast height is below 10cm,is lower 3%, this implies it is very important that how to prompt the proportion of Mongolian oak' young trees by management measures, in order to maintain their dominant species (TANAKA, 2002).

As to the forest resources change in the Laoshigou Forestry Farm, the Forest Resources Survey data employed in 1993 and 2002 showed the stand areas only were increased 6ha. However, the stand area in age of over 30 years old reached 46.8%, were increased 12.4%. The stand stock increased 9,400m³, which the stand stock in age of 30 years over reached 65.1%, were increased 15.4% during the 10 years (Fig. 3). The proportions of stand area and stock between the coniferales and broadleaf trees were not changed basically. They can be seen in the Table 2.

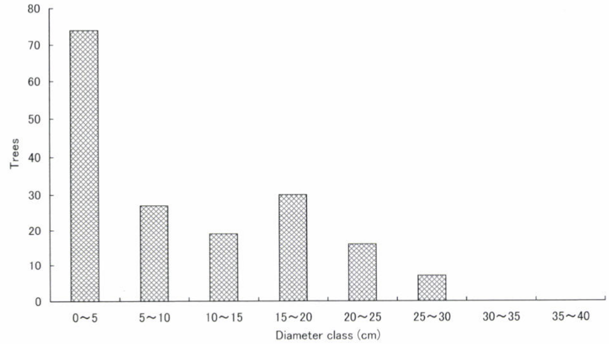

Fig. 2 Diameter distribution in the Laoshigou Forestry Farm. Source: Tanaka, T., 2003, Studies on the relation between aridness and change of vegetation in the northeastern China

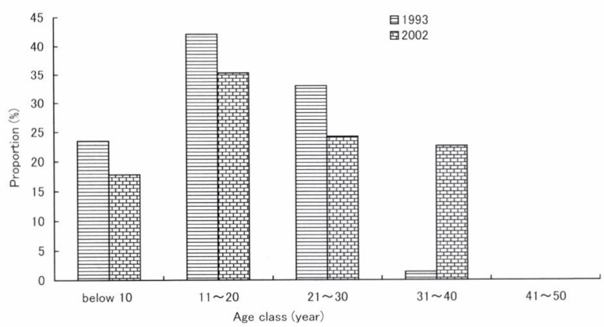

Fig. 3 The stand age class change between 1993 and 2002 in Laoshigou Forestry Farm
Sources: Shenyang Forestry Department, 2003, Forest Resources Survey

Forest Management and Resources Change in Qipanshan Scenic Forest

Since the Qipanshan Scenic Forest was founded in 1980, the artificial forests have been implemented every year at a scale of 80ha, the artificial forest densities were from 3,500 trees/ha to 4,500 trees/ha. The important change of management technology was that clear cutting was replaced by the thinning. The annual thinning timber was about 2,000m³, in order to improve the forest growth. The thinning rate varied from 10% to 15%. Though forest thinning was employed every year, the stand densities are still very high. In Qipanshan Scenic Forest, the stand area of Chinese pine and Japanese larch took up 72.6% and 9.6% of all stand respectively, and stand stock of Chinese pine and Japanese larch made up 77.3% and 11.1% of all stand stock respectively. They are the dominant species in the Qipanshan Scenic Forest. The plot investigation data showed the stand densities of Chinese pine and Japanese larch at different age class varied from 2,080 trees/ha to 3,872 trees/ha (Table 3).

With the high stand density caused by the management purpose was to produce timber before 1980, this is not available for forest scenic beauty. How to transfer the timber forests into scenic forests need to be studied furthermore. In Japan, some research results showed it is possible that timber forests were transferred into multiple-storied scenic forests by scenic thinning (BABA, 1989; ITO, 1994; SHIMIZU, 2003). The scenic thinning was employed mainly to cut trees by intensive thinning to make gaps in forests. It can be thought the scenic

Table 2 Forest resources change between 1993 and 2002 in Laoshigou Forestry Farm

Year	Forest stand					Coniferales		Broadleaf Trees	
	area (ha)	proportion of over 30 years old (%)	stock (100m³)	proportion of over 30 years old (%)	m³/ha	area (ha)	stock (100m³)	area (ha)	stock (100m³)
1993	652	34.4	571	49.7	88	362	432	290	139
2002	658	46.8	665	65.1	101	361	479	297	186

Sources: Shenyang Forestry Department, 2003, Forest Resources Survey Data

Table 3 The stand densities change in Qipanshan Scenic Forest

Plot No.	Amount of plot	Area (m×m)	Trees	Stand density (tree/ha)	Satnd age (year)	Tree species
A1-A3	3	25×25	230～242	3,680～3,872	Below 10	Japanese pine
B1-B5	5	25×25	225～232	3,600～3,712	11～20	Chinese pine,Japanese pine
C1-C5	5	25×25	195～220	3,120～3,520	21～30	Chinese pine,Japanese pine
D1-D5	5	25×25	180～200	2,880～3,200	30～40	Japanese larch
E1-E5	5	25×25	160～175	2,560～2,800	41～50	Japanese larch
F1-F3	3	25×25	130～141	2,080～2,256	Over 51	Japanese larch

Table 4 Forest resources change between 1993 and 2002 in Qipanshan Scenic Forest

Year	Forest stand					Coniferales		Broadleaf Trees	
	area (ha)	proportion of over 30 years old (%)	stock (100m³)	proportion of over 30 years old (%)	m³/ha	area (ha)	stock (100m³)	area (ha)	stock (100m³)
1993	3,522	24.8	2,240	37.7	64	3,085	2,051	437	189
2002	3,411	42.6	2,576	58.2	76	2,960	2,337	451	239

Sources: Shenyang Forestry Department, 2003, Forest Resources Survey Data

thinning approach should be induced into Qipanshan Scenic Forest for improving their amenity.

As to the forest resources change in the Qipanshan Scenic Forest, the Forest Resources Survey data employed in 1993 and 2002 showed the stand areas were not increased, on the contrary, were decreased 112ha, because of 196ha forests were transferred to construct hotel, ski run and other artificial recreational facilities. The stand areas in age of over 30 years old reached 42.6%, were increased 17.8%. The stand stock increased about 33,000m³, which the stand stock in age of 30 years over reached 58.2%, which are lower than that in Laoshiguo Forestry Farm during the 10 years (Fig.4). The proportions of stand area and stock between the coniferales and broadleaf trees were not changed basically. They can be seen in the Table 4.

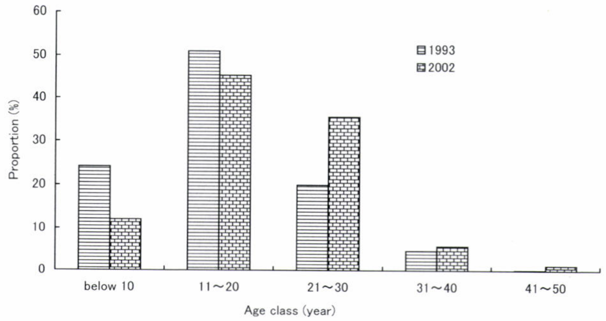

Fig. 4 The stand age class change between 1993 and 2002 in Qipanshan Scenic Forest
Sources: Shenyang Forestry Department, 2003, Forest Resources Survey

Forest Management and Resources Change in Magang town

In Magang town, all forests are artificial forests employed to produce timber. From 1950 to 1985, the annual artificial forests were about 50ha, majored in Chinese pine. Clear cutting was implemented every year, and the timber production was about 1,000m³. From 1986 to 1990, the annual artificial forests were about 80ha, majored in Chinese pine and Black locust (*Robinia pseudoacacia* L.), timber production was about 2,000m³ by clear cutting. After 1991, because the government decided to limit the clear cutting, thinning, which was taken as a major ways to produce timber was implemented every year, and timber production was about 3,000m³, annual artificial forests reached 100ha, majored in Japanese larch.

The artificial forest densities of Japanese larch varied

Table 5 Forest resources change between 1993 and 2002 in Magang town

Year	Forest stand					Coniferales		Broadleaf Trees	
	area (ha)	proportion of over 30 years old (%)	stock ($100m^3$)	proportion of over 30 years old (%)	m^3/ha	area (ha)	stock ($100m^3$)	area (ha)	stock ($100m^3$)
1993	1,326	5.7	676	15.2	51	984	520	342	156
2002	1,409	35.4	795	62.9	56	1,077	590	332	205

Sources: Shenyang Forestry Department, 2003, Forest Resources Survey Data

from 1,330 trees/ha to 4,050 trees/ha according to growth and site index and cultivation purposes. If the cultivation purpose is to produce small diameter wood, which DBH is less than14cm, and growth and site index is poor, the artificial forest densities will be decided from 1,330 trees/ha to 2,400 trees/ha. If the cultivation purpose is to produce large diameter wood, which DBH is over 24cm, and growth and site index is better, the artificial forest densities will vary from 3,300 trees/ha to 4,050 trees/ha. The thinning will be implemented in age of over 10 years old. The thinning rates changed from 10% to 30% according to the artificial forest density and forest age. Usually, if the artificial forest densities are high, the thinning rates will be decided from 20% to 30% at age of 20 years old and 30 years old. As to final cutting ages of Japanese larch, they are same as Japanese larch located in Shenyang watershed, no matter what cultivation purpose and how growth and site index they are in, all of final cutting ages are below 45 years old, the management of Japanese larch in Magang town is characterized with a short-term cutting.

According to the new Forest Classification Management Policy, which classifies forests in to 2 categories, one is Public Welfare Forest and another is Commercial Forest, and classification results in Shenyang city, the artificial forests in Magang town were designated as Commercial Forest, the cultivation of large diameter wood with long-term cutting is necessary. How to change short-term cutting into long-term cutting is a big issue in Shengyang. In Nagano prefecture, Japan, there are many successful cases of cultivation of large diameter wood of Japanese larch by intensive thinning. (SHIMASAKI, 1986; KANAI, 1998). This effectively management technology should be introduced to Magang town for cultivation of large diameter wood.

As to the forest resources change in the Magang town, the Forest Resources Survey data employed in 1993 and 2002 showed the stand areas were increased 82ha, the stand area in age of over 30 years old reached 35.4%, were increased 29.7%. The stand stock increased about 12,000m^3, which the stand stock in age of 30 years over reached 62.9%, were increased 47.7% during the 10 years. The stand stock per ha reached 61.8m^3, which are higher than that of Laoshigou Forestry Farm and Qipanshan Scenic Forest (Fig. 5). The proportions of stand area and stock between the coniferales and broadleaf trees were not changed basically. They can be seen in Table 5.

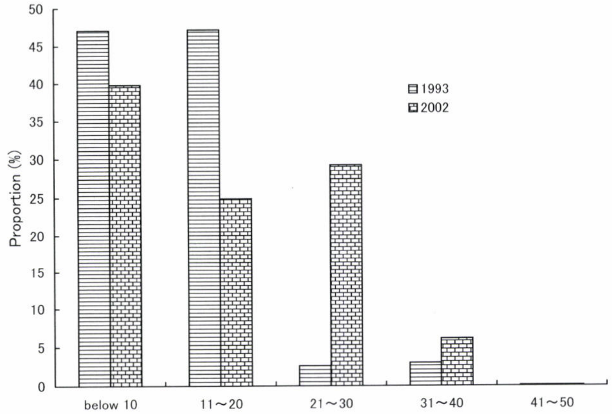

Fig. 5 The stand age class change between 1993 and 2002 in Magang town
Sources: Shenyang Forestry Department, 2003, Forest Resources Survey

CONCLUSION

At present, forest classification management of 14 prefectures in China has been completed according to the Forest Classification Management Policy (FCMP), which is taken as one of the most important policies. However some issues related to the policy have not been solved yet, such as available forest management practices for the implementation of FCMP in China, especially in the metropolises. The investigation results showed three forests management types in Shenyang suburbs are different in the composition of age class, dominant trees, coniferales and broadleaf and growth of stand area and stock, because different management measures were implemented, though they were at approximate growth and site index 30 year ago. The management practices in Laoshigou Forestry Farm implied multi-storied and mixed forests could be brought out. This is available for the management of Public Welfare Forests in Shenyang according to the FCMP. As the effective management measures in Japan, the intensive thinning for artificial forests, and scenic thinning for transformation from artificial forests to recreational forests should be introduced to Shenyang.

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Article

Studies on the Relationship between Desertification and Forest Policies in China

Hongyi Chen[*1] and Yasuaki Kurokawa[*2]

ABSTRACT

Desertification has become such a serious issue that there is a pressing need for us to resolve it immediately. Nearly 20 percent of China's land territory has turned to desertified land due to natural and human factors, and overall desertification continues worsen. The policy of forest exploitation and monoculture in China is the primary cause that has led to disastrous consequences, including degradation of forests and landscapes, serious soil erosion and catastrophic flooding, and especially deforestation. In order to resolve this desertification and realize the sustainable development of forestry, the Chinese government has begun to modify Chinese forest policies and make a series of plans and programs on forest resources and combating desertification. Hence there have been many statutes with provisions relating to forest conservation. Although since the "reform and opening", much has been done in reforming Chinese forest policy, the situation of the desertification is still worsening. In this paper, we will analyze the relationship between the desertification and current Chinese forest policy in order to develop an adequate forest policy system to control and resolve the desertification and to realize sustainable development of the environment in China.

Keywords: desertification, forest policy, sustainable development of environment, China

INTRODUCTION

Desertification is one of the most serious environmental and social economic problems in the world that has been harming China for a long time. Desertification has brought about environmental deterioration and land degradation, which have caused heavy losses in the economy. Therefore, it is absolutely necessary to implement project for combating desertification. According to the research and practices of nearly 50 years, we consider that land degradation from desertification has mainly resulted from interaction between excessive human activities and vulnerable environment (Zhu, 1989). In the past 20 years, great achievements and experience have been obtained in the technology and typical models for combating desertification in China. Although the study and countermeasures against desertification have been made for nearly half a century, the danger of desertification has become more and more serious. There have been some studies that show that the forest policy factor is the main cause of the desertification in China. Since the "reform and opening", China has taken a series of measures to cope with this issue. National policies, plans and projects on forest conservation were adopted and implemented over the past two decades. Forest conservation objects were set forth for short, middle, and long terms. The logging of natural forests has been banned by the government in recent years. In addition, China has established a legislative framework on forest conservation consisting of constitutional clauses, statutes and regulations, as well as local regulations. However, the desertification continues to worsen. In the 60s-70s, the expanding speed was 1,560km² each year; in the 80s, it was 2,100km² each year; in the 90s, it has reached 2,460km² each year (Feng, 2003). Therefore, it is necessary for us to examine our current forest policy system for flaws and to make further forest policy reforms.

THE SITUATION OF DESERTIFICATION IN CHINA

Desertification in China is very serious and has become

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one of the main environmental problems. Desertification are mainly distributed in arid, semi-arid and dry sub-humid areas, covering 471 counties in 18 provinces and autonomous regions in the west part of Northeast China, the northern part of North China and in most regions of Northwest China (ZHU, 1999) (see Fig. 1). In the arid and semi-arid regions of North China the main aspect of degradation is desertification (including shifting sand dunes, sand dune reactivation, shifting sands spreading into grasslands and wind erosion in dry farmland). It covers about 334,000km², of which 197,000km² has already been desertified and 137,000km² is being threatened in the process. A population of about 35 million people is affected. By comparing and interpreting aerial photographs taken at the end of the 1950s and the middle of the 1970s, we note that the desertified land has increased from the previous 137,000km² to 176,000km². In other words, 39,000km² of land was desertified during this 15 year period, an average annual loss of 1,560km² (ZHU, 1999). From the view point of spatial distribution of the desertification in the last 10 years, the following points are worth mentioning:

1. The dry farmlands in the sandy steppe region represent territories prone to desertification or land with high rates of ongoing desertification. In the last 10 years the desertification of grassland has developed at the annual spread rate of desertified land reaching 5-10% (FENG, 2003).

2. In some pre-existing desertified regions such as sandy land in Horqin and along the Great Wall in SHaanxi province, recent development and the adoption of some control measures has reduced the rate of desertification. The annual spread rate varies between 2-5% (FENG, 2003).

3. In the last 10 years, desertification of grasslands has also developed very quickly. For example, in the north pan of the Ulanqab league the desertified land area has increased from 18.1%in the 1970s to 30.4% in the 1980s. It is characterized by the ground surface becoming rough, the appearance of shifting sand and the deterioration in quality of the grasslands (FENG, 2003).

4. When some control measures were adopted over 10 years ago, the spatial range of desertified land has contracted. In the southeast part of the sandy land in MuUs, after 10 years of rehabilitation, the vegetative cover has increased from 10% to 23%, the total grain yield increased by 32% and average personal income increased 7 times (FENG, 2003).

5. In desertified regions with "ecological elasticity" in the semi-arid zone, desertified land can be rehabilitated in 5-7 years as long as some measures are adopted, including readjustment of the land use structure, fencing to exclude grazing animals, and afforestation and stabilization of shifting sand dunes. This can be seen, in particular, in the Huihe region of Hulun Buir steppe where the natural condition is better than other sandy areas. The desertified land has been transformed into woodland of Pinus sylvestris (ZHANG, 2002).

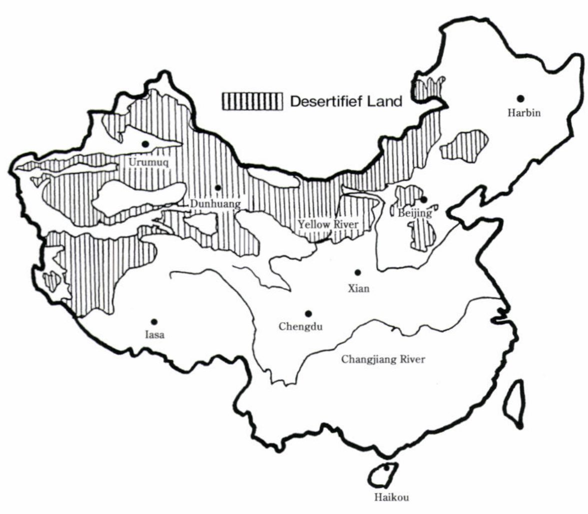

Fig. 1 The distribution of desertification in China

THE DEVELOPMENT OF CHINESE FOREST POLICIES

The development of desertification in China is a process of national exploitation policies being carrying out at different times in history. That is to say, unsuitable forest policies at different times in history have caused and aggravated the desertification. And at the same time, the desertification problem has led to forest policy reform. The development process of Chinese forest policy can be divided into the following three periods:

Early Period of China's Foundation (1949-1978)

In the early years of the People's Republic of China, the government pursued a forest policy characterized by tree planting on barren lands and timber harvesting in major forest regions, while expressing concern about forest protection. Large-scale tree planting in the wastelands, especially in the north, began in the mid period of the 1950s.

Apart from tree planting, a theme characterizing Chinese forestry to the present, which was the main focus of the forestry sector was timber production. However, the "Big Leap Forward" campaign launched in 1958 encouraged the use of homemade furnaces for steeling making, but that led to thousands of inefficient furnaces and massive destruction of forests. The compulsory elevation of millions of peasants' cooperative to people's Communes, along with the failure of "the Big Leap Forward", contributed to a famine that lasted for three years (1960-1962). Nationwide calamities and tragedies forced the central government to readjust policies and adopt measures to relax taxation riles in rural areas. In the countryside, for example farmers were allowed to retain more agricultural produce on collectively-owned land. This enabled the national economy to recover rather quickly. Forest industries began to grow rapidly with the opening of the Great

Xingan Mountains in the northeast and the Jinsha River forest region in the southwest in the 1960s. However, the Cultural Revelution (1966-1976) catapulted China into unprecedented political chaos and anarchy. During this period, most forestry programs were discontinued, except for rampant timber cutting and highly inefficient afforestation campaigns.

For three decades prior to the 1978 economic reforms, the forest sector supplied under-priced logs to support the national economic development. Although many professional foresters appealed for the protection of the ecosystem and wildlife habitat, for increased investment in silviculture, the sector was seen only as a supplier of cheap raw materials. As a consequence, while over one billion cubic meters of timber was supplied nationwide during the period 1949-1979, the country's forest resources base was devastated. Achievements on the tree-planting front were dismal: out of a total of 104 million ha planted during the same period, the rate of success was a mere 20%. The perform period was characterized by rhetoric-laden campaigns aimed at mass mobilization for tree planting and by unsustainable timber harvest in primary forest areas (RICHARDSON, 2000).

The proportion of growing stock destroyed in these provinces during the Great Leap Forward ranges from one third (HUNAN, HUBEI) to one tenth (SICHUAN) (ZHU, 1999). The situation in many other provinces was no better (the datum for other provinces in Table 1). This trend of declining forest coverage during the Great Leap Forward continued through the early 1980s.

During this period of the "Great Leap Forward" and "Cultural Revelution", the study of combating desertification was greatly affected, and was even forced to be at a standstill. In the mid-1950s, China began exploring the vast resources of the Great Xingan Mountain forest. Since then, the average forestry line has retreated 50 kilometers due to over logging and forest resources were reduced greatly (see Table 2 and 3). With the great movement of opening up the wasteland, a great

Table 1 The change of forest coverage (the provinces with serious desertification)

(103ha)

Year	Province				
	Hebei	Shanxi	Gansu	Ningxia	Qinhai
1948	126	971	2,285	59	1,456
1976	2,010	1,090	1,87	60	190
1981	1,677	810	1,769	95	195
1988	2,011	893	2,029	118	266

Source: Zhu (1999)

Table 2 Chin ese forest resources

Forest type	Young and Middle-aged		Mature and Over-mature		Total	
	Area (10^6ha)	Volume (10^6m^3)	Area (10^6ha)	Volume (10^6m^3)	Area (10^6ha)	Volume (10^6m^3)
Timber forest	74.0	3,368.6	25.4	3,837.6	99.4	7,206.2
Shelterbelts	11.9	554.0	9.5	1,639.0	21.4	2,193.0
Fuelwood forest	4.2	66.9	0.3	20.6	4.5	87.5
Special forest	1.8	161.7	2.1	437.3	4.0	599.0
Total	91.9	4,151.1	37.3	5,934.5	129.2	10,086

Souce: SFA (2000)

Table 3 Chinese forest resources (1949-1995)

Period	Forest Area (1,000km^2)	Forest Coverage (%)
Before 1949	1,340	13.92
Early Period (1950-1972)	760	8.90
1st National Survey (1973-1978)	1,220	12.70
2nd National Survey (1979-1984)	1,152	12.00
3rd National Survey (1985-1990)	1,246	12.98
4th National Survey (1991-1995)	1,336	13.92

Source: SFA (2000)

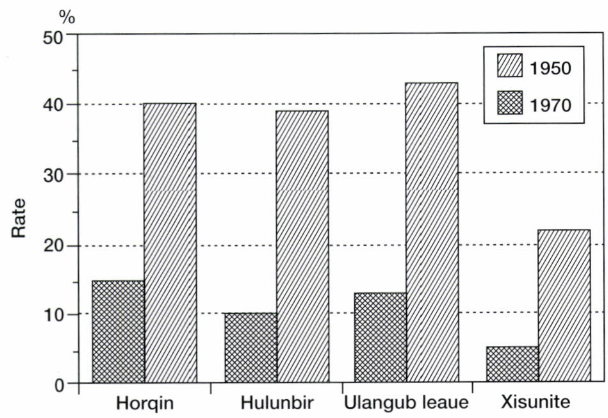

Fig. 2 The rate changes of flowing tunes

number of mountains and grassland were destroyed, that flowing tunes were spread more widely, and desertification became more serious (see Fig. 2). The statistical data shows the situation of flowing tune changes in this period.

By comparing and interpreting aerial photographs taken at the end of the 1950s and the middle of the 1970s, we note that the desertified land has increased from the previous 137,000km² to 176,000km². In other words, 39,000km² of land was desertified during this 15-year period, an average annual loss of 1,560km² (ZHU, 1989).

Early Period of Reform (1978-1985)

In 1978, the Chinese government decided to promote forestry by providing the Ministry of Forestry with the mandate, among other things, to oversee timber production in state-owned forests and afforestation across the country. Due to central planning, the Ministry functioned on administrative linkages with forestry departments at the provincial level, forestry bureaus at the country level, and work stations at the grass-roots level of township. In the meantime, the Chinese Academy of Forestry, which came into being in 1958, was strengthened and several forestry colleges were expanded under the auspices of the Ministry.

On the other hand, another focus was on the rural reform. Public ownership was the main focus for rural forest, while various economic elements coexisted. A breakthrough was made in the establishment of pluralistic, multi-level and multi-type forestry management entities.

As a result of a series of reforms in the administrative hierarchy in the late 1980s and early 1990s, the Ministry of Forestry can focus on administration as well as the formulation of policies, leaving production decisions and operations to the companies (WANG, 2001).

Although improvement has been made in forest area and storage by the early 1990s, there is still a big disparity between the supply and demand for timber. The reason is that the increase in forest area and storage is mainly due to the growth of young forests unsuitable for logging. The existing area and storage of mature and over-mature forests is not large enough to maintain a sustainable yield of timber. They cannot even afford to meet the rather low level of timber consumption in China. The annual deficit of standing forest storage from 1984 to 1988 was 40 million cubic meters. Basically two methods were applied to fill the disparity (see Table 4) and lower reaches. One was to log more of the exciting mature and cover-mature forests; the other was to import timber. Both methods were not adequate. The first one intensifies the timber deficit; the second not only causes a large financial burden, it also increases pressure on world forest resources.

Table 4 The reduction of forest resource (timber forest)

Period	Total		Mature timber	
	Area (10^5ha)	Store ($10m^3$)	Area (10^5ha)	Store ($10m^3$)
1977-1981	8,243	639,951	2,188	384,593
1984-1988	7,958	615,752	1,419	262,164
Increment	-285	-78,199	-769	-122,430
Annually	-40	-11,171	-110	-17,490

Source: CFD (1998)

The loss of forest-coverage has caused serious ecological problems:

Soil erosion:

The Yellow River is famous for her muddy waters. The soil and sand in the water come from the upper and middle reaches of the river. In these areas, forest coverage has been gone for thousands of years. In another major river basin, the Chang Jiang River, the soil erosion area increased from 360 thousand square kilometers in the 1950s to 560 thousand square kilometers by the 1980s. The loss of forest coverage in the upper and middle reaches of the river is one of the main causes of the destruction in the middle and lower reaches.

Desertification:

The loss of forest-coverage has caused the expansion of desert in northern and northwestern China. Every year, 170,000 hectares of land turn into desert. Farmland and grasslands are damaged by sandstorm disasters. In the northwestern, northern and northeastern areas, 13,33 million hectares of farmland and 100 million hectares of grassland suffer from sand storm disasters each year.

Devolution in Forest Tenures Period (1985-present)

In 1998, the Chinese government established the NFCP (National Forest Care Program), which articulated the new forest policy. Its purposes were to restore natural forests in ecologically sensitive areas, to plant forests for soil and water protection, increase timber production in forest plantations, to protect existing natural forests from excessive cutting, and maintain the multiple-use policy in natural forests. The NFCP applies to 18 provinces and autonomous regions, which contain the upstream regions of major river systems, including specifically the Yellow and Chang Jiang Rivers, which have suffered massive ecological and environmental degradation during the past 50 years. The target area is divided into two priority regions. The state forest regions are classified as the first priority for the NFCP. The two priorities receive different levels of financial support from the central government, ranging from 20 to 100% of all costs.

By the mid-1980s, a great number of collectively-owned woodlots had been distributed to peasants under a variety of contractual forms that granted them an entitlement to the forested land and its harvest. The changes in forest tenures have been recognized as a crucial driver in China's forest policy reform (RICHARDSON, 1990).

Despite thousands of years of human land-use, large areas of old-growth forest still existed in China at the beginning of the 20th century. Before the 1950s, most of China's forests have been naturally regenerated. Since then, demand for timber has resulted in extensive cutting of forests, and timber harvests increased from 20 million m^3/year in the 1950s to 63 million m^3/year in the 1990s. Government policy did not require that native tree species be planted after logging, but promoted planting of fast-growing tree species, such as larch (*Larix spp.*), poplar (*Populus spp.*), and Chinese fir (*Cunninghamia Lanceolata*). Although a large-scale increase of plantation-style forests in non-forested areas increased the total forest coverage in China from 5.2% in 1950 to 13.9% in 1995, natural forests declined to 30% of the total forest area in China and unit-area stocking of natural forests decreased by 32% (CHINA ENVIRONMENTAL REVIEW, 1999) (see Table 4 and 5).

China's human population has increased about 2.5 times over the past 50 years, yet the human population in forested areas has increased five-fold. Scientists foresaw the potential conflict between human population growth and forest resource use and began advocating changes in China's forest policy as early as the 1960s. They had little success. In the 1970s, government policy limited clear-cut areas to <10ha in northeastern China, but departures from this standard were routine in field application. During the 1990s, eroded lands continued to increase by >10,000km^2 annually, with the result that 38% of China's total land area is now considered badly eroded (CHEN, 1998).

The sharp decline in the quantity and quality of natural forests resulted in loss and fragmentation of natural habitats. At least 200 plant species have become extinct in China since the 1950s, and >61% of wildlife species have suffered severe habitat losses. Valuable and rare species, such as ginseng (*Panax Ginseng*) are threatened with extinction. Changes in forest composition have also caused severe ecological and environmental disasters. Insect infestations have damaged >9.3 million ha of forests per year, causing >10 million m^3 of timber loss. Flash flooding, partly due to loss of natural vegetative cover, caused a total loss of 166.6 billion yuan (RMB, US$20 billion) in the summer of 1998 alone (CHEN, 1998).

The degradation of natural forests was inevitable because the old forest policy was designed to maximize timber production for economic development, and in its implementation, the amount of timber harvested exceeded that which was sustainable by at least a third; natural forest conditions were not accurately and systematically monitored, and no effective effort was made to evaluate the old forest policy.

In general, in the traditional high consumption extensive economic rising pattern, a public-owned system of forest resources is not suitable for sustainable management of the forest. It is also impossible to form an effective running system for sustainable development of the ecological environment and forestry economy. It shows that the desertification in China was mainly caused by unsound forest policies and in the view of combating desertification and making sustainable development in Chinese forestry, the reform of Chinese forest policy reform has become an extremely urgent task.

Table 5 Growth and consumption

Period	Annual Growth (ha)	Consumptin (m^3)	Deficit (ha)	Mature Timber (m^3)
1977-1981	2.940.19	2.75	0.644	
1984-1988	3.16	3.44	0.28	0.961
Growth(%)	14.90	17.01	47.36	49.22

Source: SFA (2003)

ANALYSIS

The information above shows that from 1958 to 1980, there were three forest deforestations in China, which were the disasters during the changing process of Chinas forest resources. In 1976, the forest coverage in China was only 12.7%. The basic causes for the three forest deforestations were no perfect legal system, the property right of forest was not steady, the legalization of property rights was neglected. After reviewing the history of forest development in China, we found that though the historic background was different, and there was a variety of causes, it is the same that the property right of forests, forest land was not steady and the policies couldn't effectively protect the benefit of the owners or users. Factors associated with deforestation and desertification usually have a strong human component, indicating that they often result from policies formulated by decision-makers at various levels. In fact, policy is increasingly targeted as a starting point for understanding the elements driving both deforestation and desertification, and eventually for reversing the trend. Simple agricultural structure and employment access, animal husbandry and rigid forest policy are the direct reasons leading to deforestation and desertification. In order to combat desertification and implement environmentally sustainable development, in 1992, China's reform of the economic system entered into the third and the key period. The Decision of Several Issues Concerning Establishment of the Market Economic System was adopted by the Plenary Session of the Fourteenth CPC Central Committee in 1993. The supplementary reform of taxation, finance, prices and foreign exchange was undertaken in 1994, which pushed the implementation of the open-door policy and the development of the socialist modernization into a new period (LI, 2002). During this period, China's forestry entered into a comprehensive and supplementary reform period. However, the Chinese forestry reform does not stop the desertification expanding trade and also is unable to adapt the present economic system. It is well known that forestry shoulders heavy tasks of treating soil and water erosion, water source conservation, combating desertification and alleviation of natural disasters, etc. Combating desertification is not only the one of the task of forestry but also the comprehensive reflection of the others. Therefore, the present forest situation shows that forestry is facing some sharp contradictions at a deeper level, seriously restricting forestry development and realization of development goals. The major problems are:

In the forest policy, forest source property right is the key problem and it is also one of the main causes of deforestation. Most of the forest policy was made in the planning economic period. It is the reflection of a socialistic public-owned system in forest resources property right system. In the following reform, the proprietary right breaking away from managerial rights, forest property rights and managerial structures were improved in some way, but the reform goal is to stress economy and weaken farmers' benefit. It is only an innovation of the economic distribution system. The reason for the forest resources property right system changing by period is that the first is the people's subjective limitation, especially to socialistic nature and task. The second is the limitation to forest function, ignored the important affection of forests in construction of environment development and the policy of laying on logging and neglecting planning led to the excessive consumption. The two aspects are the main subjective reasons, and the objective reason is our environmental awareness behind the times. These are the main reasons affecting forest policy reform and preventing ecological development. In the end of twenty century, there was a serious flood. When people were faced with the great loss of lives and properties, the attitude towards forest resources changed, and they paid more attention on the preventing function of forests. The government began to reform the forest policy and invested several million yuan to start six key forest projects, including the famous SANBEI SHELTER FOREST PROJECT. There is no doubt that these projects are valuable in prevent and rebuilding the ecological environment, but it is well known that ecological prevention is a long-term task and needs much expenditure for a long period of time. But China is still a developing country; the fiscal solvency of the central government and local governments are limited. There is not that much capacity to support these projects. Therefore, it is impossible to ecological prevention only by the government investment. The only choice is to arouse the whole social forces to participant. Then the question is, how to lead the social fund, labor, management and technology to ecological prevention? The way is to make liberal policy to abstract social forces. When we use material benefits as a guide, we will face further forest policy reform, that is to say, forest resource property right system reform.

CONCLUSION

From the perspective of the forest ecological prevention, social forestry mechanism is the trade of the world. It can overcome the expansion of private property economic benefit and cut down expenses for managing public welfare forests. In general, it can promote efficiency of forest management.

Social forest mechanism means that forests are managed by local people (living near or in the concerned forest area) for their own benefit. Social forest mechanism comprises of others community forestry, private forestry and lease-hold forestry (TAYLOR, 2000)

Social forest mechanism is that forests, forest land and forestry production are managed by the local people in a participatory way and their own benefit. It includes plantation, forest protection, harvesting and processing; benefit considers both material and immaterial benefits (including ecological and environmental aspects). Social forestry can provide the participants with an opportunity to improve their knowledge and technical skills. The participants are expected to have:

1. Fully understood the concept of social forestry and its usefulness in enhancing forest conservation and mitigating desertification in the region.

2. Development their abilities in policy formulation to promote Social forestry, which enable the application of social forestry strategies to various local conditions of participating countries.

3. Learnt effective measures to be taken to disseminate the practices and relate techniques of the social forestry to farmers and other beneficiaries.

4. Re-developed their abilities to resolve problems in the promotion of social forestry by expanding their knowledge and techniques and by exchanging experiences among participants from other countries.

The target and partners of social forestry even include urban and sub-urban population because of the forest products and impacts.

It can be stated that forest property rights include five aspects and they are land use, transfer, lease, heritage and mortgage. Chinese forest policy reform have been done for many years, but forest property right system reform still can not meet with the need of combating desertification and environmental prevention. Desertification is one of the main environmental problems in China and the main cause is human factors. Deforestation is the most important factor.

There are many reasons for deforestation but the most important one is farmers are lack of initiative and long plan in managing forest. Because the forests are not their own, and they can not get any benefit from it.

Social forestry is a new concept that aims to establish a sustainable forest resource management. It will probe a new path for the establishment of the technological innovation system in the forestry domain. At the same time, it will impel forestry activity from departmental responsibility to social responsibility, guide and organize the whole of society to participate in the protection, restoration and construction of forest resources and ecological environment according to state forestry development primary goal, impulse forestry industrial development under a new situation, enhance forestry's service quality to the whole society and human being, and bring about extensive scope and greater benefits to forestry development in the 21-th century. It can make a greater contribution towards combating desertification and ecological environment construction in China.

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Article

The Present Situation and Constraints of Beijing' Forests for Holding 2008 "Green Olympic"

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ABSTRACT

"Green Olympic", as one theme of the 2008 Olympic held in Beijing, will make a great change in Beijing's environment. In the recent several years, a tremendous amount of attention has been paid to forest resources that can take an important role in improving environmental quality. Up to now, there are many researches about Beijing' forests, but there is a little research about Beijing' forests on the views of connecting historical change with current constraints for holding 2008 Olympic. This paper aims to get a better understanding of lessons that come from historical change of forest resources, to discuss present situation and constraints and to put forward the proposals that can solve the issues for the implementation of the "Green Olympic" in Beijing. The results showed that policy-making could give a great effect on the change of forest resources. The forest resources could not fully maintain their environmental services at current capacity, because of low forest coverage, high proportion of young forest and low stock per hectare. On the other hand, the urbanization was a serious threat to forest resources in Beijing with the rapid economical growth. Keeping the policy consistent was very necessary. Enhancing the management and conservation of young forests and secondary forests were critical. Minimizing the conversion of forest resources by implement of relative laws and regulations was important.

Keywords: Beijing, forest resources, "Green Olympic", policy-making, urbanization

INTRODUCTION

Beijing, as the capital of the People's Republic of China, is one of the most famous metropolises in the world with its long history of about 3,000 years and as the national political and cultural center of the country. Since China opened its door to the world in 1979, the growth of Beijing's economy, measured in conventional terms, is astonishing. Its Gross Domestic Product (GDP) jumped to about 34.1 billion US dollars in 2001, which represents a 26-fold increase of its value in 1978. While, at same period, the total population in Beijing had a fast increase from 8.7 million in 1978 to 13.8 million in 2001 (Beijing Statistical Bureau, 2001). However, accompanying with the fast growth of economy and population in Beijing, a lots of environmental problems occurred in the recent years such as air pollution, water pollution, water shortage etc. Now, per capita water resources in Beijing are only 300m^3, it equals one eighth and one thirtieth of average national and world level respectively (Qian and Zhang 2001). Water crisis has occurred several times since 1980's. Water resources shortage has become an important factor that affects economic development in Beijing (Water Resources Department of Beijing, 2001). In order to improve Beijing's environmental quality, since 1998, Beijing has invested 3.6 billion US dollars in spreading the use of clean fuel, controlling gas pollutant emission, treating wastewater, safe disposal of solid and protecting wild life species etc (Beijing Environmental Bureau, 2002). After Beijing was awarded the 2008 Olympic Games in 2001, hosting the Games successfully has become the most important job in Beijing in the next 7 years. The government of Beijing made a Beijing Olympic Action Plan with total investment of 8.6 billion US dollars from 2002 to 2007 to host the Games. Most of the investment will be used to improve

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environmental quality and sport facilities. One of the themes for the 2008 Olympic is a "Green Olympic". The goal of "Green Olympic" is turning Beijing into a "green city" (Beijing Organizing Committee for the Games of the XXIX Olympiad (BOCOG), 2002). Because many measures were implemented, environmental quality was improved at some extent, but it was not solved thoroughly.

Forests, as the most important part of "Green City", has been taken much more attention than before in Beijing. Up to now, there are many researches about Beijing' forest (Yu and Yu, 2001; Wang, 1998), but there is a little research about Beijing' forest on the views of connecting historical change with current constraints for holding 2008 Olympic. The objective of this paper is to get a better understanding of lessons that come from historical change of forest resources, to discuss present situation and constraints and to put forward the proposals that can solve the issues for holding 2008 "Green Olympic" in Beijing successfully.

STUDY SITE AND METHODOLOGY

Beijing is one of the biggest cities in China with the total population of 13.8 million, it is located in the north of the Huabei plain between east longitude 115°25'-117°30' and north latitude 39°28'-41°05', in the temperate zone. The annual average precipitation in Beijing is about 600mm. It has a whole area of 1,782 thousand ha, of which 38% is plain and 62% is mountainous region, stretching 160km from east to west and over 180km from south to north. It governs 18 districts and counties with Dongcheng, Xicheng, Xuanwu and Chongwen 4 districts that are in the city proper, Chaoyang, Haidian, Fengtai and Shijingshan 4 districts that are in the near suburbs, Mentougou and Fangshan 2 districts that are in the outer suburbs, Changping, Tongxian, Shunyi, Daxing, Huairou, Miyun, Pinggu and Yianqing 8 counties that are in the countryside.

In Beijing, five Forest Resources Surveys were conducted from 1973 to 1998 about once every five years. By comparing the data from the 5 Forest Resources Surveys and other historical data, the historical change and present situation of Beijing' forests was analyzed. Based on the recent key documents and information collected from field survey and observation, constraints on Beijing' forests and challenges that government and foresters face were discussed.

RESEARCH RESULTS

Historical Change

Beijing originated more than 3,000 years ago as the local economic and political center of Yan State. It had not been the national center until the periods of Sui and Tang Dynasty (7-10 centuries). It was during the periods of 10-13 centuries (Liao and Jin Dynasties) that Beijing gradually became the political and economic center of the nation accompanying founding of capital of Liao Dynasties (916-1125) A.D.). Since then, Beijing started its national capital of China (Qi 1999).

Historically, Beijing was abundant in forest resources. But because of civil war, foreign invasions and economic development etc, forest resources were decreased gradually, the most serious destruction were began at Yuan Dynasties (1271-1368), Ming (1368-1644) and Qing (1644-1911) Dynasties. The forests were distributed only in the scenic spot, temples and remote mountains in the end of Qing Dynasties. During the period of Republic of China (1912-1949), the forest resources were decreased further more because of civil war and Japanese invasion. Till the founding of the People's Republic of China (New China) in 1949, the forest area of Beijing was only 43.1 thousand ha, mainly distributed in the deep mountainous areas of Huairou, Yanqing, Miyun, Fangshan counties, and forest coverage was 2.6% (Editorial Broad of Annals of Beijing Forestry, 1993).

Generally speaking, forest resources in Beijing have been increased gradually since the founding of New China, it can be seen in Table 1. But the forest resources were fluctuated following the change of national policies in some periods.

From 1950 to beginning of 1960', accompanying the private ownership of land were changed into public and national ownership, the people had initiative to construct new China. The central government took a serious of policy to conserve forest resources and encourage plantation, the total plantation area reached 77.4 thousand ha in Beijing. By 1962, forest area reached 72.2 thousand ha, forest coverage was 4.3% in Beijing (State Forestry Administration (SFA), 1996). At this period, many workers, soldiers and officials were organized to take part in obligatory plantation. The Code of Forest Conservation in Suburbs of Beijing was implemented, illegal cutting and forest fire were controlled effectively.

However, from 1958 to 1960, because the central government put forward policies that Chinese economics should be developed at high speed, which was called "Great Leap Forward" afterward, the plantation area were increased several times than before, but the plantation survival rate was very low. On the other hand, the "Great Leap Forward" committed workers across the country to setting up neighborhoods furnaces to make steel, caused huge amounts of timber wasted, which was used to feed these furnaces (Harkness, 1998). Forest resources were decreased firstly after the founding of New China. In 1962, the central government recognized that the "Great Leap Forward" was incorrect, the economic policies were adjusted. From 1962-1965, the plantation area reached 53.5 thousand ha, the forest resources developments were recovered at stable speed.

After 1965, the plantation was done not only in the mountainous areas but also in the plain areas, according to the Forest Resources Survey in 1973-1976, the forest area reached the 200 thousand ha, over 2 times of forest resources was increased than that in 1960'. But this period was also the

Table 1 The change of forest resources in Beijing

Period (Year)	Area of Beijing (1,000ha)	Forest land (1,000ha)	Forest area (1,000ha)	Forest coverage (%)	Stand area (1,000ha)			Stand stock (million m³)			Per capita forest area (ha)	Per capita forest stock (m³)
					sub-total	timber forest	shelter forest	sub-total	timber forest	shelter forest		
1949	1,664		43.1	2.6								
1962	1,664	593	72.2	4.3								
1973-1976	1,780	610	200.0	11.2	120	110	1.9	1.9		0.020	0.200	
1977-1981	1,780	628	143.8	8.1	65.4	43.9	14.4	1.5	1.1	0.4	0.020	0.200
1984-1988	1,780	1,057	215.3	12.1	131	57.7	54.7	3.8	1.1	2.4	0.022	0.386
1989-1993	1,780	920	267.1	15.0	146	41.4	80.3	4.5	1.5	2.5	0.024	0.405
1994-1998	1,780	931	337.4	18.9	207	33.4	139.5	6.9	1.6	4.4	0.027	0.545

Sources: Editorial Broad of Annals of Beijing Forestry, 1993, Annals of Beijing Forestry
State Forestry Administration of China, 1973-1976, 1977-1981, 1984-1988, 1989-1993, 1994-1998, Forest Resources Survey

serious destruction of forest resources because of the "Cultural Revolution" from 1966 to 1976. Many forests were cut illegally due to unimplemented laws and regulations, a lot of forestland was converted to farmland to cultivate crops in the mountainous areas with the implement of policies, which was called "Production of Grain Is the Center in the Rural Areas".

In 1977, accompanying the end of "Cultural Revolution", and implement of economic reform policies in 1979, the Chinese government formulated a serious of laws and policies to increase and conserve forest resources including the first Forest Law promulgated in 1981. In Beijing, in order to increase forest resources, many forest projects have been constructing such as Plain Greening, Shelter Forest for Water Conservation and Combating Desertification since 1980'. From 1991 to 2000, the annual average plantation reached to about 40 thousand ha (SFA, 1988-2001), forest area reached to 337 thousand ha, the forest coverage was about 19% in 1998 (SFA, 2000).

However, with the rapid economic growth, from 1984 to 1988, 137 thousand ha forest land was converted to urban uses such as the construction of road, houses, mine etc. Forestland was converted into farmland was another important reason.

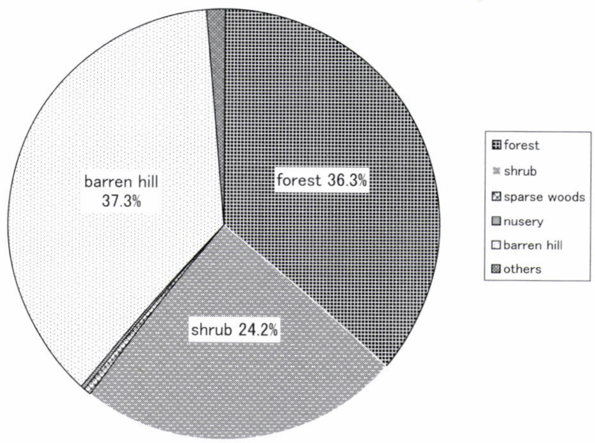

Fig. 1 The composition of forest land in Beijing
Sources: State Forestry Administration of China, 1994-1998, Forest Resources Survey

Present Situation

According to the fifth Forest Resources Survey (1994-1998) in Beijing, the forestland area is about 931 thousand ha, it accounts for 52.2% of total land area. The forest area is about 337 thousand ha with the stock of 6.9 million m³. The area of shrub and sparse woods are 225 thousand ha and 5 thousand ha, the survey identified 347 thousand ha forestland need to be planted. The forest coverage is only 18.9%. The composition of forestland can be seen in the Fig. 1.

The forests are mainly distributed in Miyun, Huairou, Yanqing, Fangshan, Changping, Pinggu, and Daxing counties that are located in the northwest and north of Beijing. The main species are Mongolian oak (*Quercus mongolica* FISCH.), Poplar (*Populus* spp.), Chinese pine (*Pinus tabulaeformis* CARR.), Oriental arborvitae (*Platycladus orientalis* FRANCO) etc. (SFA, 1996). The forest area and stock per capita are 0.027ha and 0.545m³ respectively, they are only 21% and 6% of the national average level.

During this same period, forest stand area and stock are 207 thousand ha and 6.9 million m³ including 67 thousand ha and 1.3 million m³ of coniferous forest and 140 thousand ha and 5.6 million m³ of broadleaf forest, and they can be divided into the 106 thousand ha and 3.5 million m³ of the artificial forest and 101 thousand ha and 3.4 million m³ of the secondary forest. Forest area and stock per capita are 0.027ha and 0.545m³, representing only 21% and 6% of the national average respectively. For all forest, stock per ha is about 33m³, making up 39% of national average.

In China, forests generally are classified into four categories. These include timber forest, shelter forest, fuel forest and "special use forest". Area of the timber forest that is

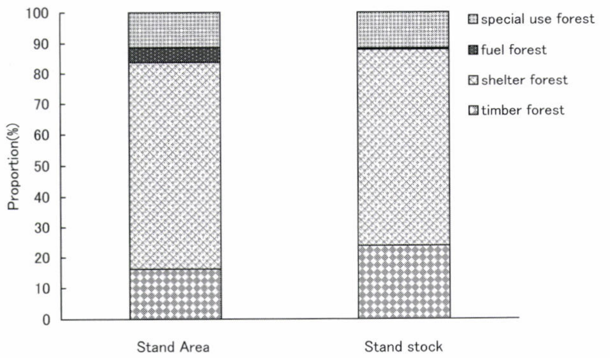

Fig. 2 The proportion of stand area and stock among the forest types
Sources: State Forestry Administration of China, 1994-1998, Forest Resources Survey

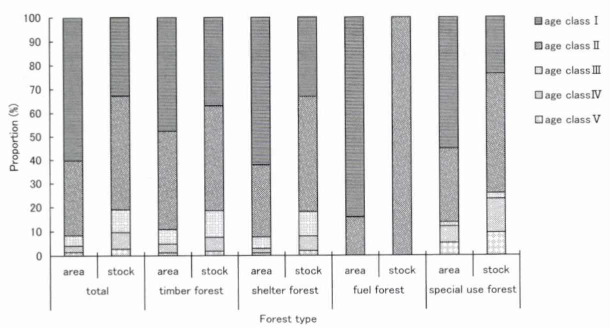

Fig. 3 The composition of stand area and stock of forest type among the age class
Sources: State Forestry Administration of China, 1994-1998, Forest Resources Survey

used to produce wood is 33 thousand ha with the stock of 1.6 million m^3, which makes up 16.2% and 23.8% of all stand area and stock in Beijing. The area of shelter forest that is used to conserve water resources, combat desertification, protect crops etc. is 139 thousand ha with the stock of 4.4 million m^3, which accounts for 67.6% and 64.1% of all area and stock. The area and stock of fuel forest and special use forest are 35 thousand ha and 0.9 million m^3. The stand area and stock proportion between different forest types are shown in Fig. 2.

As to the composition of forest age class at stand area, stock and different forest types, they can be seen in Fig. 3. According to the fifth forest resources survey in Beijing (1994-1998), the area and stock of young forest that age is below 10 years (broadleaf forest, bf.) or 20 years (coniferous forest, cf.) are 124 thousand ha and 225 million m^3, they account for 60.1% and 32.9% in all stand area and stock of Beijing. The area and stock of middle-age forest that age is between 11-20 (bf.) and 21-40 years (cf.) are 65 thousand ha and 3.3 million m^3, they make up 31.4% and 48.2% of all stand area and stock. Only 8.5% in area and 18.9% in stock are near mature forest, mature forest and over-mature forest that age are over 21(bf.) and 41(cf.). As to the composition of forest age among the different forest types, the proportions of area and stock in young forest and middle-age forest are 89.2% and 81.0% in the timber forest. In the shelter forest, they are 92.4% and 90.0% respectively.

Major Constraints

Based on the Ecological Environmental Construction Planning of Beijing (2001-2005), the forest coverage in Beijing will reach 48% by 2005, it will reach 50% by 2007 that has been put forward in the Beijing Olympic Action Plan. However, at present, the forest coverage is only 18.9% in Beijing, it is much lower than the targets that were put forward above. There is 347 thousand ha forestland need to be planted now, but most of them are distributed in the remote mountains in which the plantation is very difficult. This implicates it is almost impossible that forest coverage will be increased about 30% in 10 years. The second constraint is the distribution of forest resources is not even in Beijing. The data of Forest Resources Survey showed that most of forests are distributed in the mountainous areas, the forest resources are not abundant in the near suburbs. The third constraint is the forest stock per capita is very low and the proportion of young stand is very high, this means that forest resources at present situation can not fully maintain their environmental services. In order to hold "Green Olympic" successfully, how to increase forest resources and improve the their quality are the great challenges for the government, citizens and foresters in Beijing.

DISCUSSIONS

Forest Management Practices

In order to increase Beijing' forest resources and to realize "Green Olympic", the 10 important forest projects have been decided to implement. They include plantation along motorways, streets, alleys and waterway, construction of shelterbelts in the plain, management and protection of forest for water conservation etc., which the plantation is utilized as a major measure to increase forest resources. But they do not include the management and conservation of young forests and secondary forests (BEIJING FORESTRY DEPARTMENT, 2001). It can be believed that these forestry projects can improve forest coverage in Beijing, but much investment is needed to finish these projects. However, according to data of Forest Resources Survey in Beijing, over 90% forests in area are young forests, there are 101 thousand ha of secondary forest with low stock. Many researches showed that Closing Mountain to Regenerate Forests (CMRF) is a best approach to manage second forest and young forest in Beijing (XU and ZHENG, 1993; YU and YU, 2001; ZHAO, 1995). CMRF can transform the secondary forests and young forests into near natural forests with low cost. It seems that the management and conservation of young forests and secondary forests are much more important than the other projects in Beijing now. Enhancing the management and conservation of young forests and secondary forests are critical.

Urbanizations and Forest Conversion

In the past several decades, a tremendous amount of attention has been paid to the environmental endangerment caused by the conversion of forestland to urban use, especially in the developed countries. According to the National Agricultural Land Study of U.S.A., between 1967 and 1975, 650 thousand ha of forestland, about 81 thousand ha per year, were converted to urban, transportation, or water uses (GORDON 1984). In Japan, during the rapid economic development in 1960's and 1970's, many forestlands were converted into industrial lands, recreational lands. In Yokohama city, 3,700ha of the forestlands were urbanized during that period (UOZUMI, 1995).

In recent years, the GDP of Beijing had been increased approximately from 1.3 billion USD in 1978 to 34.1 billion USD in 2001. Its change can be seen in the Fig. 4. The average rate of economic growth was over 7% in each year, which is very high in the China (BEIJING STATISTICAL BUREAU, 2001). However, the rapid economic development also caused many problems. One problem was urbanization, which caused forest conversion, similar to other cities in the world.

Urbanization in Beijing, the largest metropolis in China, has been observed clearly since 1980's (QI, 1999; GAUNATZ, 1995). The area of city proper in Beijing increased from 151km² in 1947 to 649km² in 1997. This implicated that about 500km² of original farmland, forestland, grassland and other land had been converted into urbanized areas in the past 50 years. From 1994 to 1998, the 362ha forestland was converted to urban uses (SFA, 1994-1998). Secondly, the urban population proportion of Beijing has been increasing continuously from 54.9% in 1978 to 77.6% in 2001. On the contrary, the rural population proportion has been decreasing from 45.1% in 1978 to 22.3% in 2001 (Fig. 5). Thirdly, the urban population density increased from 284 persons/km² in 1978 to 637 persons/km² in 2001 (BEIJING STATISTICAL BUREAU, 2001).

Urbanization is an inevitable phenomenon accompanying with rapid economic growth in the world. It will cause the conversion of forests, especially in the suburban district. How to minimize the conversion of suburban forests is another great challenge for Beijing' government and foresters.

CONCLUSION

Olympic Game will be held in Beijing, 2008, it will take a great chance for its development, but at same time, there many challenges that Beijing has to face. As the center of politics and culture of China, Beijing has been doing its best in order to host Olympic Game. However, according to the present situation of forest resources, it cannot match target of "Green Olympics" now. Though many forestry projects have been doing in order to increase forest resources and improve environmental quality, the management and conservation of young forests and secondary forests are very important for holding of "Green Olympics" in Beijing. From the lessons of historical change of Beijing' forest resources, they were fluctuated with the change of policy-making. To keep the

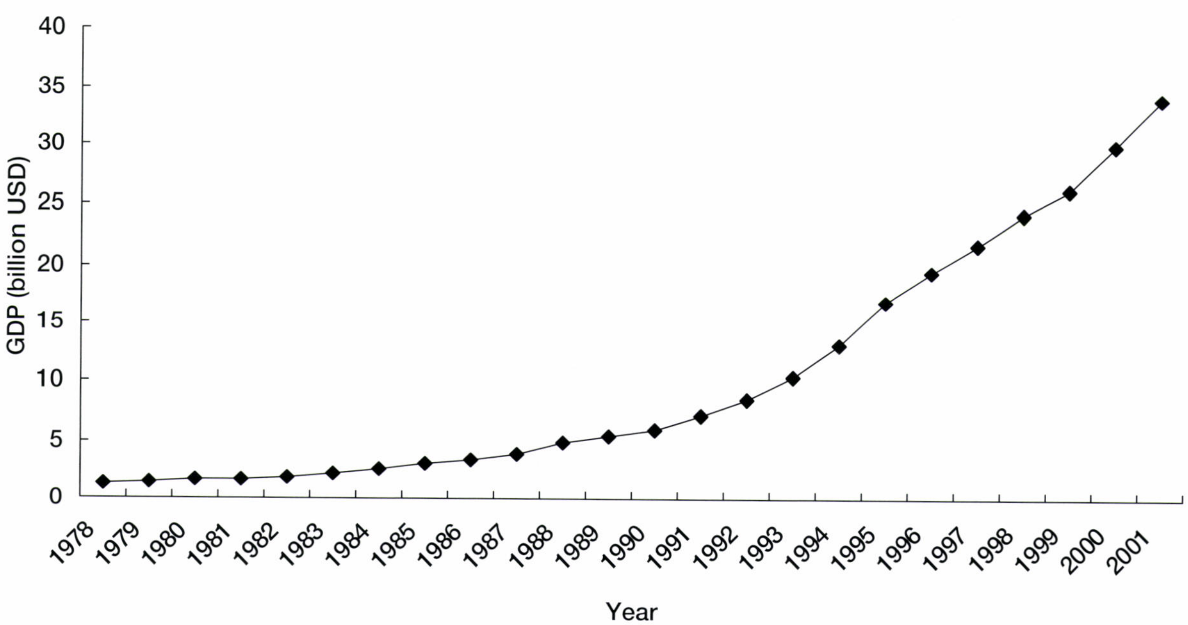

Fig. 4 The change of GDP in Beijing
Source: Beijing Statistical Bureau, 2001, Beijing Statistical Yearbook

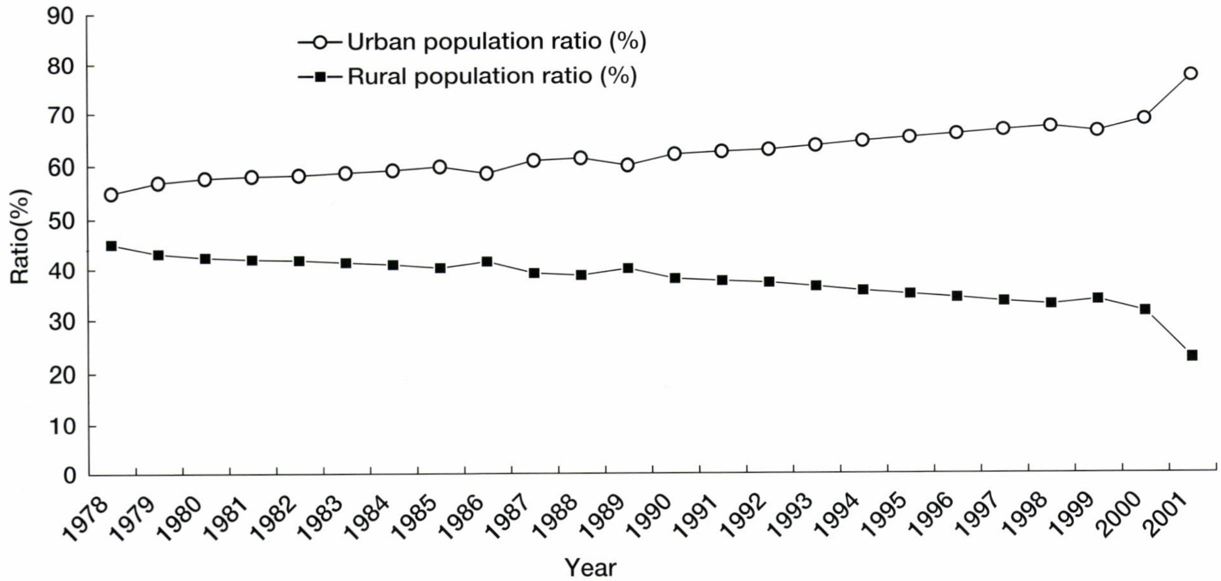

Fig. 5 The change of population ratios between urban and rural areas in Beijing
Source: Beijing Statistical Bureau, 2001, Beijing Statistical Yearbook

consistent policy of forest resources is very necessary in order to increase forest resources. With the rapid development of economics, the urbanization is inevitable, it is a serious threat to the forest resources in Beijing now. To minimize the conversion of forest resources is critical by the implementation of relative laws and regulations and communication of citizens.

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Article

Causes of Historical Deforestation and Forest Degradation in Cambodia

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ABSTRACT

Various demands for forestlands, wood, goods and services to meet the rapid economic development and fast growing population have put great pressures on tropical forests. Although forest clearing for agricultural land and pasture, and commercial logging coupled with government' policy failures are generally recognized as the major causes of deforestation, other causes have not been well documented. As a case study, this article aims at documenting forestry development and analysing the causes of deforestation and forest degradation in Cambodia. Forestry development in six different political regimes, namely, before 1970; 1970 to 1975; 1975 to 1979; 1979 to 1989; 1989 to 1993 and 1993 to the present was studied. Based on our analyses, we concluded that deforestation in Cambodia may have caused by intensive bombardments during the war time, forest clearing for resettlements, wood extraction for re-construction of war-devastated infrastructures, agricultural cultivation, and indiscriminate logging in recent years. Additional to deforestation, forest degradation may have resulted from indiscriminate felling and overexploitation. Cambodia would lose its important natural resource if immediate actions to stop deforestation and forest degradation is no undertaken.

Keywords: politics, war, forest degradation, deforestation, forest management

INTRODUCTION

If tropical forests are sustainably managed they can provide wood and non-wood products (medicines, nuts, fruits, resins, and food) as well as various goods and services, on a perpetual basis. The tropical forest is home to many species of flora and fauna, and it is also a pool for billions of tonnes of carbon that flows between terrestrial ecosystems and the atmosphere (Houghton, 1999; IPCC, 2001; Bolin and Sukumar, 2002). Carbon flux in the atmosphere has become a key issue for the 21st century because of global climate change caused by excessive emissions of carbon dioxide and other greenhouse gases through fossil fuel burning, deforestation, and other changes in land use. According to the forest resource assessment of the Food and Agriculture Organization of the United Nations (FAO FRA, 2000), natural tropical deforestation accounts for a large proportion of worldwide deforestation, about 0.39% (or 15.2 million ha) per year between 1990 and 2000 (annual worldwide natural deforestation is about 0.42%). As parts of the deforested natural forests have been offset by plantation establishment of mainly fast growing species (FAO, 2000), net change annual rate of tropical deforestation was estimated at 0.3% (or 12.3 million ha). Kirschbaum (2001) estimated that loss of tropical forests results in the release of approximately 1 billion tonnes of carbon to the atmosphere every year.

Some studies have attempted to explain tropical deforestation and its causes on a regional or a global scale (Brown and Pearce, 1994; Kaimowitz and Angelsen, 1998; FAO, 1997; FAO, 2000; FAO, 2001; 2003). Forest clearing for crop cultivation and pasture, and commercial logging (Kaimowitz and Angelsen, 1998; Geist and Lambin, 2001; Revington, 1992; FAO, 2003) are recognized as the major causes of tropical deforestation. As individual countries have different social, political and economic backgrounds, deforestation may have resulted from the same, similar or additional causes. Therefore, it is essential that causes of deforestation in

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a particular country be studied before any appropriate solutions can be taken to address the problems. Until recently, although only a few studies had examined forestry issues in Cambodia (KIM PHAT *et al.*, 1998; 1999; 2000; 2001; 2002), these studies were limited to case studies of forest concessions and growing stocks only. The WORLD BANK *et al.* (1996) has produced a comprehensive report on forest policy in Cambodia. According to this report, about 3 million ha of the remaining area has been degraded or negatively affected in some way in addition to the millions of hectares being converted to other uses. The causes of such deforestation and forest degradation have not been documented in Cambodia. Our main objective is to analyze and document the causes of forest degradation and deforestation in Cambodia.

Our research was based on rare unpublished forestry documents written in the local Khmer language. Due to the fact that Cambodia had gone through many political regimes whose development perspectives were differed from one to another, understanding the causes of deforestation and forest degradation in each regime would help us propose the effective measures or mechanisms to reduce or stop deforestation and/or degradation. Therefore, we divided our analysis into six regimes, namely, before 1970; 1970 to 1975; 1975 to 1979; 1979 to 1989; 1989 to 1993 and 1993 to the present. Since many forestry documents were burned during the years of political instability and wartime, especially during the Pol Pot's Democratic Kampuchea regime, reliable scientific references for our study are very limited. This study is the first scientific attempt to understanding the forestry practices in Cambodia.

FOREST RESOURCE AND FOREST COVER CHANGE

Forests are among Cambodia's most important and developmentally significant resources (WORLD BANK *et al.*, 1996). Unfortunately, during periods of civil war, Cambodia's forests have been destroyed and overexploited for many purposes. During the period of political stability between 1958 and 1969, Cambodian forest resources were stable at 13.2 million ha or 73% of the country's total land area. However, by 1973 this figure had declined to 12.7 million ha (TRAN and KOL, 1987), representing a loss of about 1% per year. Based on the Landsat remote sensing data with visual interpreting by the Land Use Mapping Office (LUMO) of the Ministry of Agriculture, Forestry and Fisheries (MAFF), and the Remote Sensing Mapping Unit of the Mekong Secretariat, the remaining forest area had declined to just below 11.3 million ha in 1993, and, by 1997, to 10.6 million ha (the 1997 data was taken from forest cover statistic produced by Forest Mapping Office of the Department of Forestry and Wildlife (DFW) with assistance of Mekong River Commission and Deutsche Gesellschaft fur Technische Zusammenarbeit (MRC/GTZ) under the Forest Cover Monitoring Project)- an annual loss of 0.6% (1969-1993) and 1.8% (1993-1997), respectively, over each period (Fig. 1). Over a 28-year period (1969 through 1997), Cambodia lost 2.6 million ha of forest - an average of 0.1 million ha (0.7%) annually.

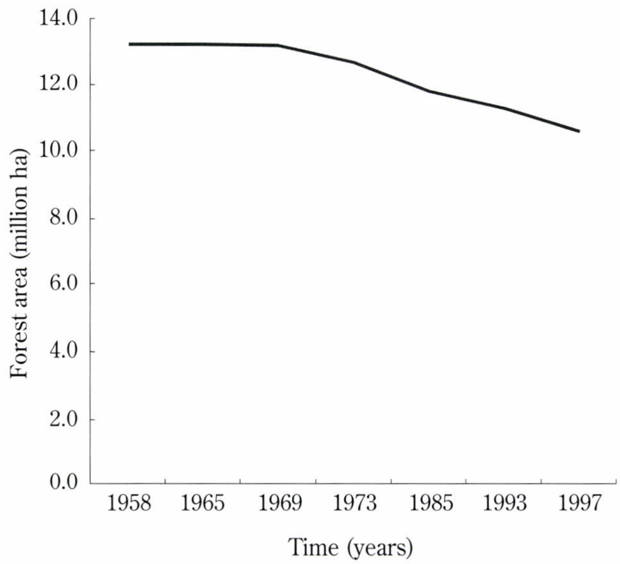

Fig. 1 Change in forest area in Cambodia (1958-1997)
Source: DFW (1998), World Bank et al. (1996), Tran and Kol (1995)

As different types of forests have different values, it is necessary to focus more detail on each type. There are 2 major types of forests in Cambodia: edaphic forests (forests along waterways) and dryland forests (the rest except plantations). Of the 10,638,206.0ha of forests that remain in 1997, edaphic forests make up 3.9% or 408,142.0ha, and dryland forests account for 96.1% or 10,230,064.0ha (Table 1). Edaphic forests comprise flooded forests (forests along the banks of freshwater streams and rivers) and mangrove forests. Edaphic forests are the source of firewood, food (fish, mammals, reptiles and other biodiversity) for local population. Dryland forests comprise evergreen, mixed, and deciduous forests and forest regrowth. Dryland forests are the major source of wood supply for local consumptions and exports.

Table 1 shows the dramatic change in forest land use that occurred between 1993 and 1997. During this period, edaphic and dryland forests lost 4,750.8ha or 1.1% and 50,621.3ha or 0.5% annually, respectively, and the area of unforested land increased by 55,372.0ha or 0.8% annually. In terms of area, although total forest area still account for 58.6% of the country's total land area, high-density forests have been converted to low-density forests such as disturbed and mosaic forests and regrowth (resulting from long-term abandonment due to limited access and security) as evident by rapid increase of such forests (Table 1). These data show clearly that Cambodia's forests are being degraded. Forest degradation will precipitate a serious wood-supply problem in Cambodia in the near future if immediate action and sound forest

Table 1 Land use change (1993-1997)

Land use	1993 (ha)	1997 (ha)	Annual loss (ha)	(%)
Total forest	10,859,694.0	10,638,206.0	-55,372.0	-0.5
Dryland	10,432,549.0	10,230,064.0	-50,621.3	-0.5
Dense evergreen closed	654,442.0	625,177.0	-7,316.3	-1.1
Disturbed evergreen	3,255,533.0	3,183,395.0	-18,034.5	-0.6
Mosaic evergreen	129,902.0	178,147.0	+12,061.3	+9.3
Subtotal (evergreen)	4,039,877.0	3,986,719.0	-13,289.5	-0.3
Dense mixed	99,124.0	95,560.0	-891.0	-0.9
Disturbed mixed	1,325,353.0	1,284,446.0	-10,226.8	-0.8
Mosaic mixed	110,066.0	125,320.0	+3,813.5	+3.5
Subtotal (mixed)	1,534,543.0	1,505,326.0	-7,304.3	-0.5
Deciduous	4,008,000.0	3,931,219.0	-19,195.3	-0.5
Deciduous mosaic	342,204.0	350,178.0	+1,993.5	0.6
Subtotal (deciduous)	4,350,204.0	4,281,397.0	-17,201.8	-0.4
Regrowth	435,618.0	374,197.0	-15,355.3	-3.5
Plantation	72,307.0	82,425.0	+2,529.5	+3.5
Edaphic	427,145.0	408,142.0	-4,750.8	-1.1
Inundated forest	229,266.0	219,906.0	-2,340.0	-1.0
Inundated forest regrowth	21,623.0	20,819.0	-201.0	-0.9
Inundated forest mosaic	98,587.0	94,582.0	-1,001.3	-1.0
Mangrove	77,669.0	72,835.0	-1,208.5	-1.6
Non-forest	7,293,290.0	7,514,778.0	+55,372.0	+0.8
Grand Total	18,152,984.0	18,152,984.0	0.0	0.0

Source: DFW (1998)

management are not undertaken. In an effort to determine the forces driving forest degradation and deforestation, we analyzed the historical causes of forest degradation and deforestation.

About 34% of the dryland forests (evergreen, mixed and deciduous forests) have been set aside for commercial logging under a forest concession system, 18% were designated as protected areas (national parks, wildlife sanctuaries, scenic protection, multipurpose-use areas, and others). Because of their social, environmental, and diversity functions, all edaphic forests were designated in 1993 as protected areas, where commercial logging is prohibited. The remainder are designated for agricultural, industrial, and other conversion (communities, resettlements) purposes.

HISTORICAL ANALYSIS OF FOREST DEGRADATION AND DEFORESTATION

Forestry Before 1970 (Socialist Period)

With more than 6,000 years of history (Rooney, 1994; Chandler, 1996), Cambodia is rich in cultural heritage and natural resources. In addition to building the great Angkor Wat, which is now World Heritage listed, and many other temples and items of hydrological infrastructure between the 9th and 13th centuries, the ancient Cambodians established a forestry administration, known as the Klong Prey Chheu (forestry office), before 634 BC in the reign of King Peak Varaman II (DFW, 1985). When Cambodia later became plagued by war, all forestry documents and records of these ancient management practices disappeared or were destroyed.

After initial studies of Cambodian forest resources by a French forest conservator and a French water conservator who visited Cambodia in early 1898, the first Cambodian ministry of forests was established in the same year with the support of French staff (DFW, 1985). Until 1942, when World War II spread to Cambodia, about 20% of the staff in Cambodia's forest sector were French. The French staffs were evacuated and did not return to Cambodia after the war, leaving forest management in the hands of the Cambodians. A forest research institute equipped with research facilities was established in 1963. The institute was well run, and good progress was made in the Cambodian forest sector (World Bank *et al.*, 1996). Annual log production during this period (before 1970) varied from 300,000 to 450,000m^3 - about 58% to 87% of the total annual allowable cut (AAC) in Cambodia (DFW, 1985; 1988).

According to a Royal Law that was adopted in 1845 under the reign of King Ang Duong and had effect until 1898 (DFW, 1985), newly married couples were authorized to fell trees freely for use as raw materials for new house construction. In addition, anyone could fell trees provided he or she paid the government 10% of the value on receipts for logs sold. Because only trees with high wood quality and high market prices (and that are primarily used for furniture), such as Afzelia (local name: Beng, scientific name: *Afzelia xylocarpa*), Indian rosewood (Nieng Nuon, *Dalbergia barriensis*), and Indochina rosewood (Kranuong, *Dalbergia cochinchinensis*) were felled, those trees gradually became extinct (DFW, 1985). In northeast Cambodia, where there are many hill tribes, between 50,000 and 100,000ha of natural forests were cleared for shifting cultivation between 1958 and 1964, and a further 10,000ha of dry dipterocarp forest was degraded into savanna each year because of fire (Ashwell, 1992). Shifting cultivators usually clear forests to plant highland crops for a bout 3-5 years. After this period when crop productivities become low, they abandon and move to clear other forests for the same purposes. This abandonment allows forests to regrowth. That would explain why forest area during this period was more or less constant. Nevertheless, as population is growing, shifting cultivation may continue to destroy forest resource if a sustainable practice is not sought for.

Forestry in the Khmer Republic under the Lon Nol Regime (1970-1975)

Lon Nol became president of the Khmer Republic as the successor of Prince Sihanouk, who was removed in 1970 (Chandler, 1996). Forestry activities were suspended when the war broke out (World Bank *et al.*, 1996). In terms of area, forests declined from 13.2 million ha in 1969 to 12.7 million ha in 1973 (Tran and Kol, 1987), representing a loss of 0.5 million ha.

When the Vietnam War broke out in 1965, Cambodia secretly provided territory along its eastern borders to the North Vietnamese for stationing their troops and for transportation of weapons, ammunition, and supplies (Chandler, 1996). These movements were known to American intelligence, and in early 1965 US B52 bomber aircraft secretly dropped bombs on targets located along the eastern border where North Vietnamese troops were stationed (Kiernam, 1985). US bombing activities continued until 1975. The use of chemical defoliants destroyed hundreds of thousands of hectares of watershed forests, wildlife sanctuaries, and rubber plantations to the east of the Mekong River. This region, including Kampong Cham, Kratie, Mondulkiri, and Ratanakiri provinces, contains around 4 million ha of forests, of which 2 million ha were devastated by this intense bombardment (Sing, 1993). Lon Nol's troops reportedly harvested many luxurious tree species such as Sena (local name: Thnong, scientific name: *Pterocarpus* spp.), Afzelia, Indian rosewood, and Indochina rosewood in Roneam Daunsam forest reserve along the Thai-Cambodian border (DFW, 1987). Continuous fighting between factions led by Lon Nol and the communist Khmer Rouge between 1970 and 1975 also contributed to the continuous destruction of forests in Cambodia. For instance, about 1,500ha of Teak plantation in Kampong Cham province was completely destroyed (DFW, 1987). Intensive US bombardment may have been a once-time cause of deforestation during this period, because since the end of the war a major fraction of bombarded forests were inaccessible or untouched due to guerrilla wars. Subsequent wars between different factions may have been the cause of forest destruction during this period.

Forestry in Democratic Kampuchea under Pol Pot (1975-1979)

Pol Pot was a communist leader who overthrew the Lon Nol regime in April 1975, and controlled Cambodia until early 1979. Shortly after he came to power, over 2 million Cambodians were pushed out of the cities and towns into remote areas toward an uncertain fate (Chandler, 1996). These displaced people were located mainly in the western part of the country, which was and is covered by forests. Although data on the amount of forest cleared are not available, it has been estimated that at least 1.3 million ha of dense forest were cleared (Kim Phat *et al.*, 1998), and at least 300,000ha of edaphic forests along the great Lake Tonle Sap and its tributaries were cleared and exploited for fuelwood (Mok, 1993). Fig. 2 shows the estimated rapid decline in the edaphic forest, which occurred at a rate of about 0.8% y^{-1} between 1973 and 1985. Deforestation rate of edaphic forests during this period is smaller than those reported at 1.1% annually between 1973 and 1997. Although no formal plans for logging were in place hundreds of thousands of trees were felled and exported to China, and some were left in the forests due to the lack of transportation means (DFW, 1987). Aside from forestry issues, between 1 and 2 million people were killed by execution, starvation, overwork, and disease during this brutal regime. Forest clearing may have been the cause of deforestation whilst logging contributed to forest degradation. As the displaced people were forced to move to the forested lands, it could be said that these forest lands were cleared for new settlements, agricultural cultivation, and other development needs as directed by the regime. As this regime ended, the displaced people returned to their hometowns. Due to the abandonment, some fraction of cleared forests may have regrown to secondary forests.

Forestry in the People's Republic of Kampuchea under Hun Sen (1979-1989)

Pol Pot was toppled from power by the Vietnamese invasion in early 1979, and his successors were Heng Samrin and later Hun Sen. Troops of the previous regimes were pushed into the dense forests, where they were treated as guerrillas[i] The country became known as the People's

Table 2 Annual log production in Cambodia (1979-1988)

Year	Volume (m^3)	Domestic consumption (m^3)	Domestic consumption (%)	Exports (m^3)	Exports (%)
1979	0.0	0.0	0.0	0.0	0.0
1980	0.0	0.0	0.0	0.0	0.0
1981	0.0	0.0	0.0	0.0	0.0
1982	67,700.0	65,947.0	97.4	1,753.0	2.6
1983	90,000.0	74,841.0	83.2	15,159.0	16.8
1984	73,279.0	58,114.0	79.3	15,165.0	20.7
1985	96,532.0	71,415.0	74.0	25,117.0	26.0
1986	126,245.0	100,773.0	79.8	25,472.0	20.2
1987	157,442.0	117,418.0	74.6	40,024.0	25.4
1988	155,445.0	97,664.0	62.8	57,781.0	37.2
Average	109,520.4	83,738.9	76.5	25,781.6	23.5

Source: DFW (1988)

Republic of Kampuchea (PRK) until 1989. After taking power in 1979, the government of PRK re-established ministries with the limited number of professional staff who survived the Khmer Rouge. Because the PRK regime was not legally recognized, its economy was internationally sanctioned for many years. Cambodia survived on its local resources and on aid from the former Soviet Union, its bloc, and India (CHANDLER, 1996). On 10 October 1979, the Department of Forestry and Wildlife (DFW) was re-established (DFW, 1988). The DFW, under the jurisdiction of the Ministry of Agriculture, Forestry, and Fisheries (MAFF), has had sole responsibility for all forestry activities in Cambodia since then. At first DFW had only 1 staff member with a bachelor's degree, 5 with some forestry education, and 10 without formal forestry education. However, by September 1988 staff numbers in the DFW had increased to 1,574 personnel. With help from Vietnamese forestry experts, some provinces in Cambodia were able to start their own forestry operations, including timber harvesting and sawmill construction (DFW, 1988).

When most of the displaced people returned to their villages after the civil war ended, they found that their houses, which were made mostly of wood, had been virtually destroyed. Wood materials for housing reconstruction were extracted from accessible forests (MOK, 1993). About 7.50 million m^3 of wood materials was required for this massive reconstruction (KIM PHAT *et al.*, 1998). This placed a heavy load on the forest resources of Cambodia. In another event, in 1979 the entire Cambodian population was authorized to harvest wood for housing construction purposes. However, this authorization triggered uncontrollable logging, because DFW did not have enough staff and resources to control and monitor tree felling and logging activities on such a large area of forest (DFW, 1987). Additionally, under a nationwide military campaign known as K5 (1983-1985), forests along the roadsides, in towns and military cantonments, and along some accessible national borders were cleared and burned to prevent guerrilla attacks (MOK, 1993). Large areas of forest were thus cleared and rendered unusable by the planting of mines. For instance, forests along National Road 4 from Phnom Penh to the town of Kampong Som were completely cleared. Although we have no official data on the area of forest area cleared for this military campaign, it has been estimated that hundreds of thousands of hectares was cleared or modified to secondary forest, dry deciduous forest, or savanna (Mok, 1993). During this regime, it could be said that anarchic wood extraction, indiscriminate felling and logging, forest clearing for security reasons may have caused forests being deforested and degraded.

Furthermore, as commercial logging during this regime became operational in 1982, annual log production increased over time from zero between 1979 and 1981 to 67,700.0m^3 in 1982 to 155,445.0m^3 in 1988; between 97.4% (1982) and 62.8% (1988) was consumed domestically. On average, the annual log production was 109,520.4m^3, 76.5% of which was consumed domestically (Table 2).

Satellite image data from 1986 show that the growing stock of all forests in Cambodia sharply declined from 1,295.42 billion m^3 in 1969 to 1,011.29 billion m^3 in 1986, representing a loss of 284.13 million m^3 - about 22% or 1.3% per year (DFW, 1988). Due to the lack of information, the quality of this satellite image was not known. This decline in growing stock no doubt resulted from overexploitation during all regimes after 1970, particularly from massive wood extraction for the reconstruction of war-devastated houses and infrastructure.

[1] guerrillas include those aligned with the Kingdom of Cambodia (Leader: Prince Norodom Sihanouk), Khmer Republic (Leader: Lon Nol, 1970-1975) and Democratic Kampuchea (Leader: Pol Pot, 1975-1979)

Forestry in the State of Cambodia Led by Hun Sen and the Transitional Government Presided by Prince Norodom Sihanuok (1989 to 1993)

It has been estimated that the forested area during this regime declined about 0.6% or about 0.12 million ha (Fig. 1). Total legal wood production increased sharply from 0.2 million m^3 in 1989 to 0.9 million m^3 in 1992 (World Bank et al., 1996). Moreover, based on available data in 1992 alone, about 378,000 and 250,000m^3 of Cambodian wood were illegally exported to Thailand and Vietnam, respectively (Sing, 1993). Only these figures of illegal wood production are about 6 times higher than the average legal wood exploited in previous regime between 1982 and 1988 (Table 2).

From 1991 to 1993, the government allowed competitive allocation of forest resource to some extent. Open stumpage sales (auctions), small in scale, were conducted by DFW for selected areas and volumes of logs. Inventory and tree marking by DFW preceded the auctions. The procedure included a post-harvest inspection to determine whether DFW would retain any part of performance guarantee payments required of all winning bidders. The system seems to have functioned reasonably well in 1991 and 1992 but became plagued by problems of collusion in 1993 (Ruzicka, 1998) before and during the first legislative election. Forest management and regrowth are included in the concession agreements. According to Sadoff (1993), these agreements could not be brought to the practice due to lack of funding and expertise to implement and enforce it. Additionally, the time frame of concessions routinely focuses on harvesting alone. Concessions did not include specified periods for replanting and regeneration. Therefore, concession holders were given little incentive to undertake adequate forest maintenance measures. It is encouraged wasteful and damaging patterns of logging (bad road construction, discriminate felling), and inevitable illegal logging and overexploitation (Sadoff, 1993; Dixon, 1993). Just before the 1993 election, about 300,000 refugees returned from refugee camps in Thailand to their villages (Chandler, 1996), where they had no land. Additional to devastated logging, theses refugee placements were likely to lead to the clearing of degraded lands, including forest lands, was presumably cleared for resettlement and agricultural cultivation. This clearing could not be avoided as population needed lands for housing and living. Overexploitation and logging were the causes of rapid degradation during this regime due to the lack of forest policy and effective law enforcement mechanism.

Forestry in the Kingdom of Cambodia under Prince Norodom Ranariddh and Hun Sen (1993-present)

Forest area declined from 11.3 million ha in 1993 to 10.6 million ha in 1997 (DFW, 1998), representing annual loss of about 0.2 million ha or 1.8%. Dryland forests lost about 0.1 million (0.9%) per year (Table 3), while edaphic forests lost about 75,000ha (10.7%) per year (Fig. 2) over the same period. Due the unavailability of information, it was impossible to provide the figures of forests being cleared for specific purposes. Indiscriminate logging is continuously practiced in this regime (Global Witness, 1996; 1997; 1998; 1999). Additionally, clearing of degraded forests for agricultural expansion (Eang, 2002) was another major cause of deforestation of dryland forests, whilst clearing of flooded forests along great lake Tonle Sap and its tributaries for agricultural cultivation, firewood and fish traps (ADB, 2002; Lamberts, 2001; Fisheries Action Coalition Team, 2001; Mok *et al.*, 2001), and clearing of mangrove forests for shrimp farming, charcoal making and firewood (Paul, 1998; Bann, 1997) were the major causes of the loss of edaphic forests.

Table 3 Changes in dryland forest cover (1958-1997)

Year	Dryland (million ha)
1958-1969	12.4
1973	11.7
1985	11.0
1993	10.6
1997	10.2

Source: DFW (1998), World Bank et al. (1996), Tran and Kol (1995)

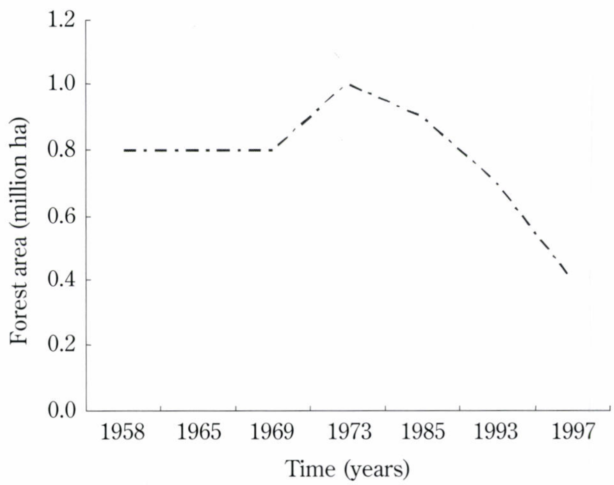

Fig. 2 Changes in edaphic forest cover (1958-1997)
Source: DFW (1998), World Bank et al. (1996), Tran and Kol (1995)

Just before and during the election campaigns in 1993 and 1998 there was widespread corruption, collusion, and illegal logging throughout the country (Global Witness, 1996; 1997; 1998; 1999). In 1993, in an effort to reduce illegal logging and increase government revenue (World Bank *et al.*, 1996), a forest concession system was introduced. The area of forest concessions increased dramatically from 2.2 million ha in 1993 to 4.8 million ha in 1999 ([2]Global Witness, 1999; DFW, 1998). However, illegal logging and overexploitation were observed taking place in both concession and non-concession areas (Kim Phat *et al.*, 2001). Total annual wood production was estimated at about 1.5 million m^3 between 1993 and 1995 (World Bank et al., 1996). In addition, another 894,000m^3 of illegal wood production was estimated in 1995 ([2]Global 1996). In 1996, wood production from illegal logging alone was estimated at about 945,000m^3 in 1996 ([2]Global Witness, 1997) additional to total wood production. In 1997 total wood production in Cambodia was estimated at 3.3 million m^3; 67% of this production came from illegal logging (Table 4). Although there is no information on present total annual allowable cut (AAC) of forests in Cambodia, available previous data gave an amount at about 0.5 million m^3 in 1960s (DFW, 1988). Even compared to this figure, legal wood production in 1997 was about 2.2 times higher than total AAC, and thus total wood production in the same year was 6.6 times higher than total AAC. This represents a serious problem in Cambodian forest sector at present and future.

Table 4 shows that illegal logs and sawn wood were found mostly in the eastern, western and northern regions of Cambodia. These are the regions that are close to Thailand and Vietnam, the countries to which almost all illegal logs and sawn wood are exported ([1]DAI, 1998). As illegal logging was still practiced without effective control and monitoring during this regime, it may have been a major cause for deforestation, and forest and environmental degradation. Furthermore, the rapid increase in total forest concessions along with ineffective measures may have been contributed to illegal logging, and thus lead to deforestation and forest degradation (the latter resulted from overexploitation).

CONCLUSION

We concluded that bombardment during the war, forest clearing for various purposes as imposed by each regime, and forest clearing for agricultural cultivation may have been the major causes of deforestation whilst indiscriminate logging (illegal logging and overexploitation) may have caused both deforestation and forest degradation. Nevertheless, as Cambodia has been in a state of peace and political stability since the second election in 1998, war is no longer a cause of deforestation. Stopping indiscriminate logging, well-planned logging operations along with enforcement mechanism will reduce deforestation and forest degradation in Cambodia.

Since the majority of Cambodians still depend almost solely on forests for fuelwood consumption, house construction and food, and agricultural production, fasting growing population will still pose a pressure on forests unless alternatives are sought for, i.e. alternative sources of cooking energy, and improvement of the productivity of existing agricultural lands. Government subsidies are required to make this happen. Proper land use planning, and reducing the rate of population growth could help to release the pressure on remaining forests. Long-term government commitment to reducing indiscriminate logging including illegal logging, deforestation and forest degradation as well as to forest monitoring and control over forest concession operations is needed if Cambodia is to bring its valuable forests under sustainable use and management. Because illegal logging and export of timber usually occur near or along borders with neighbouring countries, it is important that all countries concerned should honestly cooperate to combat illegal logging. Besides deforestation, forest degradation is a serious problem for Cambodia as it can not be easily observed. Enrichment planting of commercial tree species is required. When necessary, logged-over forest areas should be set aside as forest reserves until they have enough mature timber to harvest.

Although with limited information sources, this study has attempted to analyze and document the causes of deforestation and forest degradation in Cambodia consecutively since the early date of forestry establishment. Our study findings would be improved when more information become available.

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[2] Since figure for illegal logs and sawn wood is not recorded, it is usually obtained through rough estimation. Global Witness, a London-based environmental watchdog conducted field research at log stockpiles along the borders, interviewed the log import-export companies concerned, and estimated the volumes of illegal logs and sawn wood. DAI estimated the illegal logs in Cambodia based on satellite imagery interpretation, surveillance flights over forest areas to confirm findings, conducting field research, and interviewing government officials, forest concession managers and workers to obtain estimates of log and sawn wood move-ments. DAI (Development Alternatives, Inc) is a US-based consultant company hired in 1997 by World Bank (IDA Credit 2664-KH) to conduct a national assessment of illegal forestry activities in Cambodia, evaluate present log tracking and timber revenue assessment systems, and recommend improved procedures within the context of a comprehensive forest law enforcement program.

Table 4 Change in percentage of forest cover by province (1969-1997) and wood production (1997)

Province or city	Total area ('000 ha)	1969 (%)	1993 (%)	1997 (%)	Log and sawn wood production (1997) in m^3	
					Legal	Illegal
Central region						
Kampong Cham	936	60.0	28.2	28.1	na	45,000
Kompong Tom	1,308	60.0	52.0	50.9	68,400	na
Kratie	1,206	90.0	75.9	75.5	80,900	48,750
Subtotal	3,450				149,300	93,750
Eastern region						
Mondulkiri	1,370	90.0	78.4	78.0	25,000	22,850
Ratanakiri	1,256	90.0	85.1	82.8	na	311,100
Subtotal	2,626				25,000	333,950
Western region						
Battambang	1,250	60.0	47.3	46.7	na	416,700
Kompong Speu	676	60.0	52.3	49.7	na	80,000
Sihanouk Vill	143	na	63.4	61.8	na	131,000
Koh Kong	1,296	90.0	87.1	84.6	15,400	44,500
Kampot	502	60.0	50.1	48.9	58,300	911,000
Pursat	1,146	90.0	70.0	69.4	na	153,500
Banteay Meanchey	748	na	29.8	26.1	na	44,500
Subtotal	5,761				73,700	1,781,200
Northern region						
Preash Vihear	1,359	90.0	89.3	88.6	na	65,000
Stung Treng	1,117	90.0	89.7	88.7	na	30,000
Siem Reap	1,573	60.0	57.3	54.9	na	20,000
Subtotal	4,049					115,000
Other regions						
Kompong Chhnang	528	60.0	32.8	32.6	na	na
Kandal	366	13.0	6.0	5.8	na	na
Prey Veng	485	13.0	1.9	1.6	na	na
Svay Rieng	285	13.0	1.8	1.6	na	na
Takeo	343	13.0	4.5	1.5	na	na
Tonle Sap lake	222	0.0	0.0	0.0	na	na
Phnom Penh	40	na	3.0	3.0	na	na
Subtotal	2,269				836,200	na
Total	18,154	72.9	60.1	58.6	1,084,200	2,208,900

Source: DAI (1998) for log and sawn wood production, and DFW (1998) for forest area

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Article

Management System for Japanese Oak on the Kyushu University Forest in Hokkaido - Experiment for the 30-year Period -

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ABSTRACT

Since 1972, an experimental management system for Japanese oak (*Quercus mongolica* var. *grosseserrata*) has been studied in a natural Japanese oak forest, approximately 200ha in area, in the Kyushu University Forest in Hokkaido. The management system was based on the clearcutting system in tongue-shaped blocks surrounded by shelterbelts; rotation was 150 years. The silvicultural process in this management system was designed to produce high-quality timber. For 30 years between 1973 and 2002, the number of first-year oak seedling established by the silvicultural process averaged 55,000 per ha per year. For 30 years between 1972 and 2002, the area managed averaged 9.11 ha per year. For 30-years, the timber volume derived from thinning and final cutting averaged 198m^3 per year. The revenue obtained by selling this timber averaged 892,000 yen per year. The cost of silvicultural process averaged 557,000 yen per year, excluding the costs of staff and other factors owing to the Kyushu University Forest. Thus the average net revenue per year was 335,000 yen for the 30-years.

Keywords: Japanese oak, management system, working system, silvicultural process, natural regeneration

INTRODUCTION

In April 1972, an experimental management area of approximately 200ha was established for Japanese oak (*Quercus mongolica* var. *grosseserrata*) in a natural Japanese oak forest of the Kyushu University Forest in Hokkaido. The management system was based on the clearcutting system in tongue-shaped blocks surrounded by shelterbelts (Imada, 1973). Its rotation was 150 years. Hence, the entire area was divided into 150 cutting blocks for annual yield and have been managed by the silvicultural process designed to produce high-quality timber of Japanese oak (Imada, 1972; 1976).

This experiment is expected to continue for 150 years between 1972 and 2121. The 150 years are divided into 15 sub-periods of 10 years each. In an earlier study, the results of 20 years between 1972 and 1991 have been already reported (Imada, 1996). The purpose of this report is to analyse the results of 30 years between 1972 and 2001 and to investigate the probability of this management system based on the data obtained through 30 years.

STUDY AREA

The study area, approximately 200ha, is a part of the Kyushu University Forest in Hokkaido which is located in eastern Hokkaido (Fig. 1). As shown in Fig. 2, this study area extends across two watersheds with mostly gentle slopes (under 15 degree slopes) from 200 to 360m in altitude. Most of this area is classified as Tertiary stratum. The ground surface is generally covered with volcanic soil of more than 10cm in depth.

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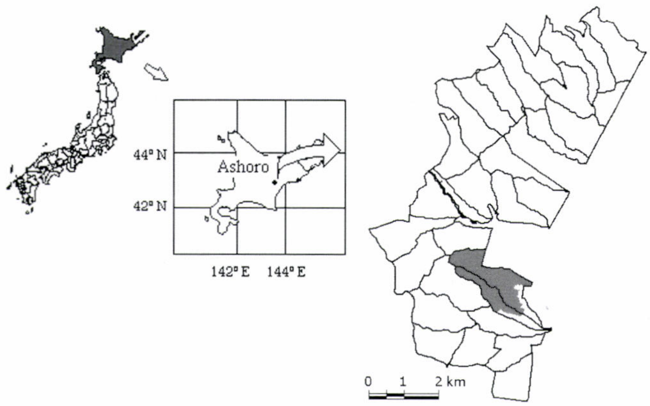

Fig. 1 Location of Kyushu University Forest of Hokkaido

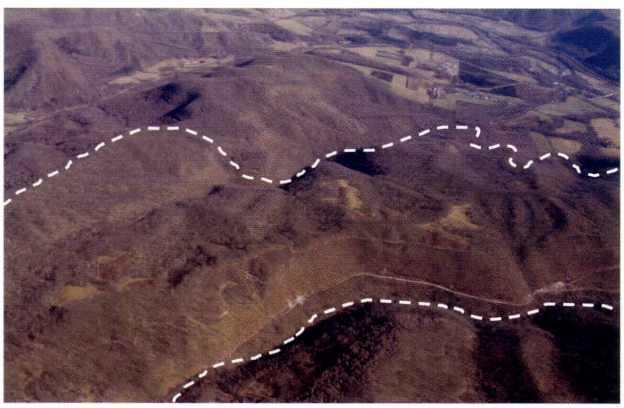

Fig. 2 Topography of experimental forest
Note: white broken line indicated experimental forest boundary

Mean annual temperature is about 6℃. In winter, the lowest temperature is sometimes -30℃ and therefore the forest floor is frozen to 1m in depth and covered with snow of 30cm in depth from middle November to early April. Mean annual precipitation is about 800mm.

When the experimental forest was set up, this area was covered with natural broad-leaved tree species, mostly composed of Japanese oak from 5 to approximately 200 years old, lacking of 80- to 130-years-old trees. The forest floor was covered with grass species, mainly composed of Miyakozasa (*Sasa nipponica*) from 30 to 50cm in height.

EXPERIMENTAL MANAGEMENT SYSTEM

Silvicultural Process

Experimental area in this natural forest was created to gain the data related to technology, ecology and economics. This was designed based on clearcutting and natural seeding system using seeds from the just-harvested trees on site. In the case of poor seed years, transplanting was added. Each step of the silvicultural process is as follows.

(1) Site preparation before regeneration cutting

Before seed dispersal on the site to be cut (early September), non-seed trees and weeds are removed and line scarification of the forest floor is carried out either by cultivator on gentle slopes or by manual hoe on steep slopes. This site preparation is applied both to the regeneration strips and non-regeneration strips. The pattern of this scarification is shown as regeneration strips in Fig. 3 and Fig. 4.

(2) Seed supply for the regeneration strips

After all of the seeds have fallen (in mid-October), the dispersed seeds on the non-regenerated strips (1m wide) are

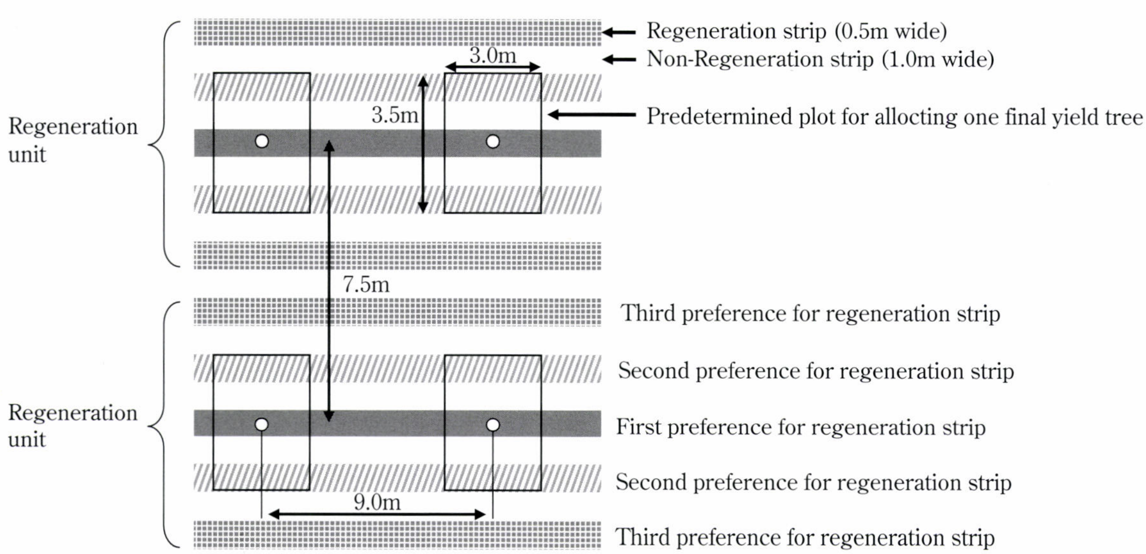

Fig. 3 Pattern of organizing of the regeneration-cut area (step6 under the silvicultural process)

collected and transferred to the regeneration strips (0.5m wide) (see Fig. 3). If the number of dispersed seeds on the regeneration strips after transfer is yet insufficient for the desired goal- a first-year stocking of 15 seedlings per 1m × 0.5m (100,000 per ha)-, the seeds collected from the near stands are simultaneously transferred to the regeneration strips.

(3) Soil covering for dispersed seeds

Immediately after seed supply, the dispersed seeds on the regeneration strips are covered with soil by the same methods used for site preparation.

(4) Regeneration cutting

When the forest floor is frozen and covered with snow (in March of the following year), the uppermost trees (seed trees) in the regeneration blocks are clear-cut and removed from the forest floor.

FI$_4$ (see Fig. 8) FI$_5$ (see Fig. 8)

Fig. 4 Line scarification of forest floor by cultivator in FI$_4$ (Regeneration I in 1994) and FI$_5$ (Regeneration I in 1998)

(5) Removal of logging debris

After the snow on the forest floor melt but the forest floor is still frozen (late April), logging debris is removed.

(6) Organizing the regeneration-cut area

After all of the seeds germinated (mid-July), the regeneration-cut area are organized as shown in Fig. 3. This operation means that allocations of the 150 trees per ha for final yield as shown in Fig. 5 is roughly predetermined and thereby the preferential order for regeneration- i.e., which strips the final yield trees are located on- is given simultaneously for each of 5 regeneration strips combined into one regeneration unit. In addition, the density of the seedlings is investigated.

(7) Seedlings supply for regeneration strips

In accordance with the above preferential order for regeneration and the data on seedling density obtained in step 6, nursery-grown seedlings and natural seedlings collected near the harvested stand are additionally planted in those regeneration strips with poor seedling. This planting is in late September when the seedlings are dormant.

(8) First weeding

In the next year of step 7, on the non-regenerated strips first weeding is applied, and on the regeneration strips both tall weeds and undesirable tree sprouts are removed.

(9) Second weeding

In the next year of the first weeding, on the non-regenerated strips second weeding is applied, and on the regeneration strips both the natural and planted seedlings (3 years old) are cut close to the ground-level with a brush cutter in order to germinate vigorous stump sprouts.

(10) Cleaning

When the stand develops into 15 years old, the first cleaning is carried out, and undesirable trees in the

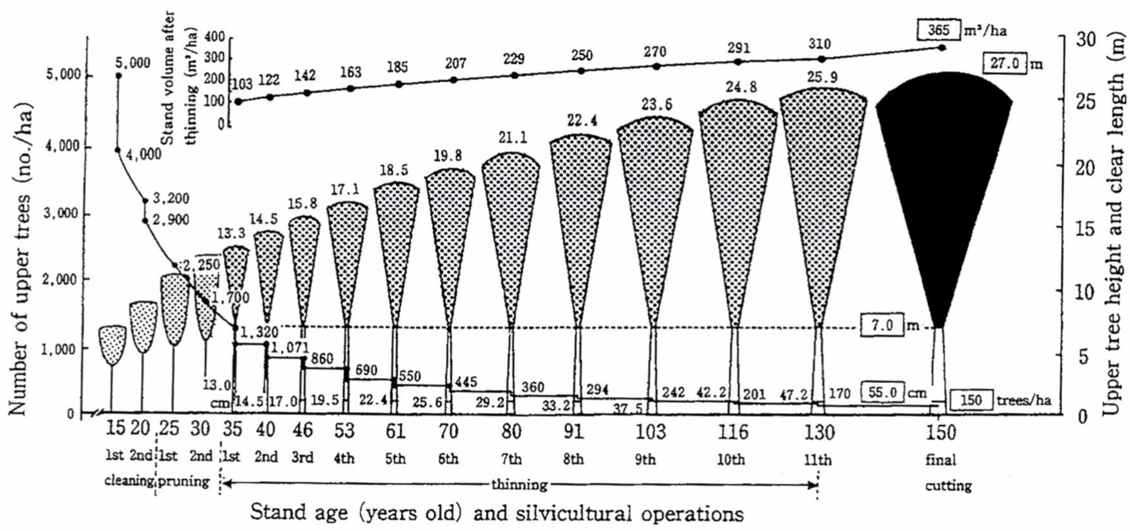

Fig. 5 Silvicultural process after first cleaning for Japanese oak stands

predetermined plots (Fig. 3) and surrounding of these plots are removed subject to the silvicultural process in Fig. 5. In the year when the stand develops into 20 years old, the second cleaning is carried out by the same method.

(11) Pruning

When the stand develops into 25 years old, the most desirable oak tree for final yield is selected from each predetermined plots in Fig. 3, and is pruned up to 6m above the ground. When the pruned trees develop into 30 years old, the second pruning is extended to 7m (the target height shown in Fig. 5).

(12) Thinning

Thinning starts when the stand develops into 35 years old, 13.0cm in DBH, 13.3m in height, 7m in clear length, 1,320 trees per ha and 103m³ per ha expected in the silvicultural process. Fig. 5 indicates that eleven thinnings are carried out for 35- to 130-year-old stand subject to the silvicultural process. The removed trees at each thinning are selected from surrounding of the final yield trees.

In Fig. 5, the 150-year-old target stand established by the above silvicultural process is expected to develop to 55cm in DBH, 27m in height, 7m in clear length, 150 trees per ha and 365m³ per ha.

On the results of the silvicultural process in first 20 years, see IMADA (1972; 1996).

Working System

This experimental management system, aiming at useful broad-leaved trees such as Japanese oak, Udaikanba (*Betula maximowicziana*), Harigiri (*Kalopanax pictus*) and Itayakaede (*Acer mono*), is composed of the above silvicultural process and the following working system termed "clearcutting system in tongue-shaped blocks surrounded by shelterbelts".

The cutting blocks and forest roads under this working system are established as shown in Fig. 6 on the assumption that two roads are constructed on the same hillside. The center part of cutting blocks is a small ridge, which is equivalent to a yarding boundary line. The production (clear-cut) area in the block is surrounded by shelterbelts, which are natural (unclearcut) oak forests. Those shelterbelts have the additional functions as follows: seed stands supplying the seed (step 2 in the silvicultural process), temporary nursery supplying for the seedlings (step 7 in the one) and forest reserves supplying timber which is yielded by individual trees cutting.

As shown in Fig. 6, the forest roads are constructed along contour so that the surface water on roads flows toward the small ridge top under standard gradient of -5% and so that the production (clearcut) area in the block is within 50-meter from the forest road. The former is due to minimize the road surface degradation and the latter due to keep the production (clearcut) area within the extraction distance by the mobile yarder. Because of the resulting road curves, the cutting block looks as if it were a tongue. Consequently, the cutting block shown in Fig. 6 is termed "tongue-shaped block".

The working group (DAVIS, 1966) aiming at sustainable production under this working system is organized as shown in Fig. 7 on the assumption that the working group is composed of two main watersheds and each watershed is

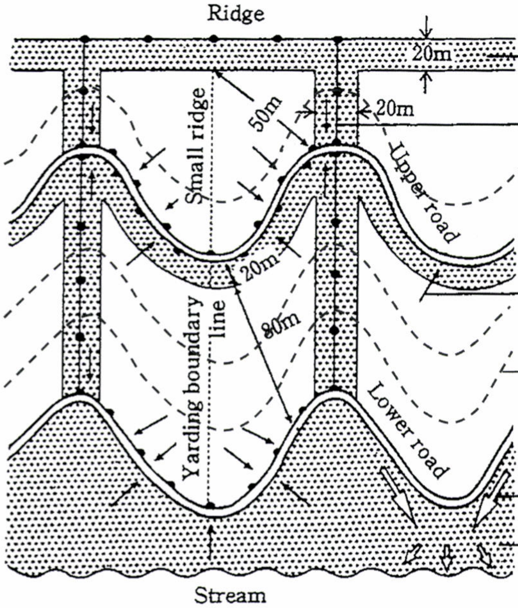

Fig. 6 Established tongue-shaped blocks and forest roads under the clearcutting system in tongue-shaped blocks surrounded by shelterbelts

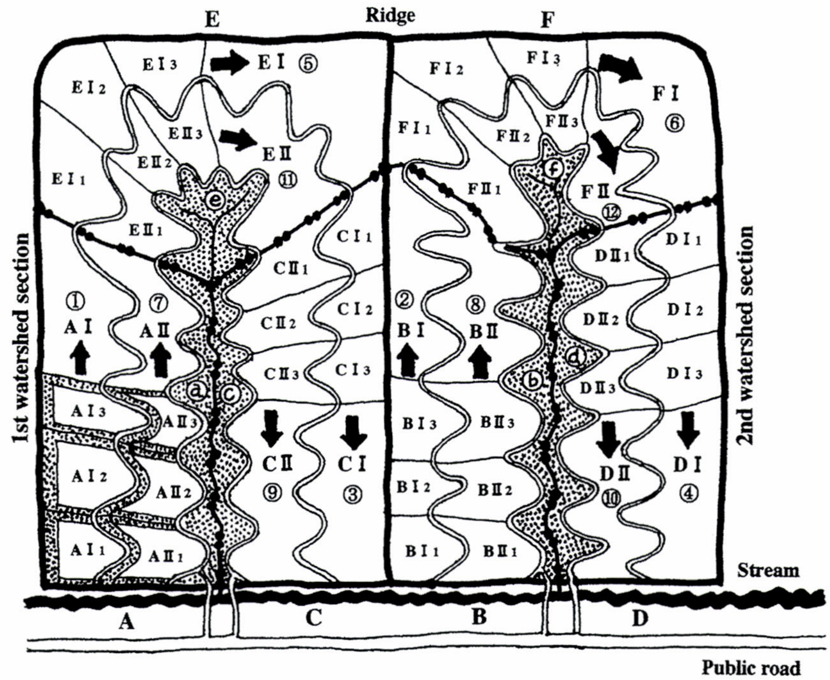

Fig. 7 Working group under the clearcutting system in tongue-shaped blocks surrounded by shelterbelts

Notes : A I$_1$—A II$_1$, A I$_2$—A II$_2$, A I$_3$—A II$_3$, and so on are equivalent to the tongue-shaped blocks as shown in Fig.6.
ⓐ,ⓑ,ⓒ,ⓓ,ⓔ,ⓕ are indicate shelterbelts for A, B,C,D,E,F sub-watershed section, respectively.
▬▬ : indicates boundary of watershed section
-•-•- : indicates boundary of sub-watershed section

divided into right, left and upper hillside and two roads are constructed on each hillside along contour as shown in Fig. 6.

This working group is firstly divided into "watershed sections" (1st and 2nd) considering the formation of watershed on the ground and the size uniformity of the area divided. These watershed sections are secondly divided into "sub-watershed sections" (A, B, , , , ,F) such as right, left and upper hillside in the same manner as division of watershed sections. The sub-watershed sections are thirdly divided into "cutting series" (AI, AII, BI, BII, , , ,F1, FII) by the forest roads constructed along contour as shown in Fig. 6. The preceding cutting blocks shown in Fig. 6, termed "tongue-shaped blocks"(AI$_1$, AII$_1$, BI$_1$, BII$_1$, , , , F1$_1$, FII$_1$, etc.) , result in being incorporated into any cutting series.

In Fig. 7, clearcutting sequence is represented on the basis of the above space organization for the working group so that clear cutted areas appear annually as far as possible. Clearcutting sequence for sub-watershed section (A, B, , , , F) is firstly determined so that annual cutting in the same watershed section and sub-watershed section is not continued at least two years. The alphabetical order from A through F indicates the annual cutting sequence per each sub-watershed section. Clearcutting sequence for cutting series (AI , AII, BI, BII, , , , , ,F1, FII) is secondly determined so that annual cutting in the same sub-watershed section proceeds from the upper cutting series to the lower one. The Rorman order from I to II indicates the annual cutting sequence per each cutting series in each sub-watershed section. The numerals such as ①, ②, ③, , , , , ,⑫ in Fig. 7 indicate the clearcutting sequence for the entire working group per each cutting series. This sequence indicated by the numerals is thirdly determined by summarizing the above sequence for each division. The arrow marks in Fig. 7 fourthly indicate fixed proceed direction for annual cutting in each cutting series. The subscripts such as $_{1,2,3}$ in AI$_1$, etc. which are "tongue-shaped blocks" regarded as cutting blocks indicate the annual cutting sequence in each cutting series.

Experimental Organized Forest

The 200-ha experimental forest which was regarded as one working group was organized by appling both the working

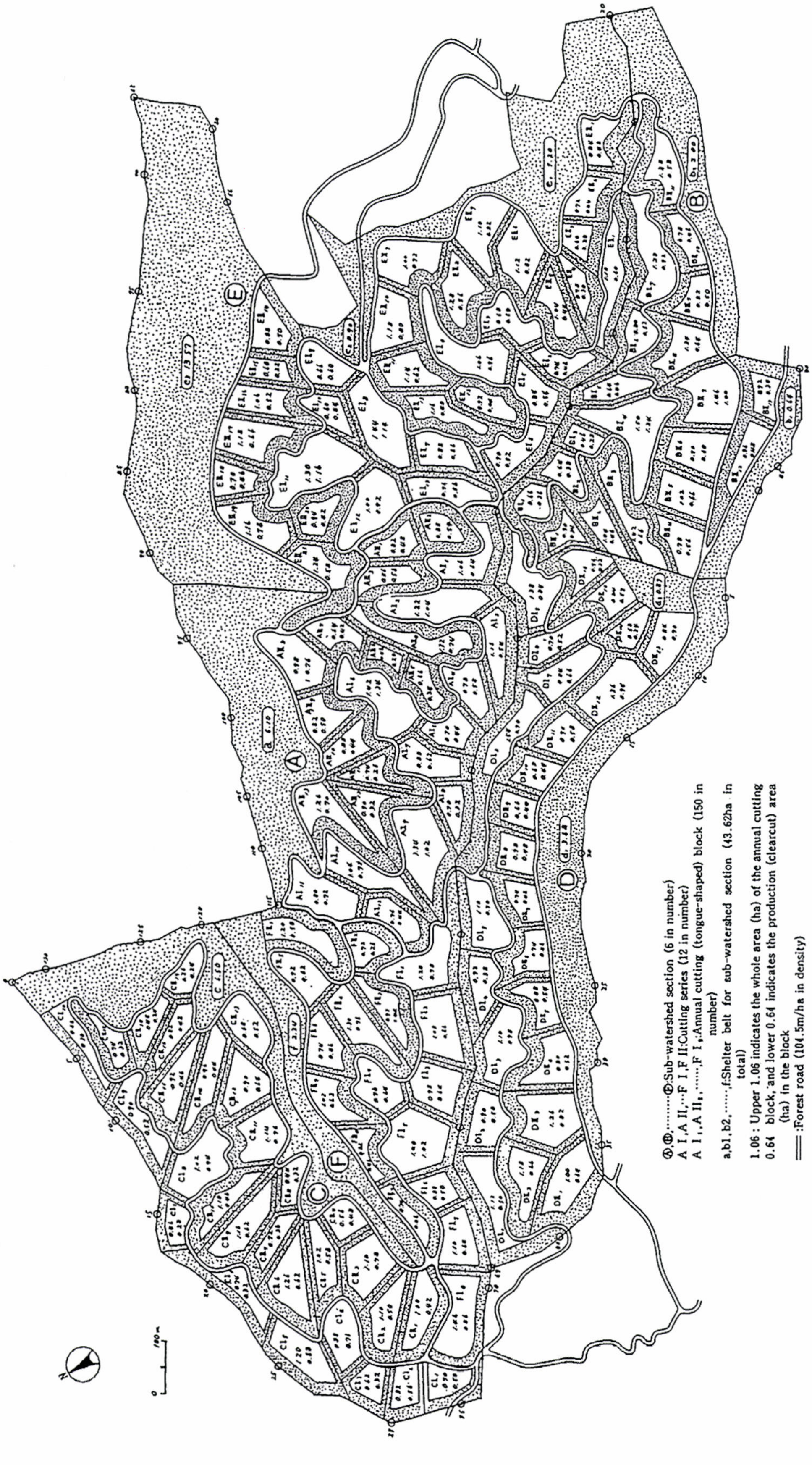

Fig. 8 The entire experimental forest under the clearcutting system in tongue-shaped blocks surrounded by shelterbelts (203.08ha)

Table 1 Areas of the divisions in the experimental forest

Sub-watershed section	Cutting series	Annual cutting block Number	Area (ha) Productioan	Area (ha) Shelterbelt	Area (ha) Total	Forest road area (ha)	Shelterbelt for Sub-watershed (ha)	Total area (ha)
A	AI	12	8.48	3.38	11.86	3.57	6.10	32.75
(9)	AII	13	6.26	4.96	11.22			
B	BI	7	4.16	1.72	5.88	3.15	2.64	23.51
(8)	BII	13	7.24	4.60	11.84			
C	CI	10	5.18	2.82	8.00	3.56	6.50	34.42
(9)	CII	19	9.18	7.18	16.36			
D	DI	9	5.66	3.74	9.40	3.37	4.55	31.32
(8)	DII	16	8.82	5.18	14.00			
E	EI	13	9.16	2.80	11.96	5.17	21.49	59.36
(9)	EII	21	11.36	9.38	20.74			
F	FI	8	5.74	3.06	8.80	2.40	2.34	21.72
(9)	FII	9	4.58	3.60	8.18			
計		150	85.82	52.42	138.24	21.22	43.62	203.08

Table 2 Experimental plan for the experimental forest for the first 30- of the 150-year period

Period	Year \ Operation	Regene-ration I	Regene-ration II	1st weed.	2nd weed.	1st. Clean	2st. Clean	1st prun.	2nd prun.	1st thin.	2nd thin.	3rd thin.	4th thin.	5th thin.	6th thin.	7th thin.	8th thin.	9th thin.	10th thin.	11th thin.
1st planning period	1972	AI1	—	—	—	EII6	AII8	BII12	DII13	DII1	DI1	DI6	AI11	AII13	EI7	—				
	1973	BI3	AI1	—	—	EI3	BI7	BII13	BII6	EI11	DII2	DII9	FII6	FII1	EII14	—				
	1974	CI1	BI3	AI1	—	EII7	EII16	BII8	DI3	DII3	DI2	FII5	FII7	CI7	CII10	—				
	1975	DI4	CI1	BI3	AI1	EII9	EII17	BII5	AI10	EI13	BI1	EII15	EII11	EI10	EII1	—				
	1976	EI4	DI4	CI1	BI3	EII8	BII11	DII12	EI12	AII12	FII3	CII7	EII2	FII8	CII15	—				
	1977	FI1	EI4	DI4	CI1	BII10	EII6	AII8	BII12	DII13	DII1	DII4	DII10	BI6	EI6	—				
	1978	AI2	FI1	EI4	DI4	EII5	EI3	BI7	BII13	BII6	EI11	DI1	DII8	EII10	BI2	—				
	1979	BI4	AI2	FI1	EI4	BII1	EII7	EII16	BII8	DI3	DII3	DII2	DI6	BII3	EI8	—				
	1980	CI2	BI4	AI2	FI1	FI6	EII9	EII17	BII5	AI10	EI13	DI2	DII9	AI11	AII2	—				
	1981	DI5	CI2	BI4	AI2	BII9	EII8	BII11	DII12	EI12	AII12	BI1	FII5	FII6	AII13	—				
2nd planning period	1982	EI2	DI5	CI2	BI4	EI1	BII10	EII6	AII8	BII12	DII13	FII3	EII15	FII7	FII1	EI7	—			
	1983	FI2	EI2	DI5	CI2	BII4	EII5	EI3	BI7	BII13	BII6	DII1	CII7	EII11	CI7	EII14	—			
	1984	AI3	FI2	EI2	DI5	DII5	BII1	EII7	EII16	BII8	DI3	EI11	DII4	EII2	EI10	CII10	—			
	1985	BI5	AI3	FI2	EI2	DII6	FI6	EII9	EII17	BII5	AI10	DII3	DI1	DII10	FII8	EII1	—			
	1986	CI3	BI5	AI3	FI2	DII7	BII9	EII8	BII11	DII12	EI12	EI13	DII2	DII8	BI6	CII15	—			
	1987	DI7	CI3	BI5	AI3	AI1	EI1	BII10	EII6	AII8	BII12	AII12	DI2	DI6	EII10	EI6	—			
	1988	EI5	DI7	CI3	BI5	BI3	BII4	EII5	EI3	BI7	BII13	DII13	BI1	DII9	BII3	BI2	—			
	1989	FI3	EI5	DI7	CI3	CI1	DII5	BII1	EII7	EII16	BII8	BII6	FII3	FII5	AI11	EI8	—			
	1990	AI4	FI3	EI5	DI7	DI4	DII6	FI6	EII9	EII17	BII5	DI3	DII1	EII15	FII6	AII2	—			
	1991	CI4	AI4	FI3	EI5	EI4	DII7	BII9	EII8	BII11	DII12	AI10	EI11	CII7	FII7	AII13	—			
3rd planning period	1992	DI8	CI4	AI4	FI3	FI1	AI1	EI1	BII10	EII6	AII8	EI12	DII3	DII4	EII11	FII1	—			
	1993	EI9	DI8	CI4	AI4	AI2	BI3	BII4	EII5	EI3	BI7	BII12	EI13	DI1	EII2	CI7	EI7	—		
	1994	FI4	EI9	DI8	CI4	BI4	CI1	DII5	BII1	EII7	EII16	BII13	AII12	DII2	DII10	EI10	EII14	—		
	1995	AI5	FI4	EI9	DI8	CI2	DI4	DII6	FI6	EII9	EII17	BII8	DII13	DI2	DII8	FII8	CII10	—		
	1996	CI5	AI5	FI4	EI9	DI5	EI4	DII7	BII9	EII8	BII11	BII5	BII6	BI1	DI6	BI6	EII1	—		
	1997	DI9	CI5	AI5	FI4	EI2	FI1	AI1	EI1	BII10	EII6	DII12	DI3	FII3	DII9	EII10	CII15	—		
	1998	FI5	DI9	CI5	AI5	FI2	AI2	BI3	BII4	EII5	EI3	AII8	AI10	DII1	FII5	BII3	EI6	—		
	1999	AI6	FI5	DI9	CI5	AI3	BI4	CI1	DII5	BII1	EII7	BI7	EI12	EI11	EII15	AI11	BI2	—		
	2000	CI6	AI6	FI5	DI9	BI5	CI2	DI4	DII6	FI6	EII9	EII16	BII12	DII3	CII7	FII6	EI8	—		
	2001	FI7	CI6	AI6	FI5	CI3	DI5	EI4	DII7	BII9	EII8	EII17	BII13	EI13	DII4	FII7	AII2	—		

Note: Regeneration I indicates the regeneration process from site preparation before regeneration cutting to regeneration cutting. Regeneration II indicates the regeneration process from removal of logging debris to seedling supply for generation strips. AII_1, BI_3, · · · · , AII_{13} indicate annual cutting (tonque-shaped) blocks in Fig. 8

system and 150-year rotation in the silvicultural process as shown in Fig. 8 and Table 1.

The allocations of divisions in this experimental forest such as 150 cutting blocks termed "tongue-shaped blocks", 12 cutting series, 6 sub-watershed sections, forest roads (104.5m/ha) and shelterbelts for sub-watershed sections (43.62ha in total) are represented in Fig. 8.

In Table 1, the areas of the divisions are summarized along the number of the cutting blocks. The production (clearcut) area within the cutting block was 0.57ha in average (85.82ha in total), varying widely from 0.20 (AII_6) to 1.34ha (AI_6) shown in Fig. 8. Such variation was due to the distribution of small ridges in the experimental forest (Fig. 2).

The experimental plan for this 150-year period was developed in 1972, based on the silvicultural process. The experimental plan for the first 30-year period (the first, second and third periods between 1972 and 2001) of the 150-year period is shown in Table 2. At the beginning of this experiment, the 7th to 11th thinnings in the silvicultural process were not carried out because of lack of the 80- to 130-year-old stands.

Table 2 shows that Regeneration I containing from site preparation before regeneration cutting (step 1 in the silvicultural process) to regeneration cutting (step 4 in the one) was applied for the cutting series allocated at the upper part of slopes for the first 30-year period between 1972 (AI_1) and 2001 (FI_7). Natural young and middle-aged stands such as BI_1, BI_2, DI_1, DI_2 and DI_3 were excluded from Regeneration I. For these natural stands, some of the silvicultural operations such as cleaning, pruning and thinning was planed. For example 2nd (40-year) thinning in 1975 for BI_1, 6th (70-year) thinning in 1978 for BI_2, 2nd (40-year) thinning in 1972 for DI_1, 2nd (40-year) thinning in 1974 for DI_2 and 2nd (30-year) prunning in 1974 for DI_3 were applied.

RESULTS AND DISCUSSION

Based on Table 2, the results obtained for the 30 years were analyzed as follows.

Number of First-year Oak Seedlings Established by Regeneration Process

First, the number of first-year oak seedlings established by the regeneration process from site preparation before regeneration cutting (Step 1 in the silvicultural process) to 2nd weeding (Step 9 in the one) for the 29 years between 1973 and 2001 was analyzed using the data on seedling density obtained in step 6 in the silvicultural process.

Fig. 9 shows the density of first-year oak seedlings established by natural seeding or planting for the 29 years between 1973 and 2001. This density varied widely from 5,000 (in 2001) to 133,000 (in 1974); it averaged 55,500. Such variation was due to variable masting in seed production of Japanese oak natural forests (IMADA *et al*, 1990).

Because of poor seed, transplanting was added to natural seeding in 1975, 1976, 1982, 1987, 1994, 1996 and 2001. The density of transplanted seedlings in these 7 years ranged from 5,000 (in 2001) to 24,000 (in 1982). In the transplantation system, a spacing of 1.5m (the interval between regeneration strips in Fig. 3) by 0.9m, that is, 7,200 seedlings per ha is the desired goal (IMADA *et al*, 1997). In comparison with this goal, the density for 1987 (6,000 per ha) and 2001 (5,000 per ha) was insufficient.

Mean density of seedlings established by natural seeding was 68,600 over the 29-year period. This mean density is insufficient for a natural seeding system, the goal being 100,000 seedlings per ha, as shown in Fig. 9. Years in which the density of 100,000 seedlings were established were 1974

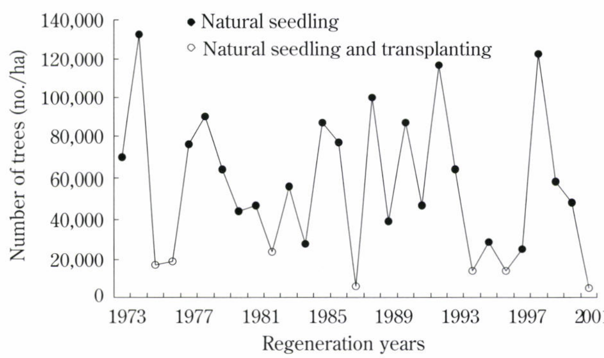

Fig. 9 First-year oak seedling established by natural seedling and transplanting for the 29 years between 1973 and 2001

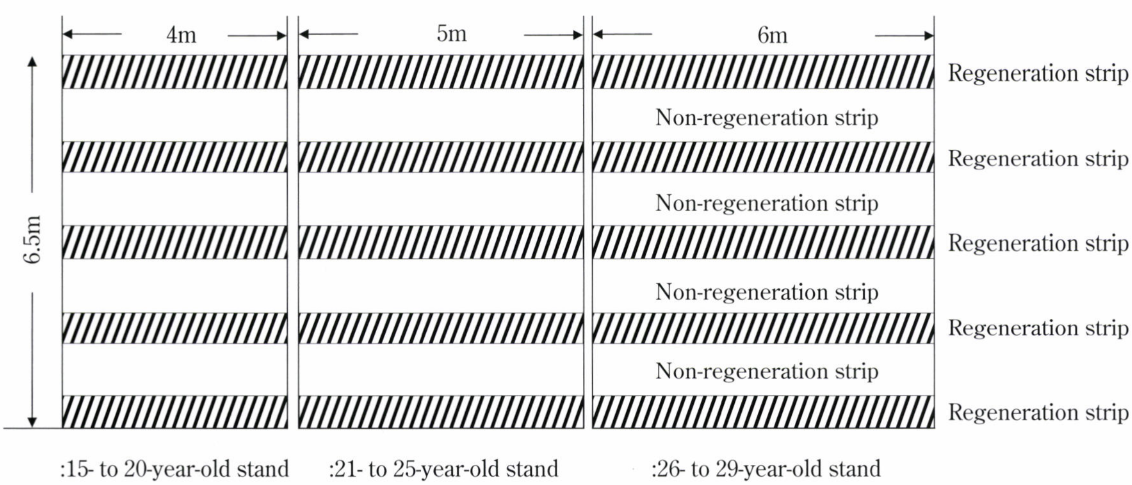

Fig. 10 Plot measured in the stands established by the regeneration process under step 1 to step 7 in the silvicultural process

(133,000), 1978 (90,000), 1985 (87,000), 1988 (99,900), 1990 (87,000), 1992 (117,000) and 1998 (123,000).

Development Patterns of Stands Operated by Silvicultural Process

Second, development patterns of the stands operated by the silvicultural process were analyzed using the data obtained from the following 15 stands (15- to 29-year-old). When the stands established by the regeneration process are near 15 years old, the vertical stratification of the canopy develops. Of course, such stratification is generally observed in the natural oak stands. In 2001 when the stand established in 1973 developed into 29-year-old, we set up 3 to 6 plots in each stand as shown in Fig. 10, at nearly equal interval according to the stand size to be measured. We measured tree height, clear length and DBH of every upper tree. Simultaneously, we measured tree height, clear length and DBH of every upper tree in the following 14 natural stands of 30-, 35-, 40-, 46-, 53-, 61-, 70-, 80- and 91-year-old, and 57-, 64-, 67-, 75- and 85-year-old. The former 9 stands have the same age after the operation designated under the silvicultural process in Table 2, and the latter 5 stands have the same mean age after two successive operations between 53- and 91-year-old. In these 14 natural stands, we set up 2 to 4 plots of 0.03 to 0.05ha, according to the stand size and age. These ages of the natural young and middle-aged stands, some operations of cleaning (for 15- and 20-year), pruning (for 25- and 30-year) and thinning (for 35-, 40-, 46-, 53-, 61- and 70-year) was applied in 1972, were estimated by comparing the number of trees per ha, DBH, tree height of previously measured natural stands with the designated stand structure shown in Fig. 5. In this study, we defined "upper trees" as trees higher than 70% height of the tallest oak tree in each plot. "All upper trees" contain the other species such as Shirakanba (*Betula platyphylla* var. *japonica*), Udaikanba (*Betula maximowicziana*), Harigiri (*Kalopanax pictus*), Itayakaede (*Acer mono*).

(1) Tree density

Fig. 11 shows the density of all upper trees from the 15- to 91-year-old stand and the stand density of all upper trees estimated under the silvicultural process. The former density in the 16- and 19- to 29-year-old stands was higher than the latter density.

Upper canopy layer in the 15- to 25-year-old stands was invaded by pioneer faster-growing trees such as Shirakanba. Consequently, the density of oak upper trees was remarkably low in these stands, but tended to increase with stand age. In the stands over 26-year-old, oak trees almost occupied upper canopy layer.

(2) Tree height

Fig. 12 shows the mean tree height of both all upper trees and oak upper trees in the 15- to 91-year-old stands and the mean height of all upper trees estimated under the silvicultural process.

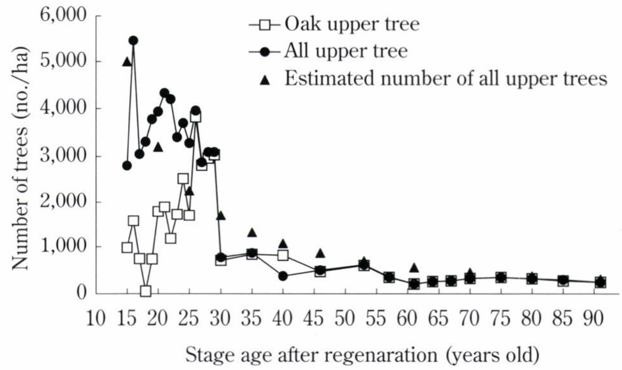

Fig. 11 Number of upper trees

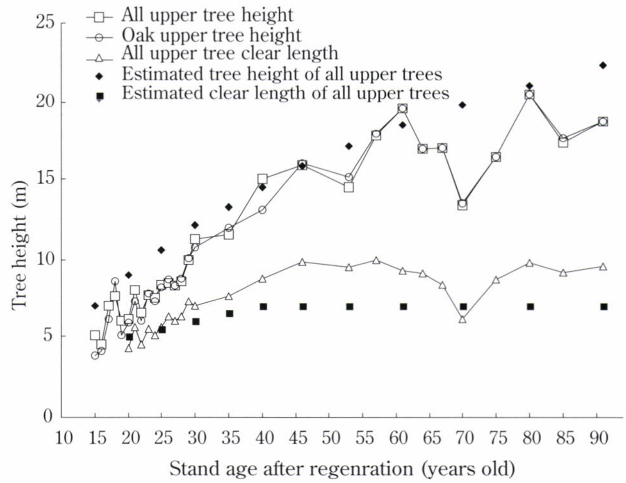

Fig. 12 Tree height and clear length of upper trees

Comparing actual upper tree heights of the 15- to 29- year-old stands with the estimated heights of all upper trees , actual upper tree heights were approximately 1 to 2m lower than the estimated heights.

(3) Clear length

Fig. 12 also shows the mean clear length of all upper trees in the 20- to 91-year-old stands and the mean clear length of all upper trees estimated under the silvicultural process. The mean clear length of oak upper trees is not shown in Fig. 12 because the clear length was nearly equal to the one of all upper trees.

Comparing the clear lengths of actual all upper trees with the clear lengths of all upper trees estimated under the silvicultural process, the former was nearly equal to or longer than the latter in the 20- to 29-year-old stands.

(4) DBH

Fig. 13 shows the mean DBH of all upper trees in the 15- to 91-year-old stands and the mean DBH of all upper trees estimated under the silvicultural process. The mean DBH of oak upper trees is not shown in Fig. 13, because the DBH was

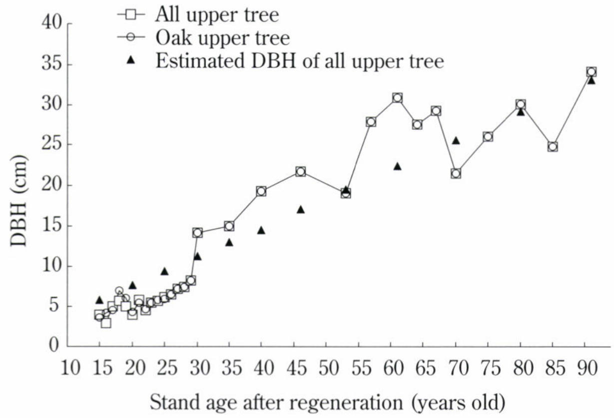

Fig. 13 DBH of upper trees

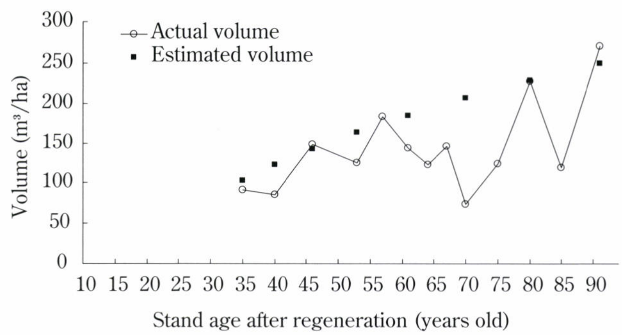

Fig. 14 Stand volume of upper trees

nearly equal to the one of all upper trees.

The DBH growth was nearly constant (approximately 5mm per year) in the 21- to 29-year-old stands. Comparing the mean DBH of all upper trees with the mean DBH of the all upper trees estimated under the silvicultural process, the former was approximately 2cm lower than the latter in the 15- to 29-year-old stands on the whole.

Stand Structure of 14 Natural Stands

(1) Tree density

The density of all upper trees in the 14 natural stands was lower than the stand density of the all upper trees estimated under the silvicultural process (Fig. 11).

(2) Tree height

In the 30- to 35- year-old stands, all upper tree heights were approximately 1 to 2m lower than the estimated heights. All upper tree heights were nearly equal to the latter in the 40- to 61-year-old stands except for the 53-year-old stand. In the stands over 64-year-old, all upper tree heights extremely varied from 13.4m (in the 70-year-old stand) to 20.5m (in the 80-year-old one) and seemed to be generally 2m to 4m lower than the estimated height (Fig. 12).

(3) Clear length

In the 30- to 46-year-old stands, the clear lengths of all upper trees were 1 to 3m longer than the estimated one and slightly increased with stand age. In the stands over 46-year-old, the increasing tendency of the clear lengths was obscure. These results suggest that the target clear length should be reconsidered (Fig. 12).

(4) DBH

In the 30- to 46-year-old stands, the actual DBH was approximately 2 to 4cm larger than the estimated DBH. In the stands over 46-year-old, the DBH extremely varied from 19.0cm (in the 53-year-old stand) to 34.2cm (in the 91-year-old stand) (Fig. 13).

(5) Stand volume

Fig. 14 shows the stand volume of all upper trees and the stand volume of all upper trees estimated under the silvicultural process. In the 35- to 57-year-old stands, the stand volume of all upper trees seemed to increase with stand age and to be 10 to 30m^3 per ha less than the estimated stand volume on the whole. On the other hand, in the stands over 61-year-old, the stand volume extremely varied from 74 (in the 70-year-old stand) to 271m^3 per ha (in the 91-year-old stand).

Wide variation of stand volume in the natural stands were due to the wide variations of the tree height and the DBH related strongly to the stand volume, irrespectively the narrow variations of the stand density in Fig. 11.

Areas Managed by the Silvicultural Process

Third, the areas managed by the silvicultural process for the first 30 years were analyzed. These analysis are limited to the areas of the stands on the cutting blocks initially converted into the managed stands through regeneration I (step 1 to 7 in the silvicultural process), such as cleaning (step 10), pruning (step 11) and thinning (step 12) for the first 30 years between 1972 and 2001.

The number of analyzed stands were 30, 20, 10 and 40, respectively, for the 30 years between 1972 and 2001 as shown in Table 2. The reason why the number of these managed stands is 100 in total (2/3 of the 150-stands on the production area within the cutting blocks) in spite of the first 30 years, was that the natural young and middle-aged stands were initially converted into the managed stands.

The areas managed by the silvicultural process for the first 30 years are shown in Fig. 15. The areas varied from 7.02 (in 1973) to 12.28ha (in 1999), with an average area of 9.11ha. Collating the areas in Fig. 15 with the experimental plan outlined in Table 2 suggests that the areas managed between 1972 and 1981 were small by the areas where the 7th thinning was not carried out and those managed between 1972 and 1974 were small by the areas where regeneration II regeneration process from removal of logging debris (step 5 in the silvicultural process) to seeding supply for regeneration strips (step 7 in the one) and weeding was not carried out;

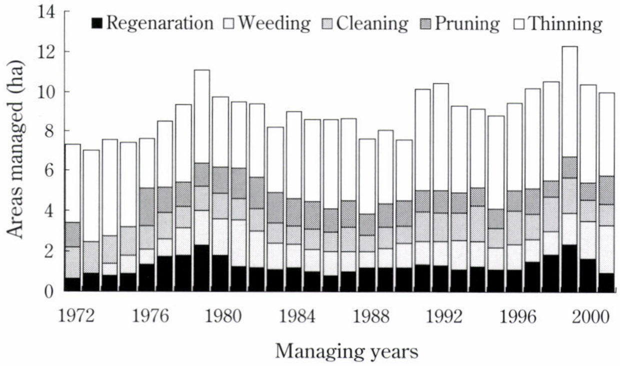

Fig. 15 Area managed by the silvilcultural process for the 30 years between 1972 and 2001

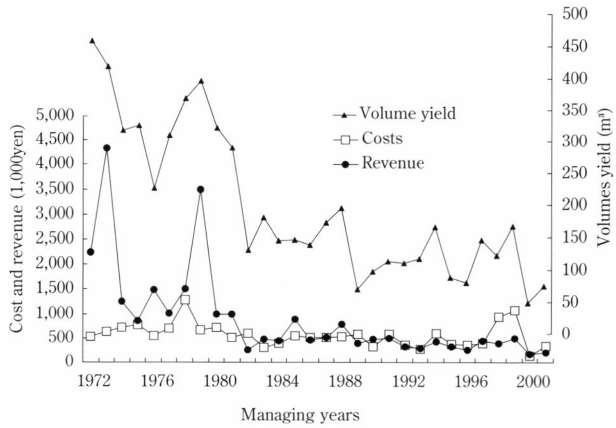

Fig. 16 Costs, revenues and volumes yield for the 30-years between 1972 and 2001

furthermore, those managed between 1982 and 1992 were small by the areas where the 8th thinning was not carried out. However, the variation in the managed areas was caused mainly by the variation in the size of the clearcutting blocks.

The areas managed by each silvicultural operation, i.e., regeneration, weeding, cleaning, pruning and thinning, as shown in Fig. 15, can be described briefly as follows:

(1) The area applied regeneration (from step 1 to step 7) averaged 1.30ha, ranging widely from 0.64 (in 1972, when regeneration II was not carried out) to 2.36ha (in 1999), although only the clear cutted areas reduced to 0.66ha on the average (19.74ha in total).

(2) The area applied weeding averaged 1.21ha over the 30-year period. The area of weeding was smaller than that of regeneration, because the areas for the first and second weedings were lacking in 1972 and 1973 and that for the second weeding was lacking in 1974 (Table 2).

It was observed that in nearly 7-year-old stands, oak trees considerably disappeared because of suppression by Ezoyama-hagi (*Lespedeza bicolor*) and Ezomurasakitutuji (*Rhododendron dauricum*) which invaded into the stands. Third weeding for non-regenerated strips, hence, was carried out in the 7-year-old stands from BI_5 (in 1988) to FI_4 (in 1997) in 2nd weeding on and after 1992 (the 3rd planning period). However, the area applied this 3rd weeding was not included in the areas managed in Fig. 15. These results suggest that we should discuss to incorporate 3rd weeding into the silvicultural process.

(3) Over the 30-year period, the area applied cleaning averaged 1.23ha and that applied pruning averaged 1.21ha. Thus, cleaning and pruning were carried out on almost equal areas. However, there was considerable variation in both areas: that for cleaning ranged from 0.84 (in 1988 and 1990) to 1.78ha (in 1999) and that for pruning ranged from 0.84 (in 1998 and 2000) to 1.86ha (in 1976).

(4) The thinning was carried out over wide area-125.16ha in total. The number of cutting blocks thinned in the first 10 years averaged 6 blocks per year; average area was 3.52ha per year. The number of the blocks thinned in the second and third 10 years averaged 7 and 8 blocks per year except for 1992, respectively; average area was 4.19 and 4.80ha per year, respectively. Despite the difference in the number of blocks thinned, the difference among the average areas for three periods was small because of variation in the areas of the cutting blocks thinned.

Costs, Revenues and Volumes Yielded

Last, the cost, revenues and volume yield for the 30 years between 1972 and 2001 were analyzed for all 442 blocks shown in Table 2.

Fig. 16 shows the costs, revenues and volume yield for the 30 years between 1972 and 2001.

(1) The volumes yielded by the final harvests and thinning averaged 198m³ per year and decreased with time.

(2) The revenues obtained by selling this timber volume varied widely from 171,000 yen (in 2000) to 4,333,000 yen (in 1973) and averaged 892,000 yen per year.

(3) The costs of the various silvicultural operations ranged from 141,000 yen (in 2000) to 1,286,000 yen (in 1978) and averaged 557,000 yen per year. Note that the annual management costs of staff and the other factors owing to the Kyushu University Forest was excluded from the computed costs.

(4) Cost exceeded revenue in the 11 years: 1982, 1986, 1989, 1991,1992, 1994, 1995, 1996, 1998, 1999 and 2001. However, the average net annual revenue for the 30-year period was 335,000 yen, an amount calculated by subtracting the average cost per year (557,000 yen) from the average revenue per year (892,000 yen).

CONCLUSIONS

This reported management system for Japanese oak

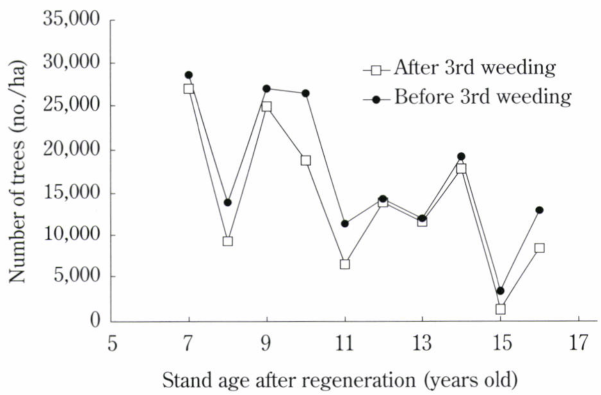

Fig. 17 Number of trees in the stand applied 3rd weeding

forest was profitable for the first 30 years since its installation in 1972. The profitability will vary in accordance both with silvicultural operations cost determined by the market prices of labor, equipment, materials, and with revenues determined mainly by the market price of Japanese oak timber. Of course, improvements should be made both to the silvicultural operations themselves and also to the clearcutting system in tongue-shaped blocks surrounded by shelterbelts.

In regard to the improvements of the silvicultural operations, the target clear length of 7m in Fig. 5 was determined for yielding two 10 feet (3.1m)-logs from each stem. Considering the result of the clear length shown in Fig. 12, the target clear length can be changed to 8.5m from each stem of which three 2.6m-log in the future.

In the case of poor seed years, transplanting was added to natural seeding system. In the present planting system, the planting is carried out after site preparation before regeneration cutting (step 1 in the silvicultural process), irrespective of the amount of oak seed supply, because of difficulty in foreseeing seed supply to the stand in advance of seed dispersal. In order to eliminate unnecessary site preparation mentioned above in the poor seed year, it is necessary to find the foreseeing method for seed supply. Furthermore, the foregone planting density of 20,000 seedlings per ha, a spacing of 1.50m by 0.35m, was already converted into the new density of the 7,200 seedlings per ha , a spacing of 1.5m by 0.9m, on and after 1997 (IMADA *et al.*, 1997).

As mentioned previously, the 3rd weeding for the 7-year-old stand was already carried out on and after 1992. Fig. 17 shows the number of trees per ha from the 7- to 16-year-old stands in 2001 which were weeded in the year when these stands developed into 7 years old for the 30 years between 1972 and 2001. The 3rd weeding was effective to survive young oak trees because of considerably high dominance ratio of oak trees on the whole. Hence, the 3rd weeding should be added to the silvicultural process and to the experimental plan for 150-year period, accordingly.

Investigating the profitability of the reported management system and improving its shortcomings will require that the experiment be continued over a long period.

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Article

A Sunny Crown Profile Equation for Hinoki Cypress based on the Height Increment

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ABSTRACT

The power equation $r = az^b$ is often used to represent the sunny crown profile of conifers, where r is the crown radius (m) at distance z (m) from the tree apex, and a and b are parameters. When parameter b is invariant between trees, parameter a is the only independent variable that determines the sunny crown profile. Assuming that parameter b is invariant between trees, this study derived a sunny crown profile equation for Hinoki cypress (*Chamaecyparis obtusa* ENDL.) based on the power equation from the relationship between parameter a and the annual height increment HI (m/year): $a = c\mathrm{HI}^d$ where c and d are parameters. First, we derived the relationship $a = c\mathrm{HI}^d$. Next, we evaluated the efficacy of the equation $r = c\mathrm{HI}^d z^b$ at representing the sunny crown profile of Hinoki cypress. Data were obtained from 112 trees in six pure stands of even-aged Hinoki cypress. The fit of the equation $a = c\mathrm{HI}^d$ to the data was good. The equation $r = c\mathrm{HI}^d z^b$ made more precise predictions than the equation $r = az^b$ assumed that each of parameters a and b is common to all trees. The values of parameters b, c, and d estimated from the sample trees were 0.686, 0.401, and -0.299, respectively. The integration of the sunny crown profile equation $r = c\mathrm{HI}^d z^b$ with a tree growth model, including the total height growth and the sunny crown length estimations, enables prediction of the sunny crown profile and its change with growth for Hinoki cypress.

Keywords: sunny crown profile equation, Hinoki cypress, height increment

INTRODUCTION

The ability to predict the crown dimensions of a tree is important in forest management because the crown dimensions determine the foliar volume of the tree and consequently its photosynthetic capacity. Gross crown dimensions are useful in modeling individual tree form (MITCHELL, 1975; SPRINTZ and BURKHART, 1987), and predicting subject tree growth (COLE and LORIMER, 1994). In particular, the sunny crown volume and surface area (*i.e.*, the volume and surface area of the crown exposed to sunlight) are effective predictors of the growth in individual tree volume. For example, INOSE (1982) found that the increment in the stem volume of Todo fir (*Abies sachalinensis* MAST.) could be predicted from the increment in the sunny crown volume. KAJIHARA (1985) used the sunny crown surface area to predict the increment in the stem volume of Japanese cedar (*Cryptomeria japonica* D. DON). These sunny crown dimensions were obtained by rotating sunny crown profiles represented as mathematical equations on the stem axis.

The sunny crown profile is given by the relationship between the crown radius r (m) at a point on the stem axis and the distance z (m) from the tree apex to this point. The following power equation is often used for conifers:

$$r = az^b \tag{1}$$

where a and b are parameters. Eq. (1) fit the sunny crown profiles for Todo fir (INOSE, 1982), Hinoki cypress (*Chamaecyparis obtusa* ENDL.), Japanese cedar (MIZUNAGA, 1992; 1998), and black spruce (*Picea mariana* BSP) (RAULIER *et al.*, 1996) well. WAGUCHI (2004) found that parameter b is invariant between trees when the sunny crown profile for Hinoki cypress tree is represented by eq. (1). In other words, parameter a in eq. (1) is the only independent variable that determines the sunny crown profile of Hinoki cypress.

KIYONO (1990) observed an inverse relationship between the tangent of the mean half apical angle of the crown ($\tan\bar{P}$), defined as the ratio of the crown diameter at the crown base to the crown length, and the mean annual height increment $\overline{\mathrm{HI}}$ (m/year) for Hinoki cypress plantations expressed as:

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$$\tan \overline{P} = 0.1943\overline{\mathrm{HI}}^{-0.1563}. \qquad (2)$$

This suggests that Hinoki cypress trees in a stand with a smaller mean HI have more obtuse or wide "umbrella-like" crowns than those with a larger mean HI. When the sunny crown profile for Hinoki cypress is represented using eq. (1), assuming that parameter b is invariant between trees, trees with more obtuse crowns have larger values of parameter a than do those with more acute crowns. These results suggest that Hinoki cypress trees with a smaller HI have larger values of parameter a than those with a larger HI, and imply that parameter a can be expressed as a function of HI as follows:

$$a = c\mathrm{HI}^{d} \qquad (3)$$

where c and d are parameters. Assuming that parameter b is invariant between trees, from eqs. (1) and (3), the sunny crown radius r at a given distance z from the tree apex is given by:

$$r = c\mathrm{HI}^{d}z^{b}. \qquad (4)$$

If the common value for each parameter in eq. (4) can be used for all Hinoki cypress trees, eq. (4) can depict the sunny crown profile using HI and the sunny crown length (*i.e.*, the distance from the apex to the base of the sunny crown). However, the adequacy of this assumption has not been tested.

The objectives of this study were (*i*) to confirm whether it was possible to derive eq. (3) from between parameter a and HI, (*ii*) to evaluate the efficacy of eq. (4) in representing the sunny crown profile, and (*iii*) to discuss the adequacy of HI as a variable to represent the sunny crown profile for stand-grown Hinoki cypress.

MATERIALS AND METHODS

Data Collection

Sunny crown profile data were obtained from six pure stands of even-aged Hinoki cypress in Nara Prefecture, Japan. Stand age ranged from 10 to 72 years, with densities from 1,000 to 5,250 trees/ha, mean diameter at breast height from 6.8 to 29.1cm, and mean total height from 5.5 to 16.8m (Table 1). One hundred and twelve sample trees were selected at random in the stands; the trees ranged from 3.6 to 32.5cm in diameter at breast height and from 4.1 to 18.7m in total height.

Each tree was felled and the crown was divided from the base of the crown to the tree apex into 1- or 0.5-m-deep vertical layers. Each layer was set vertically on the ground and the crown radius at the middle of the layer was measured in four directions, at right angles, using a surveyor's tape. The separation between the sunny and shade crowns (*i.e.*, the base of the sunny crown) for each tree was averaged visually to find the point representing the average height to the top point of the crown contact in the contour direction. The separation height was measured using a wide-scale Spiegel relascope before felling. A 5-m pole was placed upright against the tree trunk for the measurements. Observations within the shade crown were eliminated from the dataset. The sunny crown length, defined as the distance from the base of the sunny crown to the tree apex, ranged from 1.5 to 7.4m.

Table 1 Stand descriptions

Stand	Age (year)	Density (trees/ha)	Mean diameter at breast height (cm)	Mean total height (m)	Number of sample trees
A	10	5,250	6.8	5.5	20
B	16	3,006	11.8	10.1	15
C	19	3,828	11.9	9.4	20
D	29	2,602	12.6	12.7	22
E	41	1,820	18.6	16.4	15
F	72	1,000	29.1	16.8	20

Height Increment Estimation

The HI in the latest year for each sample tree was estimated using the ordinary stem analysis technique (OSUMI *et al.*, 1987). Disks were removed from the stem at stump height (0.2m), and at intervals of 0.5, 1, or 2m below the base of the crown and at intervals of 0.5 or 1m within the crown beginning at stump height. The disks were brought to the lab and the annual rings were counted. To describe the height-age relationship for each of the sample trees, RICHARDS' function (RICHARDS, 1959; OSUMI and ISHIKAWA, 1983) was used:

$$\mathrm{H}_t = A\{1 - \exp(-kt)\}^{\frac{1}{1-m}} \qquad (5)$$

where H_t is the total height at age t, and A, k, and m are parameters. To estimate these parameters for each sample tree, eq. (5) was fitted to the height and age data using the maximum likelihood method (ITO, 1989). The HI in the latest year for each sample tree was calculated as:

$$\mathrm{HI} = \mathrm{H}_{tm} - \mathrm{H}_{tm-1} \qquad (6)$$

where tm is the total age at the time of measurement.

Data Analysis

To estimate parameters a and b, eq. (1) was fitted to the crown radius and the distance from the tree apex for each sample tree, under the condition that parameter b was invariant between trees, using the maximum likelihood method (WAGUCHI, 2004). The sunny crown profile equation for i-th sample tree (i = 1, 2, ..., 112) is:

$$r_{ijk} = a_i z_{ij}^{b_i} + \varepsilon_{ijk} \qquad (7)$$

where r_{ijk} is the k-th crown radius (m) (k = 1, 2, 3, 4) on the j-th distance z_{ij} (m) from the apex ($j = 1, 2, \ldots, n_i$), ε_{ijk} is the normal random variable with mean zero and variance σ_i^2, and a_i and b_i are parameters. The log likelihood is given by:

$$l(a_1, a_2, \ldots, a_{112}, b_1, b_2, \ldots, b_{112}, \sigma_1^2, \sigma_2^2, \ldots, \sigma_{112}^2)$$
$$= -\frac{1}{2}\sum_{i=1}^{112} 4n_i \log 2\pi - \frac{1}{2}\sum_{i=1}^{112} 4n_i \log \sigma_i^2 - \frac{1}{2}\sum_{i=1}^{112}\left\{\frac{1}{\sigma_i^2}\sum_{j=1}^{n_i}\sum_{k=1}^{4}(r_{ijk} - a_i z_{ij}^{b_i})^2\right\}. \quad (9)$$

To obtain the maximum likelihood estimates, we must find the values of parameters that maximize the log likelihood. Assuming that each value of b_i and σ_i^2 is common to all sample trees (*i.e.*, $b_1=b_2=\ldots=b_{112}=b$ and $\sigma_1^2=\sigma_2^2=\ldots=\sigma_{112}^2=\sigma^2$), the log likelihood is maximized with respect a_i and b when

$$S = \sum_{i=1}^{112}\sum_{j=1}^{n_i}\sum_{k=1}^{4}(r_{ijk} - a_i z_{ij}^{b})^2 \quad (9)$$

is minimized. In this case, the maximum likelihood method is equivalent to the ordinary least squares method and the maximum likelihood estimates $\hat{a}_i$ and $\hat{b}$ are obtained by solving

$$\frac{\partial S}{\partial \hat{a}_i} = \frac{\partial S}{\partial \hat{b}} = 0. \quad (10)$$

Since eq. (1) is non-liner with respect to its parameters a and b, an iterative procedure is necessary for solving eq. (10). As the procedure, GAUSS-NEWTON method was used.

To estimate parameters c and d, eq. (3) was fitted to parameter a and HI using the nonlinear least squares method. To confirm that the relationship expressed as eq. (3) between parameter a and HI could be derived, the coefficient of determination R^2 was calculated and tested statistically using the F-test. The root mean square error was used to evaluate the efficacy of eq. (4) in representing the sunny crown profile for Hinoki cypress.

RESULTS

The assumed invariant value of parameter b was 0.686. The value of parameter a increased exponentially with decreasing HI, indicating that the apical obtuseness of the crown became more pronounced as HI decreased (Fig. 1). The apical obtuseness with decreasing HI for Hinoki cypress agreed with that reported by KIYONO (1990). The values of parameters c and d were 0.401 and -0.299, respectively. The R^2 value for the fitted eq. (3) was statistically significant (R^2 = 0.471, F = 97.940, $P < 0.001$). This indicates that the relationship expressed as eq. (3) between parameter a and HI can be derived for Hinoki cypress.

The value of the root mean square error for eq. (4) was 0.217m. WAGUCHI (2004) found that, when the sunny crown profile of a Hinoki cypress was represented by eq. (1), it should be assumed that parameter a varied from tree-to-tree, whereas parameter b was invariant between trees. Eq. (3) is one of methods to estimate parameter a for each tree. Thus, if eq. (4) makes more precise predictions than eq. (1) assumed that each of the parameters a and b is common to all trees, the efficacy of eq. (4) in representing sunny crown profile for Hinoki cypress can be evaluated. The value of the root mean square error for eq. (1) obtained using the sunny crown profile data which is identical to that used in this study, assuming each of the parameters was common to all trees, was 0.239m (WAGUCHI, 2004). The difference in root mean square error between the two equations was 0.022m, suggesting that the inclusion of eq. (3) improved precision of prediction of eq. (1) assumed that each of the parameters is common to all trees. Therefore, this result indicates the efficacy of eq. (4) in representing the sunny crown profile for Hinoki cypress.

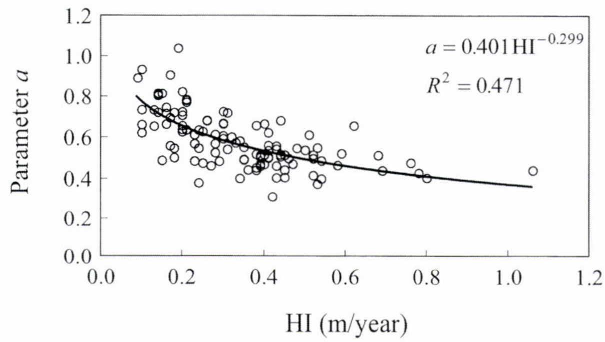

Fig. 1 The relationship between the annual height increment, HI, and parameter a in eq. (1), assuming that parameter b is invariant between trees

DISCUSSION

The choice of tree attributes used in crown profile equations has differed among studies. For example, BALDWIN and PETERSON (1997) included the diameter at breast height and ratio of crown length to total height in their equation for the crown profile of loblolly pine (*Pinus taeda* L.). BIGING and WENSEL (1990) used total height, diameter at breast height, and the ratio of crown length to total height as predictors of crown area for six coniferous tree species. HONER (1971) included total height in his equations for balsam fir (*Abies balsamea* MILL.) and black spruce. In this study, we used HI as a tree attribute representing the sunny crown profile for Hinoki cypress. The attributes used in these equations can be divided into two groups: one incorporates the effect of stand density, and the other does not.

The ratio of crown length to total height has been used explicitly as the effect of stand density. An effect of stand density is also implicit in the diameter at breast height. However, stand density might not have a very important effect on the sunny crown profile. For white spruce (*Picea glauca* VOSS), MITCHELL (1969) observed that branches on the free-growing side of a tree grew at the same rate as the branches of completely free-growing trees. HONER (1971) has shown that the crown profiles above the point of crown contact of forest-grown balsam fir and black spruce trees were similar to those of open-grown trees of the same height and species, and concluded that it was reasonable to apply his results to other species. For common ash (*Fraxinus excelsior* L.), CLUZEAU *et al.* (1994) observed that competition between trees had no noticeable effect on branch growth in the part of the crown free from competition. Although eq. (4) did not include variables representing the effect of stand density, the equation still represented the sunny crown profile for Hinoki cypress. Therefore, it is not necessary to include attributes reflecting the effect of stand density in the sunny crown profile equation.

Total height is independent of the effect of stand density because growth in total height is not affected by stand density (ANDO, 1968). The relationship between total height and apical obtuseness of the crown among trees in different growing stages contrasts strikingly with that among trees in a given stand. When the apical obtuseness of trees classified in different growing stages was compared, taller trees had more obtuse crowns than shorter trees. In Hinoki cypress plantations, KIYONO (1990) observed that trees in older stands had more obtuse crowns than trees in younger stands. MIZUNAGA (1998) reported that Japanese cedar and Hinoki cypress crowns became more obtuse at maturity. CLUZEAU *et al.* (1994) developed a crown profile model for common ash. The model implied that the crown of common ash changed from conical to more parabolic, as the tree matures. These results indicate that the relationship between total height and apical obtuseness of the crown among trees in different growing stages is positively correlated, because trees in older stands were taller than those in younger stands. In fact, when we grouped trees from the six sample stands in different growing stages, the relationship between total height and parameter a (*i.e.*, apical obtuseness of crown) had a significant positive correlation (Table 2).

By contrast, when the apical obtuseness of trees in a given stand was compared, taller trees had more acute crowns than shorter trees. HANN (1998) reported that dominant trees had more conic crowns and understory trees had more parabolic crowns in Douglas fir (*Pseudotsuga menziesii* FRANCO) stands. In a Japanese cedar stand, HASHIMOTO (1990) observed that apical obtuseness of the crown became more pronounced as the total height decreased. These results indicate that the relationship between total height and apical obtuseness of the crown among trees in a given stand has a negative correlation. Although negative correlation was not observed between total height and parameter a for every sample stand in this study (Table 2), this result still has not exploded the inference from the results by HANN (1998) and HASHIMOTO (1990). Therefore, it is difficult to use total height as a tree attribute representing the sunny crown profile for Hinoki cypress, regardless of growing stage and dominance in a stand.

HI is also an independent variable because there is no relationship between total height and stand density. No relationship between HI and apical obtuseness of the crown for individual trees has yet been demonstrated. Trees in older stands may have smaller values of HI than those in younger stands, as total height growth can often be represented using a convex curve, such as that of MITCHERICH's function (SHIRAISHI, 1986). Therefore, when the apical obtuseness of trees classified in different growing stages are compared, trees with a smaller HI may have more obtuse crowns than those with a larger HI, because trees in older stands have more obtuse crowns than those in younger stands. As expected, negative correlation between HI and parameter a was observed for all the stands combined in this study (Table 2).

Conversely, in a given stand, shorter trees may have a smaller HI than taller trees. Therefore, when the apical obtuseness of trees in a given stand is compared, trees with a smaller HI may have more obtuse crowns than those with a larger HI because shorter trees have more obtuse crowns than taller trees, within a given stand. In this study, negative correlation between HI and parameter a was observed for two sample stands (Stand D and E) (Table 2). This result suggests that the relationship between HI and apical obtuseness of the crown among trees in different growing stages has the same trend as that found among trees within a given stand, indicating that trees with a smaller HI have more obtuse crowns than those with a larger HI, regardless of growing stage or dominance in a stand. Furthermore, at the present time, no factor suggests that the relationship between HI and apical obtuseness of the crown among trees in different growing stages contrasts with that among trees in a given stand. Therefore, HI would be better than total height, with regard to representing the sunny crown profile for Hinoki cypress.

Table 2 Correlation coefficients between parameter a and total height, and the annual height increment HI for each sample stand and for all stands combined

Stand	Total height	HI
A	-0.170	-0.180
B	-0.048	-0.255
C	0.230	-0.020
D	-0.121	-0.568**
E	-0.076	-0.548*
F	-0.191	-0.347
all stands	0.666***	-0.635***

*: $P < 0.01$, **: $P < 0.01$, ***: $P < 0.001$. Significance levels are based on t-tests.

CONCLUSION

The sunny crown profile equation described here is a useful tool for managing Hinoki cypress stands because the equation makes more precise predictions than eq. (1) assumed that each of the parameters a and b is common to all trees. The integration of the equation with a tree growth model, including the total height growth and the sunny crown length estimations, enables one to predict the sunny crown profile and its change with the growth of Hinoki cypress trees, at different growing stages and dominances. Further development of this result should focus on the effect of stand density on crown radius at the base of a sunny crown, or on sunny crown length, for obtaining the sunny crown volume and surface area.

The value of parameter a decreased slowly with increasing HI for larger HI (Fig. 1). This allows us to extrapolate the results to trees with still larger HI. However, it was not feasible to determine the apical obtuseness of the crown at very small HI because of the relationship between parameter a and HI, expressed as eq. (3). Therefore, our sunny crown profile equation should not be applied to trees with still smaller HI, for which the value of parameter a remains unknown.

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