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Article

Teak Yield Regulation in the Natural Forests of the Tharrawaddy Forest Division, Myanmar —138 Years of the Girth Limit Selection System—

San Win*[1] and Minoru Kumazaki*[2]

ABSTRACT

Attempts to introduce scientific management techniques to forestry in Myanmar began in 1856 with the appointment of Dr. Dietrich BRANDIS, a German botanist, to manage the Pegu[1] hill forests of the then Burma. One of Brandis's main management objectives was to ensure a permanent and sustained yield of teak logs from the area's natural forests. He adopted a girth limit selection system in the Tharrawaddy forests of Pegu, and set the minimum exploitable girth limit at 6 feet. Since then the actual yield has fluctuated widely between 1,588 and 9, 250 trees per year, because of changes in the estimates of forest growth rates. Until 1927, the actual rate of harvesting by girdling[2] was based on estimates of annual yield. However, unstable social and political conditions prevented regular girdling and silvicultural treatment between 1928 and the early 1960s. As social conditions improved from the 1960s, girdling was able to be conducted in some years.

This analysis of the status of the Tharrawaddy forest division's teak stocks uses data from 1912-13, 1982-86 and 1994. It shows that there was poor teak regeneration in low girth classes but an increase in the number of trees in higher girth-classes between 1912 and 1982, and a drastic drop in the growing stock of all girth classes between 1982 and 1994. The poor regeneration was caused by a lack of adequate silvicultural operations during the 40 to 50 years prior to the 1980s, while illegal logging is the primary cause of the decline in growing stock. Strong action needs to be taken to expand the area of new plantings, to prevent excessive logging, and to increase public participation in forest management. Clear and firm policies to achieve these objectives should become fundamental components of all of Myanmar's future forest management plans.

Keyword : Girdling, reserved forests, selection system, teak, working plan

INTRODUCTION

The teak tree (*Tectona grandis*) is native to India, Myanmar, Laos and Thailand. Its timber is one of the most valuable in the world. In 1752, the then King of what is now known as Myanmar made all of the nation's teak trees the property of the royal family. The practices of girdling, planting and levying a fee on all teak extracted have been conducted throughout the rule of the Myanmar kings and the British colonial government up to the present day.

Teak timber has not only long been important in Myanmar's economy, but it has also played a critical role in the nation's history. Teak has been one of Myanmar's major foreign exchange earners since the 17th century. Ships made of teak were exported as long ago as the early 17th century, while substantial volumes of teak were exported by the British in the 19th and 20th centuries (DIOKNO 1983). Until very recently timber exports accounted for a third of all Myanmar's foreign exchange earnings (FOREST DEPARTMENT 1996).

Teak's economic value had other very substantial historical implications for Myanmar. MOREHEAD (1942) states that the acquisition of new, and apparently inexhaustible, supplies of teak of Myanmar was particular interest to the British Government as both English Oak and teak from Malabar and western India, for the Admiralty,

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were running short. Teak timber is said second to non for ship building. In 1885 the nation's king took punitive action against a joint British-Indian trading company for malpractice in the teak timber trade. This action was the excuse used by the British for their third and final annexation war in 1885 that resulted in all of Myanmar coming under British rule.

The economic and political importance of teak to Myanmar means that substantial yield production of teak logs should be given high priority in the nation's forest management. The British colonial powers eventually came to realize this.

After the first British annexation war in 1826, the Tenasserim forests in southern Myanmar were occupied by the British and devastated by uncontrolled logging. The second annexation war in 1852 allowed the British to extend their control into lower Myanmar including the Pegu hill forest areas. This time, however, they decided to manage the forests for sustained yield timber production. The governor-general Dalhousie said: "I hold it to be the duty of the Government of India to preserve the forest resources of Pegu and not to allow them to be wasted as the forest resources of other provinces have been wasted" (Brandis 1896).

Dr. Dietrich Brandis, a German botanist, was appointed to manage the newly annexed Pegu forests in 1856, and he adopted a selection logging system variously called "Brandis's selection system", "girth limit selection system" and "the Burma selection system" for managing teak which was the only marketable timber to abroad at that time. This selection system has been used up to the present day in the Tharrawaddy forest division.

The objectives of this paper are to study the historical development of yield regulation, harvesting and the structure of teak stands in the Tharrawaddy forest division under the selection system, as well as to discuss the future of natural forest management in this division, which is about 125 Km north of Rangoon. The Tharrawaddy forest division contains Minhla, Mokka, Kadinbilin, Konbilin and Thonze reserved forests. These forests cover 85% of the whole division (see Fig. 1) and are some of Myanmar's main teak producing forests.

BRANDIS'S CONCEPT OF SUSTAINED YIELD

Yield regulation

From the beginning of his appointment, Brandis's

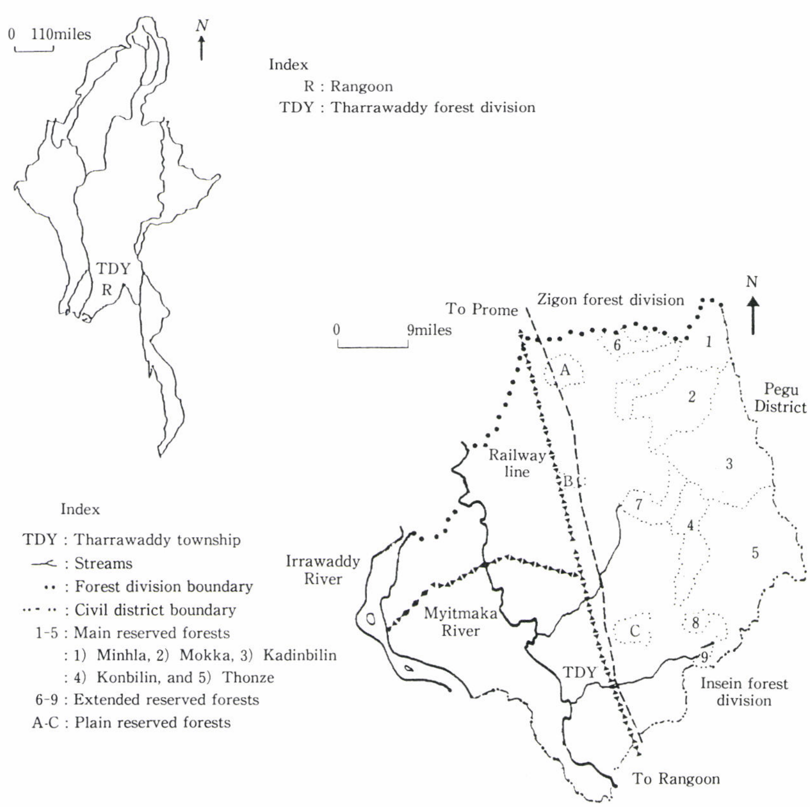

Fig. 1 The location of Tharrawaddy forest division (Southern Tharrawaddy District) in Myanmar

primary objective was to ensure a permanent and sustained yield of timber from the division's natural forests, arranging the cuttings so as to keep log output well within the forests' productive potential. From line surveys Brandis found that teak trees made up of only 10 to 20 % of the forests (excluding bamboo), and realized that to achieve a sustained yield of teak from such forests, girdling must be conducted sparingly.

Brandis set 6 feet as the minimum girth[3], below which no tree should, as a rule, be felled. Teak trees over this girth were classified as first-class trees, while second-class trees were those between 4 feet 6 inches and 6 feet. Third-class trees were between 1 foot 6 inches and 4 feet 6 inches, and fourth-class trees were those smaller than 1 foot 6 inches. Based on survey data on the teak growth in other forests, he estimated that all second-class trees would grow into first-class trees within 24 years, and decided to spread the girdling of the first class trees then standing over a period of 24 years (Brandis 1896).

The harvesting rate was to be regulated on the basis of volume, and because teak comprised only a small proportion of the natural forests, Brandis decided to do this by stipulating the number of trees to be cut annually within an area.

Forest Improvement

Brandis considered that it was important to plant more teak trees to increase the proportion of teak in natural forests. Other activities taken to increase the growth of the teak included, cutting vines at the time of girdling, thinning of immature teak, removing a certain proportion of silviculturally undesirable mature trees, opening up patches of established advanced growth, removal of commercially inferior tree species suppressing teak and its valuable associates (group one species which are also famous species for domestic use)[4], and cutting of dead and moribund trees. All of these activities were called "improvement fellings" and conducted twice in a rotation of 30 years.

AN OVERVIEW OF THE REGION'S WORKING PLANS

This section will review the changes in the permitted annual yield and consequently the girdling that occurred under this system since its introduction. The reasons for these changes will be explained in the discussion of seven working plans (see Table 1). The first three plans, those of 1856, 1868 and 1884- were prepared when Brandis was responsible for the division's management. The changes in the permitted annual yields and the actual rate of girdling are shown in Fig. 2 with the number of teak trees girdled presented as ten-year totals (see Table 2).

The 1856 working plan

The first working plan estimated there were a total of 220,000 first class trees in the five main forests of Tharrawaddy (Govt. of Burma 1919). Accordingly, the annual yield was set at 9,250 trees assuming it would take 24 years for the second class trees to mature into first class trees. Actual girdling, which seems to have started in 1861, could only be done in four years, and totalled 12,002 trees. Brandis stated that girdling could not be carried out regularly because of the lack of officers sufficiently competent to conduct supervision. The number of trees harvested between 1856 and 1867 was 55,780, but this figure includes 43,778 trees that were girdled before Brandis's arrival (Govt. of Burma 1918).

Table 1 The level of teak harvest permitted by different working plans

Working plan	ANTPC	Remarks
1856	9,250	In the first plan R was 24 years.
1868	1,588	R was 72 years, but 80 years was used to set the permitted yield.
1884	3,100	In this special plan, R was 38 years. A separate yield was set for each forest.
1918	2,400	Yield was controlled by area. After 1924, the permitted yield was 3,952 trees.
1928	3,190	Yield was controlled using the Burmese version of Von Mantel's formula.
1946-47	8,241	Because documents were lost, the permitted yield was based on a ratio basis.
1963-64	3,100	In this most recent paln, the permitted yield was set using the same method as in the 1946-47 plan.

ANTPC: Annual number of trees permitted to be cut

R: The number of years required for trees to grow from the 2^{nd} class into 1^{st} class

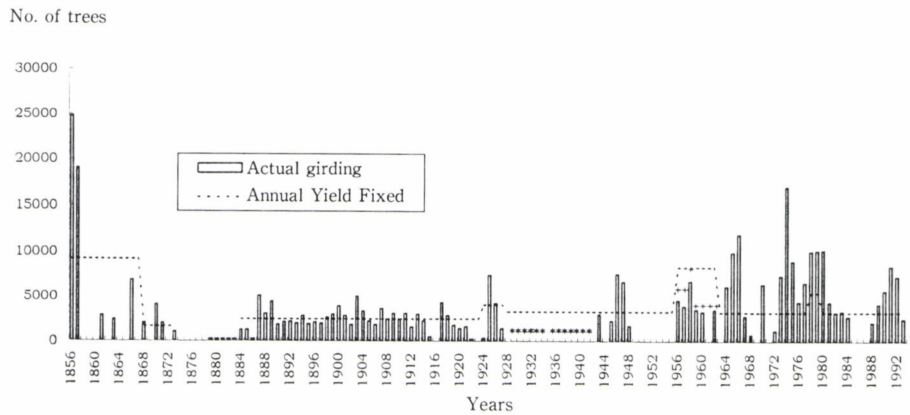

Fig. 2 The annual permitted level of teak harvest and actual removals between 1856 and 1993
Source: Tharrawaddy Working Plans (1918, 1919, 1928, 1946-47, 1963-64, and Forest Department, 199).
"*" represents the years when gidling was conducted, but for which no data are available.
"+" represents the years for which partial data are available

Table 2 The number of trees girdled in the major forest areas of the Tharrawaddy district-presented as 10 year totals

Year/Reserve	Thonze	Minhla	Mokka	Kadinbilin	Konbilin	Total
1856-1865	18,979	6,290	4,839	10,541	8,325	48,974
1866-1875	4,015	4,025	1,003	5,406	1,400	15,849
1876-1885	0	2,008	1,000	402	0	3,410
1886-1895	5,816	2,289	3,039	11,579	2,377	25,100
1896-1905	9,063	3,946	2,671	11,191	1,390	28,261
1906-1915	8,676	5,461	1,599	5,165	2,163	23,064
1916-1925	7,646	7,366	2,145	1,783	431	19,371
1926-1935	1,060	0	1,066	3,373	0	15,194*
1936-1945	3,567	0	0	1,504	0	13,381#
1946-1955	5,461	0	0	9,001	1,036	15,678
1956-1965	0	7,784	4,569	12,494	0	81,631&
1966-1975						55,949
1976-1985						54,064
1986-1993						29,357
Total						429,283

Source: Working Plans (1918-19, 1928, 1946-47, 1963-64)
Notes: The numbers of trees girdled in each reserved forest after 1962-63 is unavailable.
"*, #, &" includes the author's own estimates of yield and they are shown as followns; *9,695 trees between 1926-35, # 8,310 between 1936-45 and & 40,852 trees in the period from 1956 to 1965. There were a total of 15,932 trees girdled in 1964 and 1965, however, it is not known in which reserve(s), these trees were girdled. These estimates are based on the density of the trees girdled in those compartments for which data are available.

The 1868 working plan

Surveys conducted in 1868 showed that the annual yield needed to be changed. The differences between assumptions made in 1856 and those required in 1868 were very serious:

"...the rate of growth assumed in 1856 was too rapid, that of 1868 was much too slow. No less than seventy-two years were supposed to be necessary to bring up a Teak-tree in the forests from a girth of four feet six inches to six feet, against twenty-three years in 1856. The second class trees having been found to be less numerous than those of the first class, it was decided to spread the removal of the latter over a period of eighty years (Brandis 1896).

In line with these changes, the number of first-class trees was estimated at 127,000 and the annual yield was set at 1,588 trees. However, it was expected that this plan would expire in 1873 and that the forests would then be managed using special management plans, so girdling was only planned for the following five years. According to Brandis (1896), it was hoped that rapid progress would then be made in the selection and demarcation of the forests to be permanently maintained as such, and that when the boundaries of these forests had been laid down, special working plans for each forest district would then be prepared. However, girdling was conducted in only three years, for a total of 9,043 trees, and introduction of the special working plans was delayed until 1884. There was no plan for the eleven years between 1873 and 1884, and only 1,200 trees were girdled.

The 1884 working plan

This plan introduced new and distinct features. Forests were divided into compartments, and the growing stock in each compartment was estimated separately using data from sample areas. The plan had 2 main points:
1) The kind of treatment to be conducted in reserved forests must be based on the characteristics of each area; and,
2) The reproduction and growth of teak trees must not be impeded, but, if possible, promoted by the removal of girdled trees.

While teak was found to have different growth rates at different localities within the Irrawaddy valley forests which contains Tharrawaddy forests, it was proposed to allow a period of 38 years for second class teak trees to mature into first class trees for those forests. Based on this growth rate, the condition of each reserved forest and an estimated total growing stock of 91,497 trees, the annual yield was fixed at 3,100 trees. According to the 1963-64 working plan, a total of 90,125 trees was girdled up to 1917, giving an annual average of 2,650 trees.

The 1918 working plan

The first Burma forest conference in 1910 decided to introduce a uniform system of logging and management in the Tharrawaddy forest division. The objective of this decision was to expand the production of teak and other valuable timber species by converting the then uneven-aged understocked forest into a fully-stocked forest containing a regular series of even-aged stands over one rotation. The annual yield was set at 2,400 trees. However, in 1924 this figure was increased to 3,952 when the yield was calculated using a Burmese version of Von Mantel's formula[5] which assumed a particular basal area is produced over a rotation of 120 years (Govt. of Burma 1928). An average of 1,266 trees were girdled each year from 1918 to 1923. This was increased to an average of 3,721 trees per year between 1924 and 1927 (Govt. of Burma 1963-64).

The 1928 working plan

In 1928 a new working plan was introduced. Its objective was to improve the forest and maintain a sustained yield using the former selection system. The girdling scheme proposed for the 30 years to 1958 was based on data from 1912-13.

Using the Burmese version of Von Mantel's formula, the annual yield was fixed at 3,190 trees, but domestic and international events disrupted the implementation of this girdling schedule. The events included: the farmers' revolt of 1930, financial stringencies in the early 1930s and World War II from 1939 to 1945. Soon after Myanmar gained its independence in 1948, internal civil unrest broke out and continued for many years. As a result, no girdling could be conducted between 1948 and 1955. In some reserved forests, girdling was done for only 9 years. The data available for the period from 1928 to 1948 show that 21,954 trees were taken (Govt. of Burma 1946-47). However, based on data in the 1928 Working Plan the author estimates that in fact about 18,000 more trees might have been girdled.

The 1946 working plan

As described above, the 1928 working plan was not able to be implemented completely. Two preliminary working plans were prepared in 1936 and 1938, but they were never officially approved and remained in draft form until the working plan of 1946-47 was introduced. It was intended that this plan would end in 1962. Teak girdling began in 1956 with a new permitted yield limit based on the intensity of previous girdlings. Many compartments left ungirdled from the previous 1928 plan were allocated for girdling in the seven years from 1956 to 1962. Thus the permitted annual yield for this 7-year period was set at 8, 241 trees- much higher than would have been calculated normally (Govt. of Burma 1946-47). The available data for 1956 to 1962 shows that 28,683 trees were girdled in this period (Govt. of Burma 1946-47). However, the author also estimates that about 40,000 more trees might have been girdled.

The 1963-64 working plan

This plan was prepared to cover the ten-year period from 1963-64 to 1973-74. A thirty-year felling cycle was proposed with a girdling schedule that extended from 1963 to 1993. An annual permitted yield of 3,100 trees was calculated using a method similar to that of the 1946 plan. The permitted yield was recalculated in 1978-79 and allowed the girdling of 5,290 trees. However the former annual yield limit of 3,100 per year was reintroduced in 1980-81. Girdling fluctuated greatly over this 30-year period, as shown in Fig. 2. The number of trees girdled in 17 of the 30 years exceeded the permitted yield. A total of 152,924 trees were girdled, and this included the felling of 6, 387 green teak trees[6], giving an average annual girdling rate of 4,885 trees per year, against the working plan's limit of 3,100 trees per year. For the whole period from 1856 to 1993, it was estimated that an annual average of 3,100 trees was taken from these reserved forests.

A HISTORICAL COMPARISON OF TEAK GROWING STOCK

An understanding of the effect of this teak selection system on the condition of the region's forests can be gained from an examination of available growing stock data (trees per 100 acres). A comparison will be made of data from three different periods: 1912-13, 1982-86, and 1994. However, the differences between the data bases need to be recognized. The 1912-13 survey used estimates of the growing stocks based on a sampling method that covered 28% of the whole reserved forest area, excluding planted areas. Compartments covering a variety of forest types were selected and sampled, and the collected data were then used to estimate the condition of the stock in adjacent compartments. The 1982-86 and 1994 surveys used systematic sampling techniques that covered all forest areas. Sample plots were located in natural forests at intervals of 3,300 yards and each plot covered 2.59 acres. It should be also noted that the classification of girth classes was changed in 1982-86 (see Tables 3, 4, and 5). There was also a reorganization of forest areas during the early 1980 s. This resulted in forestry and civil administrative areas sharing the same boundaries, with some reserved forests being divided between two townships. Strictly speaking, therefore, the growing stock data for 1912-13 are not comparable with those of 1982-86 and 1994. Nevertheless, the average stocking rates indicate some very interesting changes in stand structure, and these changes are seen in Tables 3, 4, and 5.

A comparison of Tables 3 and 4 shows that the number of trees with a girth of 3 feet or more in 1982-86 was about 1.3 times that in 1912. Similarly the number of trees with a girth of 6 feet or more in 1982 was 2.4 times the number in 1912. A decline is only observed in the lower girth class which shows that there had been a lack of regeneration. The Forest Department found the same situation in many forest areas across Myanmar (Forest Department 1990). Keh (1993) also found a similar situation in the Zamayi reserved forests of Pegu hill forests. Tables 4 and 5 show important changes between 1982-86 and 1994. The total growing stock for all girth classes declined by about 50% or more over the 12 years. This decline in growing stock is quite serious and occurred in spite of the fact that the reported actual harvest from 1982 to 1993 was on average about 3,200 trees a year, close to the permitted yield level (Forest Department 1995a).

POSSIBLE REASONS FOR THE POOR REGENERATION AND THE DEGRADATION OF TEAK STOCKS

The poor regeneration can be explained by inadequate improvement fellings, especially between 1942 and 1957 (Chein Hoe 1969). The social and political situation of Tharrawaddy for the 30 to 50 years prior to 1980 prevented regular girdling, logging and adequate improvement fellings. The other factor that likely contributed to the low numbers of teak trees in smaller girth classes was illegal felling. Small teak trees are of a size of that can be easily removed by some villagers on bullock carts for either sale or for use in their houses. Both Myanmar's natural forests and plantations were devastated during World War II and subsequent periods of civil unrest (Lwin 1967). In Tharrawaddy forest division, a total of 7,100 forest offences were committed between 1946-47 and 1972-73, of which 5,311 were for unauthorized fellings (Govt. of Burma 1963-64).

The drastic fall in teak stocks between 1982 and 1994 can be explained by plantation establishment and illegal logging. Plantation establishment increased after 1980 and a total of 23,000 acres were planted in these forests between 1982 and 1993. Generally, plantations had to be established in degraded forests. However, in 1982 the Forest Department required plantations to be established in blocks of 200 acres or larger, so it was inevitable that natural forests were sometimes included in blocks chosen for planting. The Forest Department allowed plantation establishment in some natural forests where there was teak and/or "Group one" species with a girth of 2 feet or more. Thus, it can be assumed that removal of teak trees from plantation sites was probably part of the reason for this reduction in growing stock. However, illegal logging is the most likely reason. Keh and Kyaw (1995) state that illegal logging and the selling of teak and other valuable hardwoods probably account for the major decline in the growing stock of Myanmar's forest, especially in accessible areas. Tharrawaddy is situated in an easily accessible area, only 125 Km from Rangoon.

CONCLUSION

Since the late 1800s, Myanmar has been attempting to apply a philosophy of sustained timber yield to the management of its native teak forests, but it has learnt that it is complex and difficult to implement. Even though it has faced many obstacles in the management of these forests for sustainable wood production, the Forest Department has persisted in applying such principles for nearly one and a half centuries.

Table 3 Teak growing stock (trees per 100 acres) - 1912-13 estimation

Reserve	Area (ac) / Girth class	1′6″ to 2′11″	3′ to 4′5″	4′6″ to 5′11″	6′ to 7′5″	7′6″ & up	Total
Minhla	25,884	89	107	77	43	28	344
Mokka	22,425	110	124	83	38	24	379
Kadinbilin	53,216	113	120	94	47	27	401
Konbilin	15,988	113	130	91	38	23	395
Thonze	69,735	158	147	101	31	14	451
Total	187,248	126	130	92	38	22	408

Source: Government of Burma, 1918.

Table 4 Teak growing stock (trees per 100 acres) - 1982-86 estimation

Townships	Area (ac) / Girth class	2′-2′11″	3′-4′11″	5′-5′11″	6′-7′11″	8′ & up	Total
Minhla	45,170	76	117	10	23	6	232
Letpadan	166,070	56	106	88	139	50	439
Tharrawaddy	77,980	79	267	108	98	14	566
Total	289,220	65	151	81	110	34	441

Source: Forest Department, Myanmar, 1991

Table 5 Teak growing stock (trees per 100 acres) - 1994 estimation

Townships	Area (ac) / Girth class	2′-2′11″	3′-4′11″	5′-5′11″	6′-7′11″	8′ & up	Total
Minhla	33,430	8	23	8	3	5	47
Letpadan	169,070	28	60	31	34	12	165
Tharrawaddy	75,860	64	141	69	127	0	401
Total	278,360	35	77	38	56	8	214

Source: Anon, 1996 (Unpubished documents).

Notes: As explained in the text, prior to 1980 the area of forestry administration was not matched with that of civil administration. In order to match forestry and civil administrative areas, reorganization of the forest areas was done in the early 1980s. As a result, some reserved forests were divided into two parts, included in two township forest areas closely located.

In Tharrawaddy forest division, because of this re-organization, Minhla reserved forest was divided into two parts: one in Minhla township and the other in Letpadan township. Konbilin reserved forest was also divided and included in Letpadan and Tharrawaddy townships. The results of forestry inventories conducted after 1980 were shown on a township basis.

The widespread use of slogans such as "forestry for sustainable development" by international development and conservation organizations, and the introduction of ITTO's guidelines on the sustainable management of natural tropical forests and tropical plantations indicate that serious efforts are being made at the regional and international levels to achieve sustained yield management of tropical wood resources. They also reflect the fact that some regions of the world have neglected basic sustained yield forest management. Myanmar's persistence in applying a sustained yield philosophy should be recognized as a historically significant effort to maintain its cover of natural forests and protect its teak resources. In theory, Myanmar's forestry working plans should be revised every 10 years. However, the plans examined in this paper were revised irregularly. As far as can be ascertained the main reasons for this irregularity were recalculations of teak growth rates and social and political changes. Clearly technical considerations alone are not sufficient to guarantee sustained yield management. Social, political, economic and administrative aspects must be considered in the development of long-term forest management principles and plans.

In particular, the sustained production of teak from natural forests will be difficult because of its low rate of occurrence in Myanmar's native forests. Brandis considered that planting teak in the natural forests to increase the potential for achieving sustainable production would offer considerable opportunities. Teak logs have mostly come from natural forests and the management of teak in natural forests is still being given priority. For example, the objectives for future forest management laid down in the forest policy of 1995 include: "to pursue a sound programme of forest development through regeneration and rehabilitation operations, to optimize productivity from natural forests, to recognize that plantation forestry is not a substitute for natural forest management" (Govt. of Myanmar 1996). However, three actions should be taken immediately to counter the decline in natural regeneration and the drastic fall in teak growing stock. They are carrying out enrichment planting, prevention of illegal logging and encouraging public participation in forest management.

Enrichment planting using teak stumps should be undertaken. Teak stumps are easy to transport and can be stored almost anywhere. Their coppice shoots outgrow weeds within a year or two if the sites are tended and weeded. They thus have important advantages when compared to the planting of teak seedlings. Between 30 and 50 teak stumps per acre could be planted in the reserved forests. Enrichment planting of this number of stumps is feasible from both labour and financial perspectives. (In teak plantations managed on 80-100 year rotations, about 40-50 trees per acre are left standing after the final tending operation at 40 years).

Prevention of illegal logging is also essential. At the time of British rule, strong punishment was meted out to those who breached the forest laws. Also, reserved forests were created in the plain areas to supply timber to local inhabitants whose population was much less than now. Such action helped protect the natural forests from being destroyed. The nation's population has grown and the plain forests have been converted to agricultural land or townships, so the population pressure on the remaining natural forests has increased. Timber products have enjoyed higher prices since 1989 when the private sector was allowed to reenter the timber trade and this has also encouraged illegal logging.

Public participation in forest management is a prerequisite for solving these problems. And in 1995, the government of Myanmar issued a "Community forestry instruction" encouraging local people to participate in forest management planning and implementation (Forest Department 1995b). Local people are now able to use reserved natural forests and plantations established for local needs on a sustainable basis. The Forest Department provides people with seedlings and explains the most appropriate methods for both plantation establishment and initial enrichment plantings. As well, it will not levy a royalty on forest products extracted from community forests for domestic use or for sale in the local area. These policy measures are expected to reduce the population pressure on forests and discourage illegal logging. If action can be taken on the three issues, the future for Myanmar's teak production will look for a more positive.

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NOTE

1) In Myanmar, the spellings of some towns and rivers, etc., have been changed. The words in parentheses show the old spelling of names as used in this paper; Bago (Pegu), Pyay (Prome). Ayeyarwady (Irrawaddy), Taung gu

(Taungoo). As this paper is concerned with the historical context, the old names are used for the sake of consistency.

2) Girdling means killing a tree with a broad circular cut through its bark and into the sapwood. Teak trees left standing for three years after being girdled dry evenly and can thus be floated down river. This produces a good quality timber and reduces extraction costs. Most teak-trees in Myanmar are harvested three years after girdling. Teak trees of under exploitable girth are also girdled if they are unlikely to survive up to next felling cycle (30 years). It is said that the number of such trees consisted of about 10% of total girdled trees.

3) This is equivalent to a stem diameter of 22.9 inches or 58.2 cm. Although the minimum girth limit was set at 6 feet in girth at 6 feet in height, the actual girdling was done to those trees of 7 feet in girth at 6 feet in height in Thonze forests in 1857. It is mentioned that the girth limit was raised to 7 feet measured at 6 feet from the ground (Govt, of Burma 1946-47). The present measurent of exploitable girth at 7 feet 6 inches in moist forest and 6 feet in dry forests measured at 4 feet 6 inches in height have been begun in 1930 (Chein Hoe 1969).

4) Group one includes Pyinkado (*Xylia dolabriformis*), Padauk (*Pterocarpus macrocarpus*), Thingan (*Hopea odorata*), Thitya (*Shorea oblongifolia*), Ingyin (*Pentacme siamensis*) and Tamalan (*Dalbergia oliveri*).

5) The application of Von Mantel's formula in selection systems might produce conservative yield estimates. Osmaston (1968) explains that the formula has frequently been used for irregular forests that are extensively managed e.g. in India and Burma where the yield has been confined mainly to those comparatively large trees above a size limit that corresponds to the exploitable age. In such a situation the yield will be conservative.

Von Mantel's formula is shown in Osmaston (1968) as,

$$AY = \frac{2AG}{R}$$

Where,

AY=Annual Yield, AG=Actual Volume of Growing stock, and R=Rotation

The Burmese version of this formula was

$$ABA = \frac{TBA}{R/2x(1-r^2/R^2)}$$

Where,

ABA=Annual Yield in Basal Area, TBA=Total Basal Area, R=Rotation, and r=number of years taken to achieve the smallest girth measured in all sample data.

6, Harvesting teak trees without conducting any girdling.

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Article

Private Forest Owners and the Forest Resource Database

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ABSTRACT

This paper investigated private forest owners' awareness of the forest resource database, *Shinrinbo*. The database is used to develop forestry plans and track forestry statistics. There are many discrepancies between the values shown in the database and the actual stands. To clarify forest owners' opinions on the *Shinrinbo* and related forest information systems, a questionnaire was conducted in Ousumi Regional Forest Planning Area in Kagoshima Prefecture in July 1996 and useful responses were obtained from 793 forest owners. It was found that : (1) 17.9% of forest owners were not aware of *Shinrinbo* itself. 60.2% were only aware of the name of *Shinrinbo* but did not know the contents. Only 15.4% indicated that they understood the contents of *Shinrinbo*. (2) 23.8% of forest owners knew that at least some part of the *Shinrinbo* data on their forests was wrong. The actual percentage of errors is probably greater, especially for area. Also, the database uses a simple yield table for data estimated before 1970, as the constant table. (3) 18.4% of forest owners clearly indicated a willingness to supply correct information on their forests to the prefectural government. (4) Most forest owners think that the prefectural government, currently managing the *Shinrinbo,* is not the appropriate organization to manage a forest resources database. The most appropriate manager was thought to be the local forest owners association (70.2%). The role of local forest owners association in private forest practices and local forestry development policy has been increasing, and forest owners' expectation that local forest owners associations should play a role building a database is also high.

As there are many small-scale forest owners in Japan, cooperation between owners to develop an accurate forest resource database is extremely important, especially as the role and social expectations of a database are increasing. However, forest owners' awareness of the *Shinrinbo* is low and awareness of the private Forest Operation Plan even lower. Approximately 90% of forest owners are formally involved in the Forest Operation Plan and obtain several benefits under related laws, for example subsidies and tax reduction, but only 20.6% of forest owners answered that they have a Forest Operation Plan. This suggests that forest owners do not adequately participate in forest planning process. An extension program for forest owners is discussed and improvements suggested for the information system and the method of forest inventory.

Keyword : private forest owner, forest resource database, *Shinrinbo,* forest information system, forest planning system

INTRODUCTION

The importance of databases in all kinds of economic and non-economic activities has grown. This also applies to forest management in Japan. The database of non-national forests in Japan is called the *Shinrinbo,* and is the source of basic statistics on forestry and forest resources in non-national forests. Non-national forests comprise 58% of the total forest area and 65% of the total standing volume in Japan. The Forestry Agency of the Government of Japan determined the contents of the current *Shinrinbo,* under Article 8 of the Regulation on the Regional Forest Plan of non-national forests and Regional Forest Plan of National Forests (Ministry of Agriculture, Forestry and Fisheries, Order No.20 of 1991 ; hereafter, Regulation on the Regional Forest Plan). Forty-seven prefectural govern-

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Table 1 Contents of the *Shinrinbo*

Category	Explanations
Administrative area	Forest planning area, Municipalities, District forestry office
Location of forest	Compartment, Sub-compartment, Section of village, Lot number
Forest owner	Name, Classification whether living in the village or not
Type of function	Timber production, Water conservation, Mountain conservation Living environmental conservation, Recreation and culture
Type of forest	Protection forest, Natural park system
Area	Unit: ha (to the second decimal place)
Classification of forest	By forest management type and story
Forest type	Artificial forest, Natural forest, Cutover land, Treeless, Bamboo
Detailed type	Single storied forest, Multi-storied forest, Improved natural forest, Naturally regenerated forest
Story	Classification by upper story and lower story
Species	Species code, Current and future
Ratio of mixed	Percentage in volume base
Ratio of area	By story in case of multi-storied forest
Age	Average and range of age in uneven-aged forest
Age class	One age class is 5 years interval
Crown density	3 classifications (sparse, medium and dense)
Site quality	For main species, Current and future
Locality	Current and future
Site class	For main species, Current and future
Method of cutting	Clear cutting, Selective cutting, Felling prohibition, Others
Method of regeneration	Plantation, Natural seedling, Sprouting, Difficult to regenerate
Improvement of forest type	Single storied forest, Improved natural forest management
Specific management area	Multi-storied forest, Long rotation management Forest specified method, Forest for promote to cut
Volume	Volume per ha, Unit: m^3, By coniferous and broad-leaf
Growth	Growth per ha, Unit: m^3, Total growth
Volume at the cutting age	Volume per ha, Unit: m^3
Forest management plan	Presence of authorized forest management plan
Profit-sharing forest	Type of profit-sharing reforestation
Recreation forest	Recreational forest, Public health forest
Remarks column	

Source: Shinrin Keikaku Seido Kenkyukai (1992) pp.96-107.

ments each created databases containing the basic items determined by the Forestry Agency, and continue to manage these databases. The items recorded in each prefectural system are almost the same because the basic contents were already specified. The basic items are shown in Table 1. For national forests managed directly by the Forestry Agency, there is another database which contains less information than the database on non-national forests. Data is recorded for each forest owner and tree stand. Most statistics used for forest resource planning derived by summing the data in the *Shinrinbo*. This type of forest data system is unique to Japan, and Continuous Forest Inventory, which is the usual method in other developed countries, is not practiced in Japan (Nishikawa, 1994).

Article 15 of the Regulation on the Regional Forest Plan states that the regional forest plan and related maps should be open to the public, but there are no articles specifying public access to the related database, the *Shinrinbo*. Most of the data in *Shinrinbo* relates to private property. The database has been used to set public policy by the Department of Forestry particularly at the prefectural level.

Recently, uses for the database have increased. These include needs in the public sector outside the department of forestry. A typical example is the environmental database system. The importance of environmental policy in Japan has been increasing and a database on the environment is now required. The forest resource is a highly important environmental resource but the Environment Agency has no national-level database on it. In forestry research, an attempt at forest resource accounting including environmental aspects has begun (KOIKE *et al.*, 1997 ; YAMAMOTO, 1997), and accurate figures are needed. Another example is the increasing need for information by other forest interests, such as, local forest owners associations. Under the most recent Amendment to the Forest Law (1991), the regional forest planning area, which is the basic unit of forestry development, has become a watershed area. Establishment of forest information centers is being discussed in each forest planning area. Recently, personal computers have become capable of coping with the large amount of data which gives greater access to the *Shinrinbo*. For example, YOSHIDA (1986) described renewal of the data in *Shinrinbo* using a personal computer in Kumamoto Prefecture and KOMAKI (1988) described the use of computers to develop a *Shinrinbo* management system for the forest owners association in Iwate Prefecture. There are many such examples. A third example of the increased need for a forest database is the development of geographical information systems (GIS). For example, Gifu Prefecture, one of the most active prefectures in the field of forestry information systems, introduced GIS, and YONEMOTO *et al.* (1994) pointed out that accurate data is needed to improve the system. MAKINO *et al.* (1994) tried to develop a GIS system for introducing highly efficient forestry machines in Fukui Prefecture. Lastly, usage of database such as *Shinrinbo* is also developing in research. TATSUHARA (1994), for example, proposed a method of predicting the growth of coniferous plantations using information from the *Shinrinbo*.

If the use of *Shinrinbo* is to increase, the accuracy of the database must be examined, because the extent to which the data can be used depends on its accuracy. If the database described in Table 1 was based completely on real stands, it would be very useful. However, there are many discrepancies between the figures in the database and the real situation, and therefore the database is not very reliable. A new national-level forest inventory system is now being developed by the Forestry Agency, and the improvement of the *Shinrinbo* is also being considered (SHIRAISHI, 1995). The current data management system has many problems particularly in the data structure and information systems. The contents of the *Shinrinbo* are also being reconsidered, for example, the kinds of broad-leaved trees included and the accuracy and precision of the yield tables. These are important consideration in updating and improving the database, but I also suggest that another important cause of the problems in the current system is related to forest owners.

Article 21 of the Regulations on the Regional Forest Plan specifies that the *Shinrinbo* and related maps must be maintained in the local offices of prefectural governments. The *Shinrinbo* can also be stored in municipal offices, particularly those which have a forest improvement plan. Thus the *Shinrinbo* is both managed and used by prefectural governments and municipal offices, rather than by the forest owners. In order to develop a national forest database and ensure effective utilization of the existing system, the accuracy of the *Shinrinbo* must first be improved. In this paper, we consider the importance of the relationship between *Shinrinbo* and forest owners in this process.

There are four important points in the relationship between the *Shinrinbo* and forest owners which affect its utilization. Firstly, the cooperation of owners is essential if any system is to be effective. This applies to every project involving privately owned forests, and is an important factor if the non-national forest resource database is to be improved. Secondly, the importance of consensus among those involved in planning forest resource utilization has recently been recognized, and clearly this must include forest owners. An accurate *Shinrinbo* can provide a common database for making decisions about forest use. Thirdly, statistical projects have generally deteriorated in Japan. Limited budgets have reduced the number of survey staff in central and local governments. Prefectural governments' local agriculture and forestry offices are unlikely to have any additional resources for survey projects in the future, so it is vital to have the cooperation of the forest owners. Lastly, a regional forestry activation program has recently begun, and a forestry information system that includes cutting activities (final cutting and thinning) is required for future business. Generally, post-war forestry policy has been one of land management and the related planning and data management systems have strictly related to these policy areas. However, cutting activity is now related to sustainable regional forestry, and forest owners can contribute to this information system. These four points must be considered and the relationship between the *Shinrinbo* and forest owners clarified.

This paper examines the attitude of forest owners to the database, using results from a questionnaire undertaken in Ousumi Regional Forest Planning Area in Kagoshima Prefecture in the southern Kyushu. In particular, the forest owners' concern regarding the system and their cooperation with the system, as well as the relationship between forest owners and the forest database are discussed. Finally, several policy implications are identified.

QUESTIONNAIRE AND SUMMARY OF FOREST OWNERS

As part of the regional forest labor study program subsidized by the Ministry of Labor of the Government of Japan, a survey of private forest owners who are representative members of local forest owners associations in Ousumi Regional Forest Planning Area was undertaken to investigate the regional situation with respect to forest resources, forest management and forest products supply. A questionnaire was sent to 1,350 forest owners on July 24, 1996 and 825 replies were received by August 30 (response rate of 61.1%). Overall, 793 (58.7%) responses were analyzed in this paper. The planning area consists of 210 thousand ha, 63.0%, 13.4% and 3.4% of which are forest, agricultural land and residential lands, respectively. The forest area covered by the Forest Law consists of 123,528 ha, 38.8% of which is national forest and 61.2% of which is public and private forest. The proportion of needle-leaved trees in the total forest resource is 68.6% in area and 77.7% in standing volume. Artificial forests comprise 69.0% of the non-national forests, the major species of which are *Cryptomeria japonica* (sugi) and *Chamaecyparis obtusa* (hinoki). The age-class distribution of artificial needle-leaved forests shown in the current Regional Forest Plan (KAGOSHIMA PREFECTURAL GOVERNMENT, 1993) is 12.3%, 19.8%, 19.1%, 15.9% and 12.5% in the 16-20 years, 21-25 years, 26-30 years, 31-35 years and 36-40 years age classes, respectively, and these age-classes represent approximately 80% of the forests. The forests in these age-classes typically require thinning. The privately owned forests are generally divided into small units with many forest owners, and the average size of holding in the study area is 0.99ha. The average size of holding in Kyushu is 1.81ha, and the overall average for Japan is 2.69ha.

The forest owners who replied to the questionnaire were generally quite old; 71.5% of respondents were over 60 years old. The most important sources of income for the owners were agriculture (33.4%), annuity (29.6%), salary (18.9%), and livestock (7.1%). In this area, livestock is a major industry. In addition, 22.2% of the forest owners received income from non-wood forest products, including self-consumption. Non-wood products include fresh Shiitake mushrooms (40.9% of forest owner with income from non-wood forest products; plural answers), bamboo shoots (31.8%), firewood (16.5%), flowers (8.5%), dried Shiitake mushrooms (6.8%), bamboo (6.3%), edible wild plants and medicinal herbs (5.1%). The percentage of forest owners who had recently received income from forestry excluding non-wood products, was 13.6%. Only 2.7% of forest owners had forestry as their most important income source. Thus, most forest owners in this area have small holdings and forestry is not the most important source of income in the majority of cases.

To ascertain the main reasons for owning such small holdings, the questionnaire listed ten alternatives and forest owners were asked to rank their importance over five levels. Those reasons ranked as "most important" were used as an index of the main reasons for forest ownership. The responses indicated that conservation of natural environments and water resources (39.9%), retaining ancestral land (30.9%), timber production (29.0%), leaving property to descendants (26.6%), preparation for extraordinary expenditure (10.6%), benefits for local residents (8.9%), pleasure of forestry work (8.9%), health and pleasure for the family (7.0%), production of by-products (3.6%) and production of agricultural materials (3.1%) were the major reasons for owning forest. These results indicate some important characteristics of forest ownership in this area. First, production objectives are not always very important. Most notably, the percentage of owners involved in production of non-wood products and agricultural materials was very small, less than 5%. Previously, these activities would have been regarded as more important, but production activities are decreasing because most forest owners are aging. Their agricultural production is also small but sufficient for their own use and they have several income sources other than forestry or agriculture. Thus, the economic role of forestry for private forest owners has been decreasing. Currently, the major reasons for owning forest are related to environmental conservation and retaining ancestral lands. The latter objective is an important, traditional reason for forest ownership in Japan. Owning forest for reasons of pleasure or maintaining health is relatively recent. Managing forests as a form of insurance against unexpected expenditure has also been a traditional reason for forest ownership, but recent low timber prices have reduced the importance of this.

A typhoon damaged forests in the study area in 1993 (MATSUSHITA, 1994). The percentages of forest owners who sustained some or extensive damage from the 13th typhoon of 1993 were 27.1% and 34.4%, respectively. This damage affected not only the local forest resources but also forest management practices. Some forest owners completely lost their will to continue managing their forests. The percentage of forest owners whose forests had been damaged but who had completely finished salvaging the damaged trees by the summer of 1996, three years after the typhoon damage, was 37.6%. However, 21.8% of forest owners simply left the damaged trees as they were. The existence of the typhoon-damaged forests is a serious forest issue in the region.

FOREST OWNERS' CONCERNS ABOUT THE FOREST RESOURCE DATABASE

Contents of the forest resource database

The private forest resource database, *Shinrinbo,* is the most important database for construction of a forest information system. The most important issue for the database is the accuracy of the contents. As previously indicated, there are many discrepancies between actual situations and the data in *Shinrinbo*. What do forest owners think about the differences? First, we asked whether forest owners were aware of the data registered in *Shinrinbo* for their own forests (see Table 2). It was found that 17.9% of

Table 2 Awareness of the *Shinrinbo* (person, %)

Answer-1	Answer-2	Person	Percentage
I am aware of the *Shinrinbo*.	My forests are correctly registered.	93	11.7
	There are some errors.	29	3.7
	I do not know.	477	60.2
I am not aware of the *Shinrinbo*.	I am interested in the contents.	67	8.4
	I am not interested in the contents.	75	9.5
No answer		52	6.6
Total		793	100.0

forest owners were not aware of *Shinrinbo* itself. *Shinrinbo* is the most basic database of forest resources managed by prefectural governments, and forest owners should be aware of that. However, only 75.5% of forest owners were aware of *Shinrinbo,* and 60.2% of forest owners only knew of *Shinrinbo* by name, but did not know the contents of the database.

Only 122 persons (15.4%) understood the contents of the database. The response "my forests are correctly registered" was selected by 11.7% of respondents, and the response "there are some errors" was selected by 3.7%. Although only 3.7% of all forest owners answered that there are some errors in the database, this represented 23.8% of those forest owners who were aware of the contents of *Shinrinbo*. This proportion is too large. It is also worth noting that a considerable number of forest owners who indicated that they are correctly registered did not know the contents of the *Shinrinbo* in detail. The real ratio of forest owners whose forests were incorrectly registered is clearly greater than the response rate would indicate.

The errors that the forest owners identified in the *Shinrinbo* were as follows: age (12 respondents); area (10 respondents); species (9 respondents); and other errors (1 respondent). In total, 19 respondents identified errors. The data in *Shinrinbo* increases every year, and if a new plantation was correctly registered in the planting year, the age in the database should not differ from the real situation. Likewise, the species of forest does not change until the final cutting and so there should be few errors in this field of the database. However, there is more likelihood of error in area. The area of each holding in Japan is very small, and each owner may have several small forests in different locations. There were several owners who indicated the area recorded for their forest in the database was wrong, although this is difficult to evaluate. Generally in Japan, the topography and configuration of forestland is complicated, and the correct area of forestland is difficult to calculate. As the area of given unit is very small and there are many units in a forest area, survey costs are high compared to the value of the forestland and in most forest areas, surveys are not actually performed. Accordingly, almost all data on the area of forestland contains some errors.

Other errors such as age or species are easy for most forest owners to notice. Approximately one-quarter of forest owners identified errors in these fields of the database. As shown in Table 1, the *Shinrinbo* includes many items, which fall into three categories, namely, unchangeable data, for example, location; data that change with forest practices, for example, road conditions; and data that change annually, for example, volume. The items in the first two categories can be revised if an initial survey is correctly undertaken or data is correctly updated in response to forest practices. However, it is difficult to evaluate data that changes annually. For example, current standing volume is not easily estimated by most forest owners. In reality, there are many differences between the volume recorded in the database and the actual standing volume, but no forest owner indicated that the volume was incorrect. In the *Shinrinbo,* standard simple yield tables are used to automatically calculate the standing volume of each stand. Thus, the value in the database is an estimate only, not an actual measure. As the forest owner does not know the actual standing volume, he can not detect errors in the database. However, logging companies or researchers on forest mensuration can identify differences. Under these circumstances, the percentage of forest owners whose forests are incorrectly recorded in the *Shinrinbo* is estimated to be over 25%.

Forest owners were asked when they noticed that the data recorded for their forest in the *Shinrinbo* was wrong. One forest owner noted errors 40 years ago. Ten out of 15 respondents stated that the errors had been found in the past ten years. However, only a few respondents indicated the year in which errors were noted and it is therefore difficult to interpret when most of the errors occurred. It is possible that the differences between data in the *Shinrinbo* and the real situation occurred recently. Forest owners who found erroneous data in the *Shinrinbo* were asked whether they contacted the administrator of the *Shinrinbo*. Only 4 forest owners had contacted the administrative office, and 17 forest owners had not. Twelve forest owners wanted to correct the data, but 8 forest owners did not. The exact reasons that most forest owners who found errors remained silent and why 40% of forest owner who found errors did not want to correct the data were not clear, but it is apparent that the existence of wrong data in the *Shinrinbo* does not affect the forest owner in any way.

Cooperation with the forest information system and the spread of personal computers

It was noted above that there are many discrepancies between the data in the *Shinrinbo* and the actual situation, but accurate forest information is necessary to properly develop a regional forest management plan. Forest owners were asked whether they were willing to supply the correct data, such as age, species and area, to prefectural governments. The response is shown in Table 3. Only 18.4% of forest owners indicated a willingness to cooperate with such a forest information system. The other responses were split between possible cooperation under certain conditions and no interest. In this case, the data would be limited to basic information such as age, species, and area of forest, but nevertheless the percentage of respondents willing to cooperate was less than 20%. Almost twice this number of forest owners were not interested in cooperating. This suggests that it would be difficult for an administrative office to obtain data from forest owners if a forest information system were started. It seemed that most forest owners thought that preparing the correct forest information for an administrative office would be similar to opening up their property. However, only basic data such as age or species was being considered, and given this, this willingness of forest owners to cooperate was low.

Forest owners were also asked whether they would cooperate with a forestry information system that required the forest owner to register data on their forest (such as age, species and area) with the local forest owners associations or regional forestry information center, and in return, receive management information, for example, recommended thinning periods. The responses are shown in Table 3. The percentage of forest owners who would like to register and obtain such information was only 10.8%, almost half the percentage willing to provide correct data to prefectural government directly. These results indicated that it would be difficult for local forest owners associations to develop a new forestry information system.

To develop a new information system in the field, access to a computer would be important. According the questionnaire, 7.8% of forest owners have a personal computer. The kind of software that forest owners are using include (multiple answers, total responses from 58 persons) : word processor (26.9%), spreadsheet (22.4), game (19.0%), education (19.0%), agriculture (10.3%), communication (10.3%), forestry (1.7%) and other (5.2%). A total of 20.7% of forest owners do not use their computers. Six forest owners were using the communication functions of their computers, and their ages were as follows: 50-59 years old (1 person), 60-69 years old (3 persons), and 70 years old and over (2 persons). Although the number is currently very small, it is interesting that some elderly forest owners are using the communication

Table 3 Registration of forest information (person, %)

	Answer	Person	Percentage
Prefectural government*[1]	I would like to cooperate with the forest information system.	146	18.4
	I would like to cooperate with the forest information system depending on the contents.	295	37.2
	I am not interested in the forest information system.	277	34.9
	No answer	75	9.5
	Total	793	100.0
Forest owners association*[2]	I would like to register with the forest information system.	86	10.8
	I would like to register with the forest information system depending on the contents.	303	38.2
	I am not interested in the forest information system.	344	43.4
	No answer	60	7.6
	Total	793	100.0

Source: Matsushita (1997) p.73

*[1]Question was: It is said that there are many discrepancies between the actual forest situation and the data in the *Shinrinbo*. Accurate forest information is necessary to correctly develop regional forest management plans. Would you supply the correct data (age, species, areas and so on) about your own forests for the prefectural government?

*[2]Question was: How do you feel about registering the forest data (age, species, area and so on) with the local forest owners association or "regional forestry information center" and obtaining management information, for example, recommended thinning periods in return.

Table 4 Forest owner with a forest management plan

Answer	Person*3	Percentage*4 (%)
Planned (Individual)*1	75	10.6
Planned (Group)*2	71	10.0
Not planned	347	48.9
Unknown	272	38.3

Source: Matsushita (1997)
*1Forest management plan based on the individual unit.
*2Forest management plan based on a grouped forest area over than 30 ha owned by multiple forest owners.
*3Multiple answers.
*4Percentage of persons answering this question (=710 persons).

function of personal computers.

Although only 7.8% of forest owners have a personal computer, the ratio is expected to exceed 10% in the near future. The total number of forest owners in the area was 19,504 in 1980 (Agriculture and Forestry Census; minimum holding of 0.1ha), so it is estimated that approximately 1,500 forest owners have personal computers. A forest information system is available on personal computer in the study area.

The ownership of personal computers is also increasing among forest owners associations and logging companies. In a 1991 survey, there was only one personal computer among all the forest owners associations in the study area (excluding the department of log marketing), only four in the local forestry office of the prefectural government, and only ten in the forestry section of the municipal offices (total 18). The total number of personal computers in the forestry and forest products processing sector of the study area was 37 at the end of fiscal year 1991, and according to the regional forestry development plan was expected to increase to 57 by fiscal year 1996. Thus, the spread of computers within local government, forest owners associations and processing companies is much lower than among forest owners.

Private forest management plan and forest resource database

The forest planning system is part of the basic forest policy of Japan. The forest planning system has several tiers; the national level (Basic Plan on Forest Resources, Long-Term Perspective on Demand and Supply for Important Forest Products, National Forest Plan), the prefectural level (Regional Forest Plan), the municipal level (Municipal Forest Plan), and the private forest owner's level (Forest Operation Plan; hereafter, FOP). The FOP is developed by the forest owner (Individual Forest Operation Plan; hereafter, IFOP) or a group of forest owners if the total forest area is greater than a specified size (Grouped Forest Operation Plan; hereafter, GFOP). These forest plans are made cooperatively. The forest resource database for private forests, *Shinrinbo,* is used by prefectural governments to develop the Regional Forest Plan. In this sense, the *Shinrinbo* is fundamental to the Japanese forest planning system. Part of the Japanese forest resource statistics is developed from the figures in the forest planning system, so the data in *Shinrinbo* is very important. In the study area, the total area of non-national forest is 80,342ha, and the total area covered by FOP was 74,464ha at the end of the fiscal year 1994. Thus, the percentage of forests covered by a FOP is 92.7%, and almost all the private forest in the study area is covered under the forest planning system. The majority of the FOPs for the area were GFOPs (92.9% and 85.3% in the area of Ousumi and Kanoya agriculture and forestry offices, respectively.

The questionnaire asked one question about the FOP: "Have you made an FOP?" The response (Table 4) show that only 10.6% forest owner had made an IFOP and only 10.0% a GFOP. These results do not correspond with the forest plan statistics shown above. Thus, Accordingly, most forest owners who answered "no plan" (48.9%) or "unknown" (38.3%) have made a FOP, but they have forgotten or do not know of the existence of their FOP. The statistics for the IFOP, made by a single forest owner, were similar in the questionnaire and the official statistics on FOP. Thus, most forest owner who made an IFOP understand the existence of the plan, but in the case of a GFOP, most forest owners do not even know there is a plan.

A FOP has to be renewed every five years. In the case of an IFOP, the forest owner himself has to update the contents and file the specific application. In the case of a GFOP, the local forest owners association generally makes the plan for all forest owners who have forests in the planned area. Thus, the forest owner's involvement with the plan is much lower than in an IFOP. GFOP also have to be renewed every five years, but in most cases, the local forest owners association handles most of the procedures for renewal, further reducing the involvement of the forest owner and thus their memory of the plan. This is not a problem if the contents of the FOP are renewed correctly, but nevertheless the forest owner should be aware of the existence of the plan. However, in most cases, the forest owner not only has limited awareness of the FOP, but the contents of the FOP are unreliable.

DISCUSSION

Reasons for the low cooperation of forest owners with the forestry information system

The results of the questionnaire showed that forest owners' cooperation with the development of a forest resource database or forestry information system is limited. Why are forest owners not willing to cooperate with the information system using the *Shinrinbo*? The following three major factors were noted. (1) Forest owners do not want to provide the data. (2) Forest owners do not oppose providing forest data but they believe there are problems with the place that is to receive the data, for example, the prefectural government or local forest owners association. (3) Forest owners are not interested in an information program if the contents are not clear to them.

Firstly, the second reason is considered. To whom are forest owners willing to provide forest resource data (assuming they are willing to provide the data)? According to the results of the survey, forest owners believes that the preferred place to manage forest resource data (age, species, area and so on) is the local forest owners association (70.2%), the municipal offices (9.5%), the prefectural forest owners association (3.4%), the Forestry Agency (2.5%), the local agriculture and forestry office of the prefectural government (2.0%), the prefectural government (1.0%), the district forestry office of the Forestry Agency (0.6%) and regional forestry office of the Forestry Agency (0.1%). Obviously, the local forest owners association was the preferred organization. Currently, the *Shinrinbo* is managed by the prefectural government, located at the prefectural seat. Only 3.0% of forest owners preferred the local agricultural and forestry offices or headquarters of the prefectural government. This suggests that the relationship between the forestry department of the prefectural government and forest owners is not well developed. Although municipal offices have almost no role in managing the *Shinrinbo* under the current system, it was the second most preferred place. It seems that forest owners want the database to be managed closer to where they live. Municipal offices are more accessible and can protect the forest owners' privacy. Under current forest resource and forestry policies, the roles of prefectural government and local forest owners associations receive considerable attention, but municipal offices generally have no specific role or budget for forestry. If the management of the forest resource database moved from the prefectural government to municipal offices or local forest owners associations, the forest owners may still not be willing to cooperate, and if they did not, the municipal office or local forest owners association do not have the authority to compel them to cooperate.

The third factor contributing to the limited cooperation by forest owners to develop a database was also important. This questionnaire did not specifically propose a new information system or changes to the policy programs in the study area. After the 1991 amendment of the Forest Law, units for forest planning were redefined, principally on the basis of major river systems. Local forestry activation centers opened and developed basic plans to activate local forestry, including developing forest resource and forestry information systems. However, in most areas, there is no defined plan to develop an information system beyond purchasing computers. Thus, forest owners have little exposure to a local forest information system. The prefectural government manages the current database, *Shinrinbo,* with little input from the forest owners, and most forest owners do not understand the system itself or its contents. Thus, an extension program is urgently needed to promote the value of an information system for forestry. Table 3 showed that a high percentage of forest owners would cooperate with a forest information system depending on its contents. Some of these respondents did not understand the system. For example, some forest owners may believe that he has to investigate his forest resources in detail to register his forest with a new information system, or that he has to go to the prefectural government office for registration.

The greatest difficulty facing the development of a forest information system is forest owners who do not want to provide data. This relates to the ownership of the forests and the general perception that a private forest owner has no obligation to reveal the contents of his property. This must be considered in the context of the broader forest management policies, and especially the relationship between FOPs and the forest resource data. FOPs include forest resource data such as age, species and area. If the FOP was developed using an accompanying forest inventory, the data in the *Shinrinbo* should be correct because the FOP is renewed every 5 years. The incentive for forest owners to make a FOP is to make them eligible for the benefits available from the government under the Forest Law. Developing a FOP includes sending correct forest data to the local government. Most forest owners have forgotten the subsidy program for forest resources, forestry and wood related industries. Subsidies are available to allow the private forest sector to manage their forest correctly despite the low price of forest products compared to labor costs and to enable forest owners to provide the non-timber values of forests that are not recognized in the market system. The argument for subsidies is well understood by the public, and a vanity of subsidies has been introduced to the forestry sector since World War II. Thus, private forests have not been maintained solely by the forest owner, and therefore the owners have an obligation to reveal basic forest data such as species and age.

Participation of forest owners in the forest planning system

Most forest owners do not know that their forests are registered in a database, and some forest owners are aware that incorrect data are listed for their forests but remain silent about the errors. Under the current system, there is no severe disruption of the system even if the forest owner does not participate. This has resulted in inadequate participation of forest owners in the planning system. Recently, the non-timber value of forest resources has risen, and the possibility of participation by the general public has also been discussed (e.g. KONOHIRA (1996) and SAITO (1997)). Public participation is required if the traditional forest plan that is limited to timber production is to be expanded to include other values in the future. Generally, these arguments assume that the participation of the forest owner has already been achieved for at least timber management. However, the results of this study show that the participation of forest owners in forest planning is limited.

There are several problems in the forest inventory process that contributes to the development of the regional forest plan. The Japanese forest planning system has several components. The most basic plan that provides an inventory of non-national forests is the Regional Forest Plan and the FOP. Both plans are revised every five years. If accurate forest inventory data is provided at the time these plans are renewed, the discrepancies in the database should decrease. Usually, however, the figures in renewed plans are automatically revised from the data of the previous plan without an actual forest inventory. Thus, in the current system, timber volumes are estimated from the species and age of the stand with no regard to the real situation.

Without conducting an inventory, the following problems can arise during renewal. (1) The species of forest, information which forest owners can easily see incorrect, can be wrong. Generally, when a new plantation is established, the forest owner receives a subsidy from the Japanese Government. To receive this, he has to report the planting activities to the department of forestry of the prefectural government. Thus, differences between the real situation and the database do not often arise at this point. The differences arise when forest owners cut their trees without permission or reporting. As shown in MATSUSHITA (1996a), the main problem is that there is a large proportion of cutting activities that are not reported. In most areas, greater than 50% of cutting activities are not reported. Reporting tends not to occur if there is potential for natural regeneration (e.g. in broad-leaved trees) or if the cutting area is small or selective cutting was used. (2) The volume listed in the database does not always approximate the real situation. The stand volume in the database is estimated automatically from the recorded species, age and site-class using the yield table in the computer. Even if the yield table is correct, the volume will not be correct if the site-class of the forest stand has not been correctly evaluated. In Kagoshima Prefecture, all forests in a sub-compartment are given the same site-class designation for convenience (YOSHIDA, 1997). This can clearly cause errors in the database. In addition, the yield tables used by most Prefectural Governments were calculated in the 1950s and 1960s. In Kagoshima Prefecture, it is not clear when and how the yield tables were estimated, but the yield tables have been used by the prefecture since before 1970 (YOSHIDA, 1997). Thus, the yield tables themselves may also be incorrect or inappropriate.

It is clear that neither the forest owner nor the forestry department of prefectural government has an adequate understanding of forest inventory and nobody knows the true status of the forests. Both forest owners and forest technicians must know that the figures in the database are inaccurate because they are calculated automatically and not checked by surveys. This removes forest owners from any involvement in the construction of the forest resource database. If the forest owner is dependent on income from his forest, he must do his own inventories. However, most forest owners cannot complete a forest inventory over a wide area on their own, and they depend on the public sector. In Kamiyahagi, Gifu Prefecture, the municipal office and regional forest owners association cooperated between 1977 and 1978 to improve the accuracy of the *Shinrinbo* (ITO *et al.,* 1983). The prefectural government first sorted the database by forest owner and combined the new database with the plan of forestry activities (cutting, planting and thinning) to create a Forest Management Register. This register was made available to the 900 forest owners of the town, and was checked by completing an inventory and confirming each owner's planned activities over the next five years. The resulting Forest Management Register was distributed to each forest owner, and each began to use the accurate forest database. This contrasts with the situation in the present study in which most forest owners do not know how their forests are listed in the official database. The Register in Kamiyahagi was an effective use of the subsidy for promotion of regional forestry. The *Shinrinbo* is the most basic database for both timber production and management of non-timber values. Only about 10% of forest owners develop an IFOP, as most forest owner's holdings are too small for an effective IFOP. Stumpage prices have been decreasing in Japan and as a result, most forest owners do not expect as high an economic return as they received previously. In this situation, it is difficult to expect participation by forest owners in forest inventory. Therefore, cooperation of the public sector (e.g. municipal offices and forest owners associations) is important.

KUMAZAKI (1997) proposed a cooperative national forest inventory to be done by the Forestry Agency, Environment Agency, prefectural governments, municipal offices, and volunteer citizens. If forest owners abandon forest inventory, such a national forest inventory will be essential, what are the implications of doing inventories without the participation of the forest owner? This proposal seems to place a low value on the contribution of forest owner, but without it, there will clearly be problems, as shown in the study. The cooperation of forest owners is thus very important. The first step in attracting the participation of private forest owners in the forest planning process seems to be to involve them in data collection.

CONCLUSION

Since the *Shinrinbo* has many problems, it is not greatly utilized, improvement of the *Shinrinbo* must be accompanied by improved utilization. Generally, the current forest statistics system in Japan was developed in the latter half of 1940's and has remained almost unchanged since (MANAGEMENT and COORDINATION AGENCY, 1995). The *Shinrinbo* system was created for use by the prefectural government and Forestry Agency. Their main purposes have been to obtain basic data to develop forest plans and to report regional or national forest resource statistics over a long time. The *Shinrinbo* has been used for this despite the discrepancies in the data. The potential uses of the *Shinrinbo* have changed, because there are now greater expectations on how forests are managed with more public interest in non-timber values. There is a general lack of statistics on environmental resources in Japan and the forest resource database must be improved and expanded to satisfy users with environmental interests. Use of the *Shinrinbo* has traditionally been limited to administrative functions within the prefectural and national forestry departments. Discrepancies in the data will become an even greater problem when use of the database expands beyond these areas. Therefore, a number of policy changes are required to reorganize the *Shinrinbo* and improve its utility.

First, the contents of the current database have to be distributed to all forest owners with a questionnaire which would allow discrepancies in the data to be identified. This would allow forest owners be become familiar with both the system and the contents of the database. After distributing the questionnaire, a forest inventory would be required to check the data. This should be done by the department of forestry of prefectural governments and local forest owners association in cooperation with the forest owners. Retired foresters, foresters from the National Forests, foresters from public forests (prefectural forests and municipal forests), foresters from university forests, as well as teachers and students from the department of forestry at universities could participate. Any other people interested in forest inventory would also be welcome to participate. A national inventory would be ideal, but the cost would be high. As a minimum, surveys should be conducted within each forest planning area, and they could be conducted over several years. Some kind of subsidy may be required to facilitate these surveys.

There are also problems, related to the forest planning system under the current Forest Law. Currently the forest inventory described above must be updated when the FOP is revised every five years. The total area covered by a FOP has been increasing, but the accuracy of the database has been deteriorating. The method of renewing this five-year plan must be reviewed. Why do prefectural governments authorize plans that are not based on a survey? As it would be difficult for both forest owners and the forest administration to repeatedly perform a forest inventory every year or even periodically, an initial survey and periodic partial review should be done. Most forest owners make a FOP, and this system has to be improved, particularly for GFOPs, but most owners are not aware of the FOP renewal procedure. The connection between *Shinrinbo* and the FOP for forest planning must also be considered. KONDO (1993) noted the important role of the "Forest Resources Conditions and Cutting & Planting Plan" that is included in the FOP. In Kondo's study, the data was not linked to the master file on forest resources, which was closely linked to the *Shinrinbo*. In this study area in Kagoshima Prefecture, records in the *Shinrinbo* have occasionally been corrected using data from FOPs in the local forest owners association. However, the number of cases is very limited, and such links are now exceptional. Statistical and administration systems must share information, but the access to information must give consideration to the protection of privacy.

A policy must also be developed to cope with forest owners who are indifferent to their forests or who do not live in the village where their forest is located. Those owners interested in forest management, expecting income from forestry or with a connection to their forest will probably be involved in the forest inventory and will contribute to improving the forest planning system. However, if the forest owner is not interested in his forest, the forest administration sector must still obtain the correct data about his forest. The recent increase in local forest owners associations managing forests is expected to continue (MATSUSHITA, 1998). As the number of forest owners who do not know even the location of their forests increases. Thus, some kind of consulting system will also need to be introduced.

The utilization of *Shinrinbo* must also be promoted. The current database contains many errors and its use is limited. Improvement of contents and increasing its use should be done together. The current policy for promoting forestry recommends introducing local forest information systems. Similar data as that in the *Shinrinbo* will be required in local systems, and it would be logical to link the two systems. Greater use of the *Shinrinbo* for research would also improve its accuracy. If there is to be greater use of the *Shinrinbo,* new systems of protecting privacy will need to be developed. These may include limiting access to the data to specific levels, such as 10% or 20%, or to specific types of data, such as time-series-data (when to cut, when to plant, and so on) which can be used for economic analysis.

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Article

A Practical Model for the Time-trajectory of Mean Phytomass and Density in the Development of Even-aged Pure Stands

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ABSTRACT

Even if a stand starts with an initial density far below the full density, mortality occurs in accordance with an increase in biomass as the stand develops. Eventually, the time-trajectory of biomass and density asymptotically approaches a straight line on logarithmic coordinates. The features of the time-trajectory of biomass and density were translated into a mathematical formula, which was in turn transformed into a model for describing the time-trajectory of mean phytomass and density. The usefulness of the models was verified in describing the time-trajectory of biomass (or mean phytomass) and density throughout the development of eastern white pine (*Pinus strobus*) stands. Another model for describing the time-trajectory of mean phytomass and biomass was derived by eliminating density from the mathematical formula. The applicability of the derived model was also examined for the eastern white pine stands.

Keyword : mean phytomass, mortality, density, the 3/2 power law of self-thinning, time-trajectory

INTRODUCTION

Self-thinning, or successive decreases in density due to competitive interactions among individuals in a stand, is considered one of the most important plant demographic processes. Although there have been significant advances in developing mathematical or simulation models for describing this remarkable phenomenon (Hozumi 1973, 1977, 1980, 1983, Firbank and Watkinson 1985, Naito 1992, Hagihara 1996b), in practice it is not easy to manipulate these models. Therefore, simple and practical models are needed (Hagihara 1995b, Shibuya 1995)

If we follow the time course of self-thinning of a stand, we can draw a trajectory for biomass and density on logarithmic coordinates. The time - trajectory shifts through the following three phases as the stand develops (Perry 1994): in phase 1, plants increase in phytomass with no corresponding decrease in density; in phase 2, density-dependent mortality begins and phytomass increments in plants are accompanied by a decrement in density; in phase 3, the relationship between increasing biomass and decreasing density becomes linear on the log-log scale, *i.e.* the growth of plants is governed by the 3/2 power law of self-thinning (Yoda *et al.* 1963), also known as the self-thinning rule.

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In this paper, the features of the time-trajectory of biomass and density are firstly translated into a mathematical formula, which is in turn transformed into a model for describing the time-trajectory of mean phytomass and density. It is then verified that these models mimic the time-trajectory of biomass (or mean phytomass) and density throughout the development of eastern white pine (*Pinus strobus*) stands as recorded by Spurr *et al.* (1956). Finally, another time-trajectory of mean phytomass and biomass is formulated by eliminating density from the mathematical formula, and the applicability of the formulation is also examined in relation to the eastern white pine stands.

EXISTING MODELS FOR THE TIME-TRAJECTORY OF MEAN PHYTOMASS AND DENSITY

Yoda *et al.* (1963) found that once a stand had reached full density, mortality occurred in such a way that

$$w = K\rho^{-\alpha} \qquad (1)$$

where w is the mean phytomass per plant, ρ is the density, *i.e.* the number of plants per unit area, K is a constant which varies from species to species and α has been widely reported to take the value of approximately 3/2 for a wide range of species (*e.g.* White 1980, Westoby 1984, Zeide

1987). Such a stand is said to be following the 3/2 power law of self-thinning (YODA *et al.* 1963), or alternatively, the self-thinning rule.

In consideration of the following definition, *i.e.*

$$w \equiv \frac{y}{\rho} \qquad (2)$$

where y is the biomass per unit area, equation (1) can be rewritten in the form:

$$y = K\rho^{-(\alpha-1)} \qquad (3)$$

It should be noted that equations (1) and (3) are mathematically equivalent, but they are not statistically equivalent (WESTOBY 1984, WELLER 1987, NIKLAS 1994).

Even if a stand starts with an initial density far below the full density, mortality occurs in accordance with increases in phytomass (*e.g.* TADAKI and SHIDEI 1959, ANDO 1962, KAYS and HARPER 1974, DREW and FLEWELLING 1977, TADAKI *et al.* 1979, WHITE 1981, OSAWA and SUGITA 1989, THORANISORN *et al.* 1990, TADAKI 1995, XUE *et al.* 1997a). TADAKI (1963) proposed a model for describing the time-trajectory of mean phytomass w and density ρ in stands which are still below full density:

$$\frac{1}{\rho} = aw + b \qquad (4)$$

where a and b are coefficients.

Equation (1) cannot describe the time-trajectory of mean phytomass and density in a stand below the full density, whereas equation (4) cannot describe the time-trajectory in a stand with full density (HOZUMI 1973, 1977).

To overcome the weak points of equations (1) and (4), SHIBUYA (1995) proposed an empirical model for the time-trajectory of mean phytomass and density by reparameterizing the power term of density in equation (4), which is a special case of a general time-trajectory model proposed by NAITO (1992). SHIBUYA (1995) examined the fit of his model to the published data of seven species, *i.e. Chamaecyparis obtusa* (TAKEUCHI 1980), *Abies sachalinensis* (HOKKAIDO PREFECTURAL FOREST OFFICE 1982), *Pinus strobus* (SPURR *et al.* 1957), pine and spruce (KHILMI 1957), *P. taeda* (PEET and CHRISTENSEN 1980) and *Picea mariana* (CARLETON and WANNAMAKER 1987). As a result, he concluded that his model was suitable and applicable to the time-trajectory of mean phytomass and density.

A NEW MODEL FOR THE TIME-TRAJECTORY OF MEAN PHYTOMASS AND DENSITY

Let us now consider a stand starting with an initial density far below the full density. If we follow the time course of self-thinning of the stand, we can draw a trajectory for biomass and density on logarithmic coordinates. The time-trajectory of biomass and density is characterized by the following three phases (PERRY 1994). During the early stage of stand development, competition among plants is not severe enough to cause mortality, and biomass increases with no corresponding decrease in stand density. In this stage, the time-trajectory parallels the y-axis of the log-log scale (phase 1). Eventually, the stand reaches a stage of crowding, where increases in the phytomass of individual plants cannot occur unless some plants die. At this stage, the time-trajectory begins to curve left, denoting a reduction in density (phase 2). Following its initial bending to the left, the time-trajectory asymptotically approaches and then follows quite closely along a straight line, as increases in the phytomass of individual plants are matched by the decrease in density (phase 3).

These trends of the time-trajectory of biomass y and density ρ can be translated into type II of the size-dependence (S-D) curve proposed by HAGIHARA (1995a):

$$y = K\left(\frac{1}{\rho} - \frac{1}{\rho_0}\right)^{\alpha-1} \qquad (5)$$

where ρ_0 is a constant related to the initial density. As

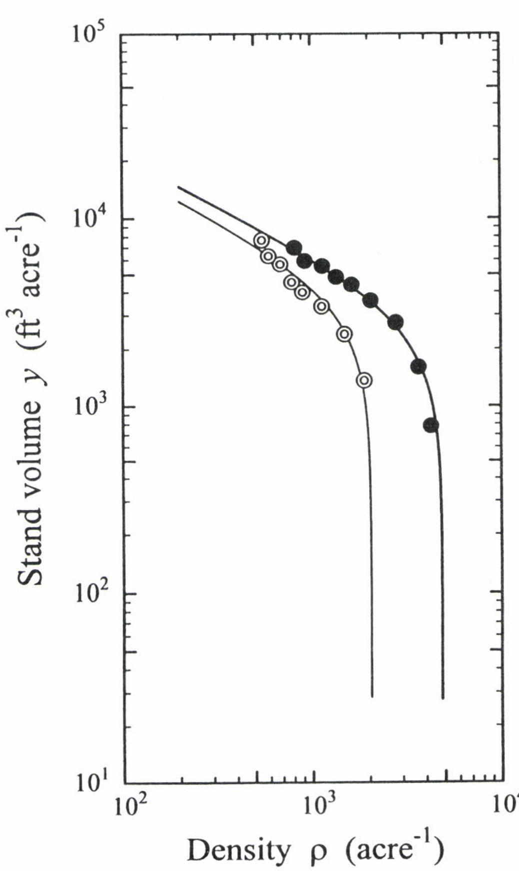

Fig. 1 Time-trajectory of biomass (stand stem volume) y and density ρ in the eastern white pine stands examined by SPURR *et al.* (1957). Unit: 1 acre=4047m^2; 1ft^3=28.32dm^3. The curves are given by equation (5)

●: $y=211571\rho^{-1/2}(1-\rho/4840)^{1/2}$ (r^2=0.993)

◎: $y=183116\rho^{-1/2}(1-\rho/2043)^{1/2}$ (r^2=0.956) shown in Fig. 1, the fit of equation (5) to the data of biomass (stand stem volume) y against density ρ obtained by SPURR *et al.* (1957) in eastern white pine (*Pinus strobus*) stands is good.

Given equation (2), equation (5) can be transformed into an equation describing the time-trajectory of mean phytomass w and density ρ:

$$w = K\rho^{-\alpha}\left(1-\frac{\rho}{\rho_0}\right)^{\alpha-1} \qquad (6)$$

As shown in Fig. 2, equation (6) successfully mimics the time-trajectories of mean phytomass (stem volume) w and density ρ throughout the development of the eastern white pine stands. This provides some evidence that equation (6) can be a suitable and practical model for describing the time-trajectory of mean phytomass and density in the development of even-aged pure stands. ZUE *et al.* (1997b) also confirmed that equation (6) fits extremely well to data collected from Prince Rupprecht's larch (*Larix principis-rupprechtii*) stands.

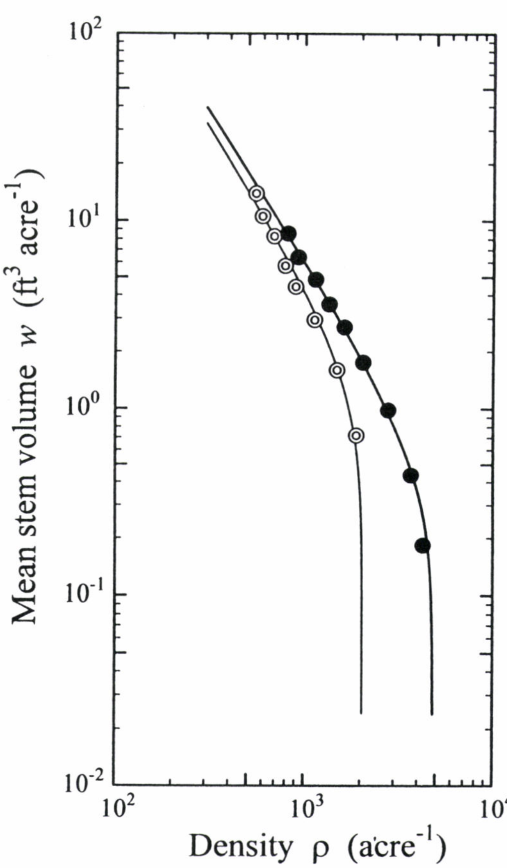

Fig. 2 Time-trajectory of mean phytomass (stem volume) w and density ρ in the eastern white pine stands. For units, see Fig. 1. The curves are given by equation (6)

●: $w = 211571\rho^{-3/2}(1-\rho/4840)^{1/2}$

◎: $w = 183116\rho^{-3/2}(1-\rho/2043)^{1/2}$

SHINOZAKI and KIRA (1956) theoretically derived the reciprocal equation of the competition-density (C-D) effect in nonself-thinning populations as follows:

$$\frac{1}{w} = A\rho_c + B \qquad (7)$$

where ρ_c is the initial density and remains constant throughout experiments, and A and B are coefficients specific to a growth stage. Recently, HAGIHARA (1996a) showed that the following reciprocal equation of the C-D effect is valid in self-thinning populations:

$$\frac{1}{w} = A_t\rho + B \qquad (8)$$

where ρ is the density of survivors, and the coefficient A_t does not coincide with the coefficient A in equation (7), though the coefficient B is common in both equations (7) and (8). Equation (8) is just the same in form, but is quite different in mathematical interpretation from equation (7).

On the assumption that both equations (1) and (8) hold, HAGIHARA (1996b) concluded that the time-trajectory of mean phytomass w and density ρ of a given self-thinning population starting with initial density ρ_i can be described with the following equation:

$$w = \frac{K\rho^{-\alpha}\left(1-\dfrac{\rho}{\rho_0}\right)^{\alpha-1}}{1+\dfrac{\rho_i^*}{\rho_0}\left(\dfrac{\rho_i^*}{\rho}-\dfrac{\rho_i^*}{\rho_0}\right)^{-\left(\frac{1}{\mu}+1-\alpha\right)}} \qquad \left(\frac{1}{\rho_0}=\frac{1}{\rho_i}-\frac{1}{\rho_i^*}\right) \qquad (9)$$

where ρ_i^* is the initial density of ρ_i^*-population (HOZUMI 1980), which follows the 3/2 power law of self-thinning from the initial growth stage, and μ stands for the relative mortality after a sufficient lapse of time. When the value of μ is in the vicinity of zero, equation (9) can be approximated by equation (6). As a result, equation (6) is regarded as a special case of equation (9).

DISCUSSION

The time-trajectories of biomass y and density ρ (see Fig. 1) and of mean phytomass w and density ρ (see Fig. 2) are respectively the projections of the time-trajectory in the three dimensional space created by biomass, mean phytomass and density on the two dimensional spaces created by biomass and density and by mean phytomass and density. There is another biologically meaningful time-trajectory, which is the projection of the time-trajectory in the three dimensional space on the two dimensional space created by mean phytomass and biomass. HOZUMI (1973) called the time-trajectory of mean phytomass w and biomass y the y-w diagram.

Eliminating density ρ from equation (5) on the basis of equation (2) gives an equation describing the time-trajectory of biomass y and mean phytomass w:

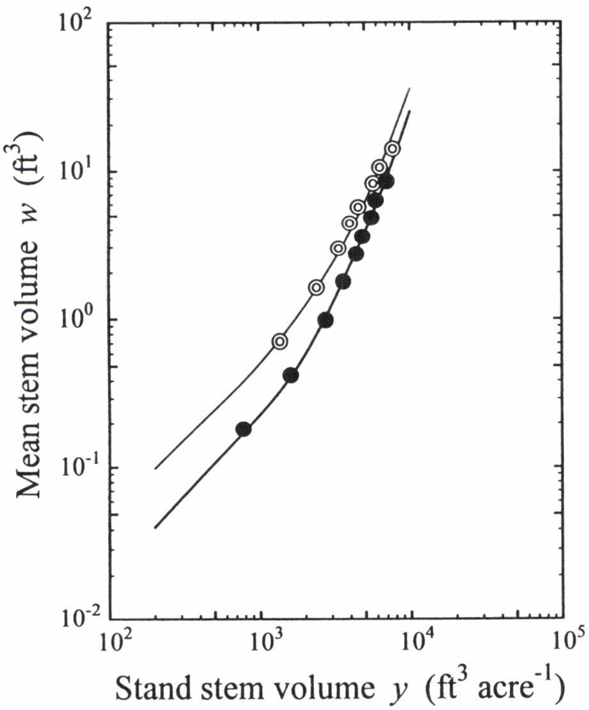

Fig. 3 Time-trajectory of mean phytomass (stem volume) w and biomass (stand stem volume) y in the eastern white pine stands. For units, see Fig. 1. The curves are given by equation (10)
●: $w = y/4840 + y^3/211571^2$
◎: $w = y/2043 + y^3/183116^2$

$$w = \frac{y}{\rho_0} + \frac{y^{\frac{\alpha}{\alpha-1}}}{K^{\frac{1}{\alpha-1}}} \tag{10}$$

As y becomes smaller, equation (10) reduces to

$$w = \frac{y}{\rho_0} \tag{11}$$

Equation (11) describes the time-trajectory of biomass y and density ρ in the early growth stage, where plants increase in phytomass with no corresponding decrease in density. On the other hand, as y becomes larger, equation (10) reduces to

$$w = \frac{y^{\frac{\alpha}{\alpha-1}}}{K^{\frac{1}{\alpha-1}}} \tag{12}$$

Equation (12) describes the time-trajectory of biomass y and density ρ in the growth stage after a sufficient lapse of time, where increases in the phytomass of individual plants are matched by a decrease in density, *i.e.* this stage is governed by the 3/2 power law of self-thinning (Yoda *et al.* 1963).

As shown in Fig. 3, equation (10), whose coefficients have the same values as in equation (5) or equation (6), accurately describes the time-trajectory of biomass (stand stem volume) y and mean phytomass (stem volume) w throughout the development of the eastern white pine stands. In the early growth stage, the mean phytomass w increases in proportion to the biomass y (*cf.* equation (11)), whereas in the later growth stage the mean phytomass w increases in proportion to the 3rd power of the biomass y (*cf.* equation (12)).

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Article

The Impact of Deforestation in Brazilian Amazonia —The Indigenous People of Rondônia State—[*1]

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ABSTRACT

Brazilian Amazonia is the biggest continuous tropical forest in the world. Thousands of species of fauna and flora, and many indigenous people, live in that forest. Today, the Amazonian environment is changing very rapidly. In 1995, Brazil's population was 162,497,250 inhabitants and population growth is expected to continue to accelerate. Population pressure is one of the most serious reasons for the deforestation in Brazilian Amazonia. The Polonoroeste Project was responsible for the construction of the BR-364 highway, bringing development to the State of Rondônia, in south-western Amazonia, and many villages of indigenous groups were removed. In 1500, Brazil was populated by approximately five to six million indigenous people, composed of 700 ethnic groups. However, today, there are only 217,778, corresponding to 146 ethnic groups. The objective of this report is to describe the situation of one of the indigenous people of Rondônia, the Karitiana group, and to develop an understanding of their needs. They have many problems, including their economic independence, health and education of their children. The relationship between the índios and FUNAI (National Indian Foundation) is very complex and leaves much room for improvement. Preservation of their language and their traditional lifestyle is of crucial importance to maintain their identity.

Keyword : Brazilian Amazonia, development projects, índios, Karitiana group, FUNAI

INTRODUCTION

The indigenous people live in 500 Indian reserves within Amazonia, administered by FUNAI. Many Indian groups have been driven off their land by the big development projects within Amazonia. Surveillance by satellite since the 1960's has revealed the existence of large mineral resources of iron, bauxite, gold, cassiterite and uranium under the Amazonian forest (IBGE, 1975). Since then, thousands of gold prospectors and mining companies began exploration within the forest. The groups within Rondônia that suffered from invasion of their traditional lands are: Arara, Zorõ, Tubarão Latunde, Cinta-Larga, Sakirabiar, Suruí, Tupari, Uru-Eu-Wau-Wau, Makurap and Gavião (KARITIANA, 1996). The Karitiana group is also currently suffering invasion on a small scale.

The increasing population of Amazonia (Fig. 1) has led to the building of many dams for hydroelectric power which have flooded the lands of many indigenous groups (CAUFIELD, 1984). The Arara and Gavião groups, for example, had their village flooded by the building of Samuel Dam in Rondônia (KARITIANA, 1996).

The Polonoroeste Project, with its tax incentives, attracted many poor peasant families from the southern and eastern parts of the country. In order to solve the problem of settlement, INCRA (National Institute for the

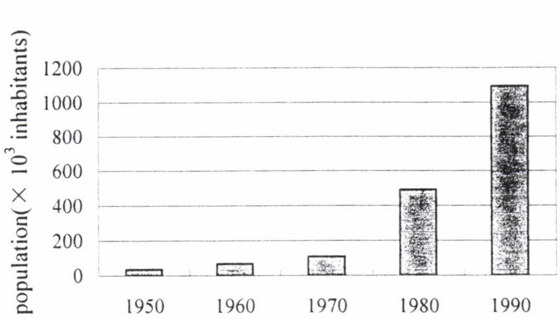

Fig. 1 Population of Rondônia State (Source: IBGE)

[*1]Part of this paper was presented at the IUFRO Symposium in Kyoto 1997.

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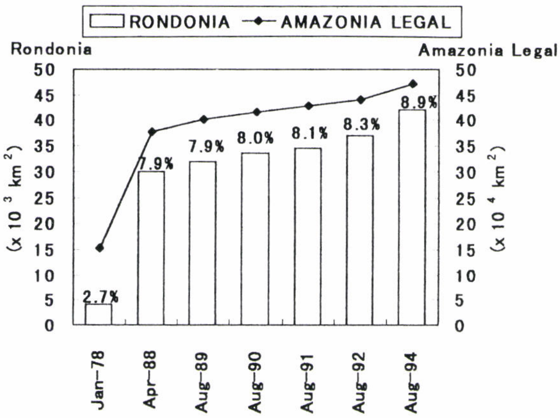

Fig. 2 Extent of deforestation in the Brazilian States of Amazonia (Amazonia Legal) and Rondônia State. The figures shown as % are the deforestation rate of Rondônia State compared to Legal Amazonia. (Source: INPE - Instituto Nacional de Pesquisas Espaciais)

Agrarian Reform) created this colonization project in Rondônia in 1970. Consequently, the forest was cut into patches along the BR-364 highway (Fig. 2) and this affected the indigenous villages.

These developments proved to be a menace not only for the Amazonian flora and fauna but also for the indigenous people (índios as they call themselves) who had lived there for thousands of years. In order to protect their rights, a number of different groups are forming an alliance.

Little literature has been published on the situation of indigenous people of Brazilian Amazonia. The problems of suicide among indigenous youngsters of Southern Amazonia can be related to the influence of development (Ishi, 1994). Problems of indigenous tribes of Brazilian Amazonia derived from the development projects are reported by Gheerbrant, 1988. Removal of indigenous villages from dam sites in Brazilian Amazonia is described by Caufield, 1984. Some interesting information is available on the specific indigenous groups within Rondônia State (Hugo, 1991).

Among the different groups of Rondônia that have contact with white people, the Karitiana was chosen for study because this group suffered particularly from influence of development and had the tragic past.

The Karitiana village has 207 people. Eleven of them are from other ethnic groups and 24 are living in Porto Velho city. Almost 70% of the population are composed of children and youngsters. There are very few old people in this group. Before the first contact, there were 3 to 5 thousand people, with many clans. Their village, occupying 89,698 ha, is located 97 km southwest of Porto Velho, the capital city of Rondônia. This land was delimited in June 1976 and was promulgated under decree No. 93,068, on 6 August 1986. The delimitation excluded the best part of their lands. The river Candeias' bank, where they lived before, was their traditional land with their cemetery and the old villages of their ancestors, but now, a road passes over it.

In this paper, problems faced by the Karitiana group are presented. It is hoped that information from this study may be useful in identifying areas of deficient knowledge for those who are responsible for planning development projects in the Amazonian forests.

ANALYSIS METHOD

This study began in September 1996, when the first contact was made with the leader of the Karitiana Group, at the Symposium on Environment of JBN (Japan-Brazil Network), held in Tokyo. Since then, through correspondence, newspaper clippings and copies of reports of the indigenous representatives' meetings sent by the leader, information concerning their problems was collected. In August 1997, a visit was made to the Karitiana's village, NGO (Non governmental Organization) of Rondônia and CIMI (Missionary Council of Indigens) of Porto Velho city of Rondônia, to add substance to the research. The representatives of Karitiana village, the House of the Indios of FUNAI, CIMI and NGO were asked about their actual situation, attitudes, thoughts and problems from their different points of view.

RESULTS AND DISCUSSION

According to the leader of the Karitiana group, they still suffer from incursion by farmers and miners, even living within the Indian reserves. There is a law to protect their rights but there are few inspectors to check or enforce it. There are so many incursions that it is almost impossible for the inspectors to defend the indigenous people effectively. One agent has to inspect some thousands of square kilometers of the forest, and many accidents happen behind him (Karitiana, 1996).

The profound social changes have resulted in alcoholism, misery and depression, increasing the suicide rate among indigenous people. In the last ten years, 206 deaths by suicide of guaranis-kaiowás were registered among Indian groups. (Folha de São Paulo, March 12, 1996). Within the Karitiana group, suicide is not common. However, deaths due to disease are routine. There are no doctors in the community, nor do doctors visit. They are attended by four health-care agents occasionally, but that is not enough. They have two shamans (pajés) who know much about medicinal plants. However, the Karitiana people are very vulnerable to the contagious diseases brought by the white people. They have sufficient food, but some have the problem of alcoholism. They use a filter to drink water from the river (Rio das Garças), but the water is polluted. They have only eight bathrooms in the village. In order to be attended legally by the public health care center in the city, they use a microscope so that they can justify the disease to be treated free of charge. Illness due to snake bite is very common in Amazonia and for that reason they need the means of urgent communication. In 1997, there was a sick índio in the village who died because there was no means of transporting him to the city. They also need medicines to treat malaria.

Assistance for health care and hygiene is the Karitiana's most important priority at present. More qualified staff of governmental institution are also required to protect their lands.

In the beginning, FUNAI concentrated their efforts on assimilating the índios to the whites' lifestyle. Today, missionaries of CIMI do not try to convert them as before, and instead help them to keep their culture, religion, language and custom, encouraging them to retain their identity. For that purpose, they try to accompany the people, living in the village whenever possible, and train them to produce their own teachers and health care agents within the community.

Education of the Karitiana people began regularly in 1982, in the village. The school (named 4 August) has two classrooms, with 95 children, youngsters and adults. Four white teachers and three indigenous teachers are working there. The languages used for teaching are Karitiana and Portuguese, and they learn mainly Mathematics and Portuguese so as to facilitate interchange and trade with the non- indigenous people. There is a lack of textbooks in the Karitiana language. However, they are using the first such book to learn Karitiana's orthography and grammar with some ancient stories of the Karitiana people.

The official organizations that assist them include FUNAI (National Indian Foundation), and Projeto Planafloro. From 1991 to 1992 the international NGO worked on a project named APARAI (Association for Environmental Protection and Recovery of Indigenous Lands) and helped them to train laboratory technicians. Unfortunatelly, in 1997 an agent of FUNAI abused two indigenous girls, and people of the village no longer trust the FUNAI agents. In the Karitiana group, some youngsters living in Porto Velho city are studying to be lawyers in order to defend their rights. The main problem is lack of financial aid for their studies. Help for their education is very important and qualified agents are needed urgently to assist the Karitiana people.

According to the Uirapuru Association of the Indigenous Group, after the delimitation of their land, the Karitiana group suffered incursions in 1977 and in 1982. The mining company "Mineradora Jacundá" explored for ore and timber, and left a degraded forest behind them. Even in 1997, some prospectors tried to explore for gold. However, the Karitiana community did not permit that incursion on their land.

Today, they seldom hunt because the size of their remaining forest does not permit it, and they have good manioc and corn fields. Besides, they plant cará potato, rice, zucchini (macaxeira), sweet-potato and beans. Their orchards bear guava, jaca (jack fruit, durian), caju (cashew), banana, avocado, lemon and orange trees. They also breed some chickens, ducks, pigs and parrots. Their traditional craft products of head ornaments, earrings, pierces, bracelets, bows and arrows are an important source of income. They have a small work- shop in Porto Velho city. Economic independence is very important to their subsistence life-style.

The Karitiana village is a relatively modern one, with electricity. There are some bicycles, an old Toyota truck, an old tractor, two chain-saws, an electric motor, a mill-house and two chicken-houses. The people wear simple clothes, but they also wear their traditional ornaments occasionally. Before the delimitation, they lived in a bigger land between the rivers Candeias and Jamari (Fig. 3), and could hunt whenever they needed. That is now not possible due to the decline in wildlife, and they only have cassava, corn and fruits to eat. To help meet their food needs, FUNAI constructed two chicken houses in the middle of their area, in 1996. However, there are no chickens because of lack of funds and the houses are being destroyed by termites. On the wall of the house of the group leader's uncle, a large ornament with black plumes was exhibited. Before, he could find birds with beautiful coloured plumes whenever he needed but now it is difficult and the ornament will never be complete.

The leader's parents were killed by the whites when he was very young. Since then, he studied Portuguese and now he can speak both languages fluently. The group

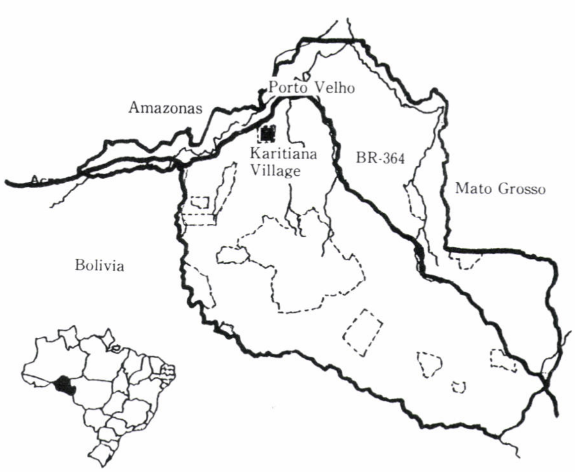

Fig. 3 Indian Reserves of Rondônia State (Source: IBGE)

Fig. 4 Representatives and youngsters of different groups of Rondônia at FUNAI's House of the Indios (Picture taken by the author in 17 August 1997)

leader is the representive of Uirapuru, an organization of different indigenous groups, and Portuguese is a tool he uses to understand other groups and to negotiate with government organizations in order to claim the rights of his people.

In Porto Velho, there is a House of the Índios of FUNAI (Fig. 4). This accommodates children who go to school in Porto Velho, sick people who need medical care, and representatives of different groups who work for the community, going back to their village once a month in turns, to help their families and keep informed. The groups living together at the time of the visit in August 17, 1997 at the House comprised the Karitiana, Tenharim, Diahoi and Parintintin. Their villages are located far from each other and trucks are needed to patrol their lands, and to transport sick people and fruit and crops to sell in Porto Velho. However, they still have no trucks, or only broken ones. Assistance for transport is an important need.

CONCLUSION

The Karitiana group consists of indigenous people who have not assimilated completely to the white population. They wish to preserve their culture, of which they are very proud. They need the help of FUNAI, ONG and CIMI, but they seek dialog at first. According to the leaders of the group, the first priority for aid is health care, followed by children's education and transport. They prefer to be economically independent and are looking for sources income, particularly through selling their crops and craftworks.

Also, in order to achieve rights at the level of Brazilian citizen, they are organizing a committee in alliance with other groups. From my contact with the Karitiana people, it was clear that they love their family, their forest and above all, peace. Other groups, however, are more militant and attack white trespassers on their lands. Sometimes, these groups also attack rubber tappers who are working lawfully.

It is ironic that Rondônia, named after Marshal Rondon who first created this organ to protect the dignity of the Índios, is one of the most deforested areas in Brazilian Amazonia, with so many suffering indian groups. Recently, the Brazilian government revised the law relating to agrarian reform and proclaimed decree No. 1775/96 to delimit the Indian lands. This decree resulted in contraction of many Indian lands, making way for farmers and colonization projects. In the last two decades, 100,000 peasant families from southern Brazil migrated to occupy four million ha of the six million ha of the agrarian lands of Rondônia State. The production of crops in Rondônia was 77,201,000 ton in 1997 (IBGE, 1998), corresponding to 88 % of the whole crop production of the Brazilian Mid-West region. The development projects in Rondônia State transformed the most remote region of Brazil to a major supplier of crops and minerals in a very short time. The development, however, had serious consequences for the indigenous people. During the field study, it was very common to hear from the INCRA's agents and farmers: "So much land for so few indigenous people". The opposite was true according to the Karitiana leader : "So much land for only one white land-owner". Also, in reference to the lands of the Arara and Gavião groups flooded by the construction of the Samuel hydroelectric dam, he says: "We're not crocodile, we're human beings".

This study suggests that the most effective way to assist the Karitiana people is to help them to become economically independent. To achieve that goal, it will be desirable to provide a nurse and a teacher who can speak their language. It is also important to provide a truck to each group and also a periodical doctor's visit in their village, until they can achieve their autonomy.

Maintaining their identity is crucial to their existence, and working together with different groups with similar objectives is a wise strategy. We can conclude with certainty that the role of FUNAI and CIMI is vital for their success.

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Article

Predicting Effects of Deferred Clearcutting on Pine Marten Habitat Suitability on the Superior National Forest

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ABSTRACT

Research was conducted on a section of the Superior National Forest in Northern Minnesota to develop and examine potential methods or approaches that may be used to integrate nontimber resources in multiple-use planning. An indicator species for old-growth conifer forests, pine marten (Martes americana), was chosen to examine potential conflicts between specific forest management practices and suitable habitat. Spatial impacts of clearcutting and of deferred harvesting on marten habitat over a fifty year planning horizon were examined. Specific management scenarios were developed to examine the impact of deferred harvesting on marten habitat over time and space. Deferred clearcutting did not improve marten habitat conditions. Other management scenarios could be designed to improve marten habitat without sacrificing economic benefits.

Keyword : forest management, pine marten, geographic information systems (GIS), Minnesota

INTRODUCTION

By the beginning of the twentieth century, the massive conifer forests of northeastern Minnesota, for the most part, had been leveled. Timber production peaked in 1905, culminating in approximately 240,000 freight cars stacked with lumber. The majority of the area's pine, spruce, and fir trees had been cutover and although efforts were made to replenish these stocks, most of the cutover lands were not replanted. So, by 1977, an inventory of the state's forested land indicated that 45% of these lands consisted of naturally regenerating aspen and birch trees (BORCHERT and GUSTAFSON 1980).

In 1902, the state's Federation of Women's Clubs began to lobby strongly for the protection of the remaining virgin pine in northern Minnesota, advocating that a national park be established in the area. Also, during this same time period, government (federal and state) attention became increasingly focused on the depletion rate of Minnesota's forests, resulting in substantial land acquisitions that would eventually be allocated to state and national parks. In 1909, the Superior National Forest was established and by 1925, with support from the Women's Club, approximately twelve hundred square miles came under the protection of the Forest. By the 1960s, public lands constituted more than 50 percent of Minnesota's commercial forest land (CLARK 1989). The two Minnesota National Forests and other federal lands encompass 14 percent of Minnesota timberlands. The Superior National Forest includes 12,140 km2 of land of which 5,076 km2 are identified as timberland (JAAKO PÖYRY 1992).

Over the last several decades, the National Forests in the U.S. have become increasingly valued for the nontimber resources that they can provide such as wildlife (game and nongame), recreation, and aesthetics. Timber harvesting, especially clearcutting, can impact the viability of wildlife habitat or the availability of recreation areas. Within this context, trade-offs between such competing activities as timber production and wildlife assumes greater importance, and spatial considerations are often critical. Greater emphasis on trade-offs between timber and non-timber resources reflects a change in public and agency values and perceptions which in turn have contributed greatly to the gradual emergence of a more holistic management approach (i.e., Ecosystem Management) to achieve multiple-use management on National Forests and Grasslands.

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GIS TECHNOLOGY AND NATURAL RESOURCE MANAGEMENT

Since its inception, GIS technology has strongly been associated with the mapping and management of natural resources. Though GIS continues to be used for map making, attention is now focused on developing and using the modeling capabilities of GIS software to analyze management options in a more integrated approach. GIS technology is increasingly interfacing with predictive models, providing forest managers with a critical tool for analyzing natural resource management alternatives.

GIS-based modeling approaches developed to integrate wildlife habitat concerns in the forest management process are relatively new. This technology has emerged as an important tool to handle spatial relationships in static and dynamic habitat modeling. Research has focused primarily on determining the availability of viable habitat for specific species types (Worah *et al.* 1989) as well as estimating the habitat needs of a given species by observing wildlife populations at specific locations (Agee et al. 1989; Cook *et al.* 1990). Dynamic habitat models encompass changes and interactions between a number of key variables over time and space. In contrast, in static habitat models the variables are evaluated at one point in time only. Static habitat models have dominated habitat assessment studies for well over the last decade.

Static habitat models have proven to be useful in evaluating an area's capacity to support the habitat needs of a given wildlife species. These models are most often represented in a raster-based GIS simply because it is more conducive to neighborhood analysis than a vector-based GIS. Burrough (1986) provides a detailed comparison of the advantages and disadvantages associated with the vector and raster spatial data structures, making specific reference to their different approaches to modeling geographic information.

A PINE MARTEN CASE STUDY

A case study was conducted on a section of the Superior National Forest in Northern Minnesota to develop potential approaches to integrating timber and nontimber resources in multiple-use planning. An indicator species for old-growth conifer forests, pine marten (*Martes americana*), was chosen as an example to examine potential conflicts between specific forest management practices and wildlife habitat values. The emphasis of this research is to estimate the spatial impacts of clearcutting on marten habitat. Simulating the intended clearcut levels using a GIS enhances the understanding of how such management practices might impact marten habitat conditions over time and of the cost of sustaining "good" habitat when attempting to maximize economic returns from timber production.

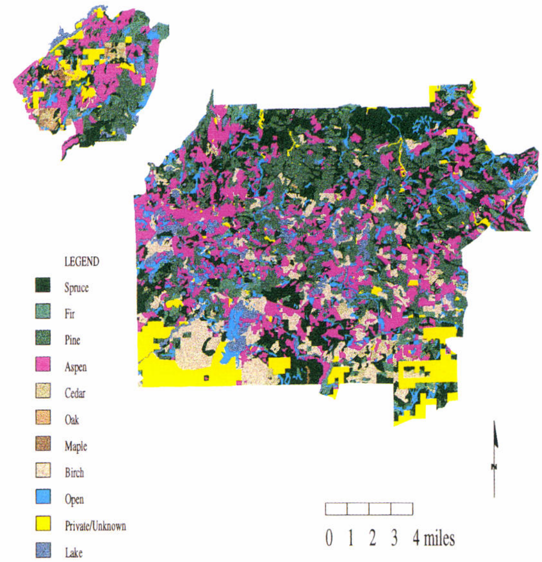

Fig 1 Forest cover types on the superior national forest

Study Area

The 490 km² study area represents approximately 4 percent of the Superior National Forest, encompassing portions of the Tofte and Kawishiwi Ranger Districts, located in northern Minnesota. The landscape is nearly continuous forest interspersed with wetlands. The forest vegetation includes both boreal and temperate components. The dominant upland coniferous tree species include black spruce (*Picea mariana*), white pine (*Pinus strobus*), red pine (*Pinus resinosa*), jack pine (*Pinus banksiana*), white spruce (*Picea glauca*), and balsam fir (*Abies balsamea*). The upland deciduous tree species include quaking aspen (*Populus tremuloides*), bigtooth aspen (*Populus grandidentata*), and paper birch (*Betula papyrifera*). The dominant tree species found dispersed throughout the wetlands include black spruce (*Picea mariana*), northern white cedar (*Thuja occidentalis*) and black ash (*Fraxinus nigra*). Peek et al. (1976) and Rogers (1987) offer a much more detailed description of the vegetation and landscape of the study area. Nearly 50 percent of the study area consists of spruce and fir stands (Fig. 1). The vegetation coverage (approximately 6,000 polygons) used in this study was digitized by the National Ecology Research Center (U.S. Fish and Wildlife Service) in PC ARC/INFO. Forest compartment/stand maps [1:15,840 (4"=1mile)] and stand exam data were obtained for each Ranger District in the study area.

Database Development

A harvest scheduling model (DTRAN) and pine marten habitat model were combined to assess the changes

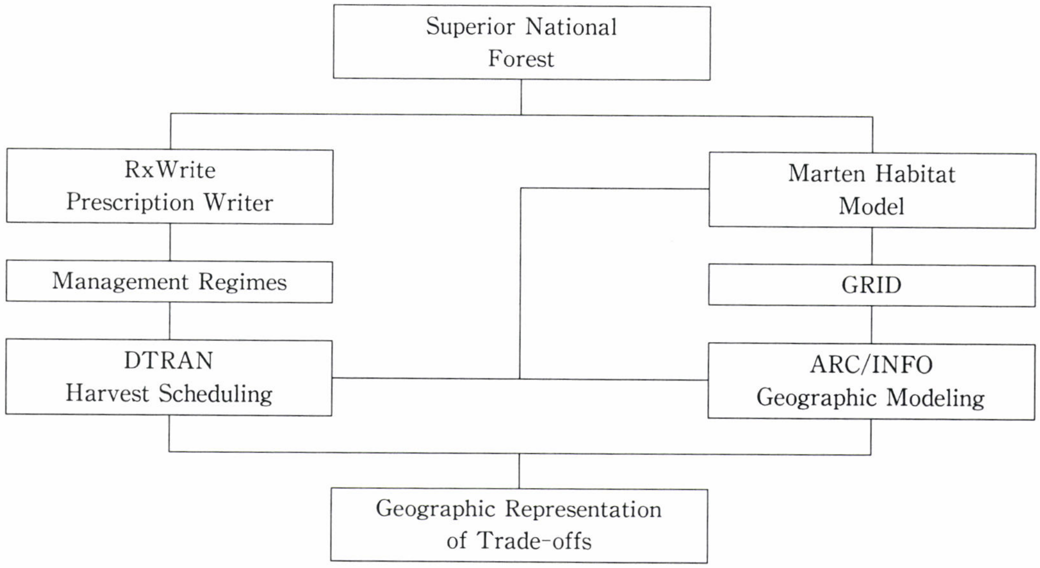

Fig. 2 Information flow chart

in pine marten habitat across time and space for a number of alternative timber harvest scenarios. The scheduling model essentially solves a model I or model II linear programming formulation (KAPPLE and HOGANSON 1991). It overcomes the technical limitations associated with large LPs by utilizing a heuristic simulation algorithm to solve the scheduling problem (see HOGANSON and ROSE 1984). In the algorithm, the identity and spatial resolution of individual stands are maintained.

The input for DTRAN was generated by a prescription writer, RxWRITE (McDILL 1991), for harvesting and forest management activities. RxWRITE encompasses a system of programs that manages forest inventory databases and allows the user considerable flexibility in establishing and simulating different stand management options. Users can specify any level of species aggregation, potential harvest ages, thinning times and intensities, conversion options, and a range of products. Once the system parameters have been established, it is possible to simulate sets of specified management options for a given stand or a group of stands. The output from these simulations is then converted into input files to be used by the forest management planning model DTRAN (ROSE et al. 1992).

DTRAN was used to generate the NPVs associated with various harvest and silviculture scenarios over a 50 year planning horizon using prices generated in the Minnesota Generic Environmental Impact Statement (GEIS) (JAAKO PÖYRY 1992) for the Duluth market. The NPVs measure discounted cash flows for an infinite planning horizon and value ending inventories at the end of the planning horizon on the basis of the shadow prices of the final planning period. The same real discount rate of 4 percent as used in the Minnesota GEIS study was applied (JAAKO PÖYRY 1992).

A habitat suitability index (HSI) model for marten was created to identify existing and potential marten habitat (NICHOLS *et al.* 1997). This index cannot be used to quantify carrying capacity, even though it might be correlated with the latter. Various spatial operations were implemented in a cell-based geoprocessing system (GRID) to derive HSI values across the entire study area (NICHOLS *et al.* 1997). The HSI values were generated for each planning period so that the impact of the clearcuts occurring in any given planning period are represented in terms of habitat losses or gains. ARC/INFO was used to develop maps based on the harvest schedule generated by DTRAN and the associated HSI values. Spatial analysis provided information on changes that occur in habitat over time and space. The display of the optimal forest management schedules in a GIS environment facilitated the interpretation of the plans, highlighted resource conflicts, and supported operational plan implementation. Fig. 2 is a flow chart of the information and processes that were used in this study.

DISCUSSION OF MANAGEMENT SCENARIO RESULTS

The potential gains or losses in marten habitat and in economic returns from timber harvesting as clearcutting is increasingly deferred were examined through three simple management scenarios over a 50-year planning horizon. Although a longer planning horizon would have been useful, the relatively short planning horizon was used because the relevant management prescriptions were already avail-

Table 1 Scenario results: acres clearcut and acres available in HSI ranges

	Planning Period 1	Planning Period 2	Planning Period 3	Planning Period 4	Planning Period 5	Total
	SCENARIO 1					
AcresCut	7,539	8,807	23,669	12,741	19,127	71,883
Total NPV	1,356,194	1,268,887	2,673,286	2,036,979	2,786,607	10,121,953
NPV/Acre	180	144	113	160	146	141
AcresAvail: High HSI	87,935	87,697	87,690	83,676	84,347	
AcresAvail: Medium HSI	14,673	15,546	14,843	19,987	23,968	
AcresAvail: Low HSI	47,032	46,397	47,107	43,977	41,325	
	SCENARIO 2					
Acres Cut	—	14,179	24,243	13,420	19,223	71,065
Total NPV	—	2,114,064	2,826,782	2,127,118	2,803,047	9,871,011
NPV/Acre	—	149	117	159	146	139
AcresAvail: High HSI	87,935	75,310	77,780	79,991	86,214	
AcresAvail: Medium HSI	14,673	21,199	19,952	23,800	22,519	
AcresAvail: Low HSI	47,032	53,130	51,908	45,849	40,907	
	SCENARIO 3					
Acres Cut	—	—	37,646	13,595	19,518	70,759
Total NPV	—	—	4,574,144	2,160,510	2,854,592	9,589,426
NPV/Acre			122	159	146	136
AcresAvail: High HSI	87,935	87,697	62,134	80,163	76,474	
AcresAvail: Medium HSI	14,673	15,546	24,693	23,579	23,287	
AcresAvail: Low HSI	47,032	46,397	62,813	45,898	49,879	

able from the GEIS.

The starting point for the analysis was a harvest schedule, permitting clearcuts of any stand above rotation age with a positive NPV over time (scenario 1). Next, harvesting was deferred by ten years (scenario 2) and then by twenty years (scenario 3). These simple representations of many possible harvest scenarios were chosen again because of data availability from the GEIS. Other scenarios, e.g., early accelerated harvests for increased NPV and potential higher HSI later in the planning horizon, might be interesting to pursue in future work. More important in future work will be to impose harvest level constraints. The difference between scenario 1 and the other two scenarios is measured via the NPV change as well as the change in HSI by planning period. Table 1 shows the amount of acres harvested and the corresponding NPV for each of the five planning periods for all management scenarios. Across all management scenarios, the total amount of lands harvested over the planning horizon remained consistent at about 71 thousand acres. This is a result of a NPV maximization in all scenarios.

Since the model objective was the maximization of NPV, it is not surprising that the acreage harvested is always the largest in the first planning period the model

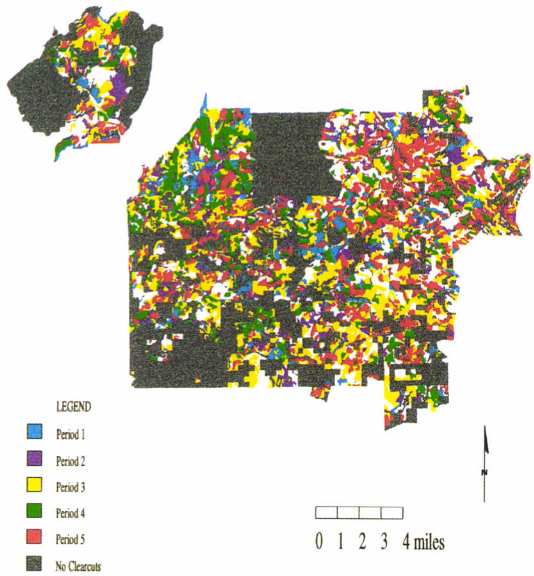

Fig 3 Distribution of clearcuts: management scenario 1

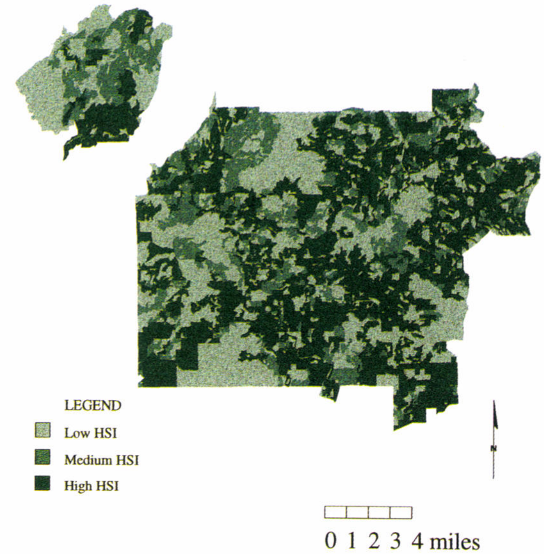

Fig 5 Marten habitat conditions: scenario 3, planning period 3

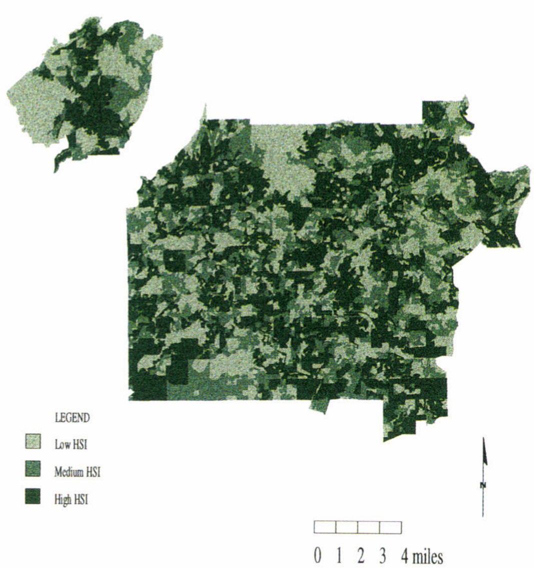

Fig 4 Initial marten habitat conditions

permitted harvesting to occur (Fig. 3). Harvest acreage systematically increased in each planning period across all scenarios with the exception of planning period 3 where a relatively large acreage of forest lands was harvested (particularly in scenario 1). By delaying harvesting by ten years (scenario 2) the model simply harvested almost the same amount of acreage in planning period two as was harvested in the first two planning periods of scenario 1. Similarly, delaying harvesting by 20 years (scenario 3) resulted in harvesting a very large acreage in planning period 3.

Management options are analyzed in terms of the NPV's and the location of clearcuts associated with each planning period. Fig. 3 provides an illustration of the distribution and extent of clearcuts by planning period across the study area. Clearcut levels are noted according to the marten HSI ranges (high, medium and low) and the species type (Nichols 1997). Total NPVs over the entire planning horizon ranged between $141/acre (Scenario 1) to $136/acre (Scenario 3). There is not a substantial difference between the NPVs associated with the management scenarios, primarily because delayed harvest increased the value of many stands which were scheduled for harvest at the next available opportunity. In general, the NPV's associated with conifer stands harvested were consistently higher than those determined for deciduous stands. In fact, the total acres harvested of conifer stands consists of over half of mature stands.

The fact that the impacts in terms of HSI loss are not more dramatic can largely be explained by the maturing forest as well as the extent and distribution of clearcuts across the study area. Often, the clearcuts are not necessarily clumped in one area, therefore the impact on the habitat value of a given stand as influenced by the values associated with surrounding stands is not necessarily serious.

CONCLUSIONS

In this research, an approach was explored to combine spatially scheduled timber production and the impacts on marten habitat for a large area, examining simple management scenarios in the form of delayed harvesting. The results of the analysis indicate that clearcutting over the planning horizon did not have a significant impact on the marten habitat conditions of the study area when the model was allowed to run unconstrained (scenario 1) or deferred clearcutting by ten years (scenario 2) or 20 years (scenario 3). In these two scenarios, the HSI values dropped only slightly below the values observed for the study area when no harvesting was permitted for the entire forest over the planning horizon. Significant changes in the HSI values were observed only in scenario 3 when clearcutting was constrained in the first two planning periods.

In future research, harvest level constraints will be imposed in all scenarios. This should increase the difference in the management scenarios. Furthermore, a prior identification of marten habitat and management restrictions on these sites will be examined to see how such restrictions would affect overall optimal forest management schedules in terms of harvest revenues and HSI values. The ultimate goal is to find management schedules that can achieve optimal economic returns with the lowest possible adverse impact on HSI.

The merits of the spatial approaches used in this research are that the impacts of proposed or simulated clearcuts can be observed across the entire study area without regard to stand boundaries. Marten habitat is assessed in a raster based GIS, relying on neighborhood analytical procedures to predict or determine the change in habitat values after clearcutting.

ACKNOWLEDGMENTS

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Short communication

Development of a Three-dimensional Computer Graphics System for Forest Stand Structures

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ABSTRACT

There have been a number of reports on the three-dimensional analysis of forest stand structures using personal computers. In recent years, it has become easy to display 3D graphics on Microsoft's Windows 95 operating system. Forest Window (FW) has been developed as a new 3D-simulation program for forest stands. This report provides an overview of FW and explains its operation. One of its features is its ability to show stem inclination. The object of this report is to appraise the usefulness of FW. As the result of the study it was recognised that we can use a simpler data structure and FW can display more complicated forest structures than in past applications. FW is a useful application and, run in conjunction with spreadsheet software, it can provide an effective way of studying forest stand structures.

Keyword : forest stand characteristics, three-dimensional structure, personal computer, simulation, application program

INTRODUCTION

There have been several reports in past years on the 3D analysis of forest stand structure. TANAKA (1944) and MITCHELL (1975) made models of tree stem and crowns based on research data. After the appearance of computers, NOBORI (1990) reported a simplified three-dimensional computer graphics system. Features of the 3D methods used in that system were that the trees were described in order from most distant to nearest and the tree forms were described by symmetric rotation. But tree data could not be sorted in the application software. In the early 1990s, personal computers became widely available and the applications were adapted for such computer systems. Nobori demonstrated the use of such 3D systems with an analysis of a mixed forest structure in central Hokkaido (NOBORI 1991) and reconstruction of a tertiary fossil forest structure from the Canadian high Arctic (NOBORI 1997).

Recently, universal operating systems for personal computers have come into use, making it easy to develop software for widespread public use. This paper reports on the development of a new 3D system for forest stand structures named Forest Window (FW).

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3D SYSTEM COMPOSITION

The 3D system that explained in this report comprises a personal computer, operating system, 3D-image software, forest information database and Microsoft Excel (MICROSOFT 1997) or compatible spreadsheet software. FW was developed on an NEC PC-9821 personal computer with the Microsoft Windows 95 operating system. The programming language used was Fujitsu F-Basic97 (FUJITSU 1997a, 1997b). An executable file is created after compilation by F-Basic97. FW also requires some dynamic link library files for user interfaces, and a quick sort library is needed to draw trees on the computer display. These libraries, which were supplied by Fujitsu, should be put in the same directory as FW or the system directory for Windows 95.

FW can run under Microsoft Windows NT or Windows 95 operating systems installed on IBM-compatible personal computers. It can also run on Apple Macintosh computers installed with a Windows 95 emulation system. FW is supplied on one 3.5 inch floppy disk containing the following 6 files: FW.EXE, the main program of FW; SAMPLE.CSV, sample data of forest stand structure; README.DOC, text of instruction manual; F1A0QSRT.DLL, quick sort library; F1A0RN50.DLL, dynamic link

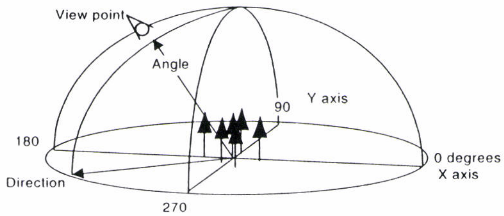

Fig.1 The relationship between viewpoints and axes of coordinates

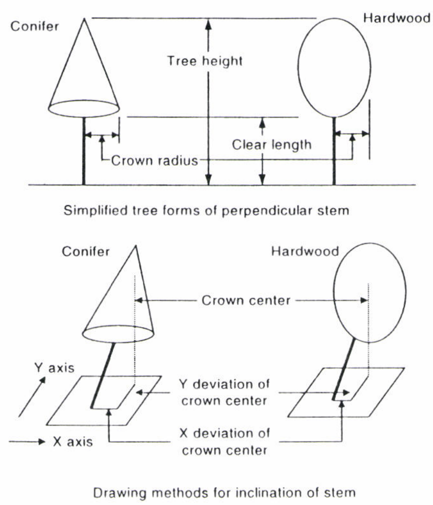

Fig.2 Tree form and requisite data

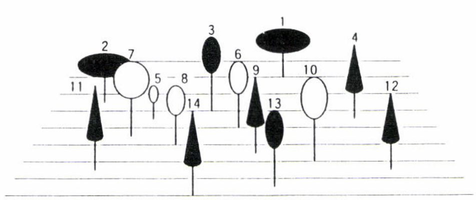

Fig.3 Simplified 3D method in FW
Note: Drawing trees in turns from distant to near

library for basic instructions; and F1A0RW50.DLL. dynamic link library for more advanced instructions.

FW can read only CSV format (comma-separated variables) data of forest stand structure. The data fields and their meanings are shown in Table 1.

FW can draw up to 1000 trees. There are advanced spreadsheet programs available that can be used to edit the CSV-format data used in FW. The relationship between angle and axis of coordinates are that the horizontal level is 0 degrees and the vertical is 90 degrees. The relation between the axes of coordinates and viewpoints is shown in Fig. 1.

SIMPLIFIED 3D METHODS IN FW

Various methods of three-dimensional computer graphics were considered. The ordinary method has parallel movement, three-dimensional axis rotation, projection transformation and transformation of the coordinates system to the computer screen. To overcome some problems found with this method, a simplified model of three-dimensional computer graphics was adopted for this study. The observation point was set as the centre of the computer display. Conifers are described by conical shapes and hardwoods are described by elliptical sphere shapes (Fig. 2). FW can display tree forms with straight inclined stems but not bent stems. When the trees are viewed from a high angle (or vertical), every crown should appear as a circle. In this case, it would not be possible to distinguish between conifers and hardwoods. Hence FW shows a half-circle shape for conifers at a high-angle viewpoint.

The trees are described in order from distant to near (Fig. 3). The three-dimensional computer graphics can be summarised as follows. The transformation of the 3D coordinates system to the computer screen is necessary only on the basis of two-dimensional axis rotations. There was no need for view transformation. The transformation

Table 1 Forest information data structure

Field code	Meaning	Unit	Format	Remarks
XA	X axis of tree direction	Meter	Real	
YA	Y axis of tree direction	Meter	Real	
ZA	Z axis of tree direction	Meter	Real	
SP	Species	String		10 characters
NL	Conifer or hard wood	String		1 characters
HI	Tree height	Meter	Real	
BL	Clear length	Meter	Real	
DB	Diameter at breast height	Centimetre	Real	
CR	Radius of tree crown	Meter	Real	
CX	X deviation of crown centre	Meter	Real	
CY	Y deviation of crown centre	Meter	Real	
CC	Color code		Integer	0-15

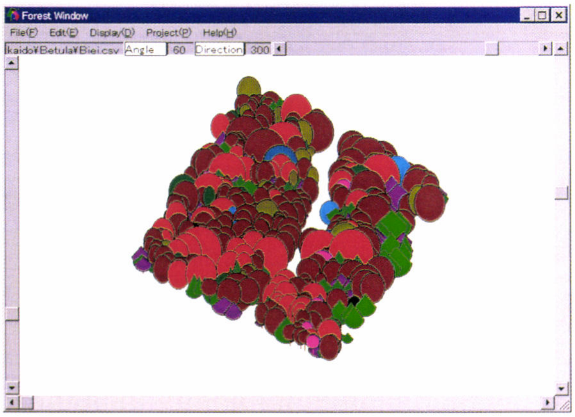

Fig.4 Display image of mixed forest structure in Hokkaido

Note: Observation point is at a direction of 300 degrees and an angle of 60 degrees.

of single tree form was necessary only on the basis of one-dimensional axis rotation. But this method has some limitations. One of them is that it is difficult to observe from a viewpoint just above the trees. FW therefore restricts the viewing angle to under 80 degrees.

OPERATION OF FW

After starting the FW program, the first window shows the menu bar as in Table 2. Forest data can be read by selecting "Open" in the "File" menu. If the data format of the file being read is not identical to the sample data, the

Table 2 Command menu of FW

File	Edit	Display	Project	Help
Open	Copy	View	Magnification	About
Exit			Zoom in	
			Zoom out	

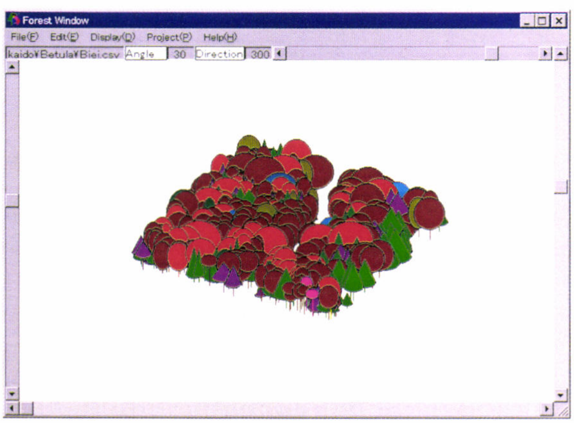

Fig.5 The same forest structure from an angle of 30 degrees

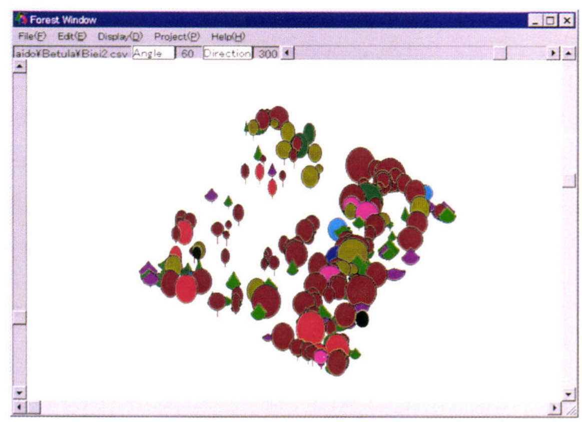

Fig.7 Forest structure after removing trees over 16-meters in height

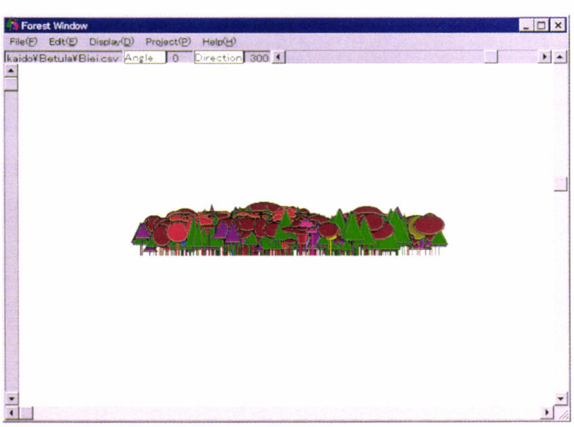

Fig.6 The same forest structure from horizontal viewpoint

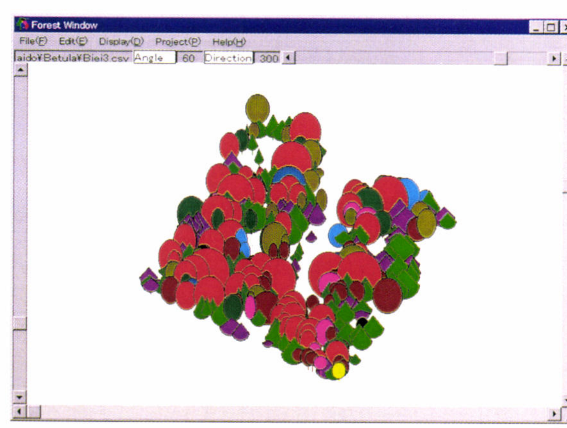

Fig.8 Forest structure after removing birches

Table 3 Color code table

Code number	Color name
0	Black
1	Gray
2	Dark navy blue
3	Light navy blue
4	Dark red
5	Light red
6	Dark purple
7	Light purple
8	Dark green
9	Light green
10	Dark blue
11	Light blue
12	Dark yellow
13	Light yellow
14	Dark white
15	Light white

message: "The fields are different from FW data" is shown. During the file reading, FW shows the file name at the upper left side of the window. When "View" in the "Display" menu is selected, the forest structure will be displayed on the screen. The initial viewpoint is at a direction of 300 degrees and at an angle of 30 degrees. The viewpoint can be moved by the left-side and topside scroll bars. The left-side scroll bar is the angle controller and the topside scroll bar is the direction controller. Also, the angle and direction can be directly entered in a text window on the upper left side.

Zoom in and out of forest view can be selected on the "project" menu. Zoom in and out can be done in steps of 20 percent, and can be repeated any number of times. The forest stand structure displayed can be copied to the clipboard to use in other applications by selecting "Copy" in the "Edit" menu. These pictures are drawn a Windows metafile, so the pictures can be edited on almost all image processors.

FW can show a forest of about one hectare area with 40 meter maximum tree height. The origin of the coordinate axes is the center of the window. The forest data can be edited using a spreadsheet. If the forest area is less than one hectare, the forest structure can be zoomed up.

Tree crowns can be displayed in 16 different colors. The color codes are set out in Table 3. Crown color is determined by the CC field numeric codes. The color codes can be related to tree species, diameter class, height class or any other characteristic. The color code can be readily calculated in the spreadsheet. FW and a spreadsheet can be run simultaneously in MS-windows 95. The spreadsheet handles input and editing of forest tree data, and FW handles the display of the 3D-image.

ANALYSIS OF FOREST STAND STRUCTURE

Fig. 4 shows an example of a one hectare stand of mixed forest in Hokkaido. The observation point is at a direction of 300 degrees and at an angle of 60 degrees. Tree crowns are displayed in 16 colors according to tree species. Birch is painted in light purple, oak is light red, fir is light green etc. The tree crowns cover the greater part of the ground. A trail can be seen through the center of the stand.

Fig. 5 shows the same forest at an angle of 30 degrees. The tree form can be seen better in this figure because of the lower angle. Fig. 6 shows the same forest at the horizontal level. This figure shows a vertical section of forest from which the height class of the trees can be seen. Fig. 7 shows a hypothetical case in which trees over 16 meters in height have been removed. Fig. 8 shows an example of the changed structure after thinning the birch species. After the thinning many oak and fir trees remain, and there are some open spaces.

These thinning operations are created by a spreadsheet application so FW can show any thinning models that can be stored in CSV format.

DISCUSSION

The old type of 3D-image viewer that was reported by authors in the past (Nobori 1990) used 8-direction tree data because of the limited speed of computer graphic displays. FW uses a simpler format for forest data and can sort the tree data rapidly. FW and a spreadsheet can be run together. The old 3D-image viewer can view the forest from the sun's position, but FW can view from any position. Hence the forest data does not need to be surveyed on the north, south, east and west cardinal points. If the axes of coordinates are fixed to the north, south, east and west cardinal points and the view-point is set on the sun's position, FW shows where solar radiation strikes the forest cover.

The old 3D-image viewer could simulate thinning of the stand in the application software. In using FW, spreadsheet software handles the input and editing of forest tree data, and FW handles the display of the 3D-image. In conclusion, it can be seen that Forest Window, used in conjunction with a spreadsheet, can provide an effective and flexible way of studying forest stand structures and the effect of different thinning strategies. Forest images can be copied from FW and used in other image processing software.

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