TECHNOLOGY OF REGENERATION OF NATURAL FORESTS IN JAPAN

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Abstract

For centuries, the planting of *Cryptomeria japonica* trees after clear cutting of natural forests has been the principal method of regeneration of forests in Japan. Because of diversity of species, management of natural forest can not compete as a wood producing industry with the monoculture of species of high economic value in temperate broadleaved forest zones which have been most developed in Japan in the past. Natural regeneration of plantations once established is also difficult and not feasible because of luxuriant growth of natural vegetation and of silvicultural characteristics of the favored species. Even in plantation forestry suppression of natural vegetation is the most labor-consuming job. Planting *Cryptomeria* trees in the final stage of crop rotation in shifting cultivation so as to utilize the fallow period had been a rather common practice in the past. This agri-silvicultural technique is supposed to have played an important role in the development of plantation forestry in Japan. Problems associated with clear cutting are also discussed, and the need for the enhancement of managerial degrees of freedom in the solution of the problems is stressed. Some thoughts about tropical forestry based on the experience in Japan are also presented.

Management of ecosystems

We, man, live on materials and energy produced by various ecosystems. Management of ecosystems was initiated when we began to apply the laws of nature with the intention of improving the use of ecosystems. Man should make the effort to adjust the various relations between man and ecosystems, in seeking a compromise between the requirements of ecology which is the law of flow and turnover of materials and energy in ecological systems, or ecosystems, and those of economics which is also the law of flow and turnover of materials and energy or money representing them in economic systems, or human societies. In the management of ecosystems we must strike a balance between these conflicting priorities. If we adhere strictly to ecological principles human society would not survive; and if we think only in terms of economics, ecosystems would be destroyed and, consequently, human society would also disintegrate. The role of management of ecosystems is to seek to discover and optimize relations between ecosystems and human society, and to keep them within their limits of flexibility.

In this context, depending on the situations in a human society and/or in an ecosystem there are many ways of managing an ecosystem, from leaving it untouched, as in nature reserves, to replacing it with another system as in agriculture. The degrees to which relations between economy and ecology can be adjusted by man might indicate the "managerial degrees of freedom". The higher the degrees of freedom, the more fully the conflicts between the two can be resolved, and the greater the options in management. When the degrees of freedom are very limited, we might decide that we should not interfere with the given ecosystem. "Doing nothing" is a management practice. The "regions where felling operation (of a forest) can not be carried out because it would not be profitable" were named "operational O-regions" by Samset (1966). To this concept, the author would like to add a phrase: "nor ecologically permissible". This is a case where the managerial degrees of freedom are so limited that "doing nothing" is a proper management decision. The degrees of freedom are not static but can be improved by man. In the past, we have improved natural ecosystems by increasing the degrees of freedom of management.

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Regeneration of forests

The ever-increasing and ever-changing needs of human society have made it necessary to improve natural forests which are of low value or to replace them by more useful ones. Neglected natural forests are not only of low economic value but sometimes are a source of trouble. To keep the forest stable, it is necessary to harvest old trees and make room for young and more vigorous ones. However, as it was too costly to harvest only scattered overmature trees, techniques of forest regeneration were initiated. There is a wide range in kind and intensity of human intervention in the regeneration of forest ecosystems. The intensity of intervention is dependent on types of forest and their successional stages. Shade-tolerant tree species invade under the canopy of pioneer species. If the former are the desired species, the regeneration technique consists only of harvesting the pioneer species and releasing the understorey, as in the case of firs and spruces invading under the canopy of second growth of birch. This is being imitated in man-made forests by planting fir trees under the canopy of larch, for example. However, where the overstorey species are more valuable than the invading understorey, succession has to be reversed. An example of this is the planting of pines in cut-over pine forests which have well developed understorey hardwoods. In such cases the development of hardwood understorey has to be stopped, that is, succession has to be halted by cutting or burning the hardwood understorey. When fuelwood was widely used, natural forests of *Pinus densiflora* were maintained in this way. In climax conifer forests, in which regeneration of conifers takes place, management consists of opening the canopy by harvesting overstorey trees and allowing the regenerating trees to develop. When natural succession does not give us the forest we want or when succession to the desired type is too slow, the natural forest may have to be replaced by a man-made forest. It is obvious that management using natural succession requires little labor and resources, but management against the trend of natural succession requires large imputs.

Characteristics of regeneration technology of forests in Japan

For centuries, the main stream of forestry in Japan has been based on planted forests of *Cryptomeria japonica*. Wood of this tree species has been widely used from time immemorial. For example, in remains, which are estimated to date back to AD 100—200, there were many relics made of wood of this tree. The origin of planting of this species is not known, but centuries old records of reforestation with this species can be found, and planted trees and forests, hundreds of years old, are still growing mostly around shrines and temples. Japanese forestry developed with planting of *Cryptomeria* on cut-over natural forests.

Silvicultural technology, which developed within the Japanese environment without any influence from the outside world, may be estimated by examining the technology prevailing before the Meizi Revolution, a century ago, and especially during the Edo Era. During that Era, for two and a half centuries from the 1600s, Japan enjoyed continued peace and developed high productivity and culture under the stable feudalism. Direct influence from the outside world on Japanese civilization then was limited to that from Korea, China and Holland. The influence of the two neighbors started from very ancient time but was mainly exerted in arts, cultural sciences, medical science and astronomy. The influence of the western civilization through the Dutch, the only western people allowed to come to Japan then, started to be felt strongly in the middle of the 18th Century but it was rather centered on medical and military sciences which had urgent needs at that time. If there were any influence on forestry from the outside world, it was that of Chinese philosophy on forest policy. Forestry schools in Europe started in the 19th Century (Devèze 1965).

Tokugawa (1941) who reviewed silvicultural technology of that Era, in a book of 372 pages, devoted only 15 pages to natural regeneration whereas 250 pages devoted to artificial regeneration were included in the book. This distribution of pages is supposed to reflect the frequency distribution of literature handling various aspects of silvicultural technology in that Era. As to natural regeneration, only seed tree system of pines was described. Forty pages were concerned with sustained yield of forest, but the most important policy for sustained yield was planting after harvest. For Natural forests, prohibition of felling by tree species and/or diameter and strict protection of selected forest areas were all that were concerned with sustained yield. Prevalence of artificial regeneration by planting illustrates silvicultural technology prevalent in that Era.

The situation did not change after the Meizi Revolution when Japan was opened up to the outside world. Prof. Honda, who studied forestry at Tokyo University and at the University of Munich, rearranged Japanese traditional silvicultural technology by the method of German forestry sciences, and wrote a series of textbooks. In his textbook comprising one volume (1908), 123 pages were devoted to artificial regeneration while only 17 pages dealt with regeneration by natural seeding. Similarly, in his textbook comprising 20 volumes, 5 volumes (1910-11) were devoted to silvicultural practices, while regeneration by natural seeding occupied only 95 pages of a volume and 3 volumes (765 pages in total) were devoted to artificial regeneration. These facts also indicate that artificial regeneration was the principal method used at that time. It may be of interest to mention that Mayr's textbook of silviculture, which was published in Germany nearly at the same time (1909), devoted 90 pages to artificial regeneration and 66 pages to regeneration by natural seeding.

This feature of Japanese forestry has continued until now. The area of planted forests increased rapidly after the Meizi Revolution with the rapid pace of industrial development and the increase of population. An example of this increase is shown in Fig. 1. In 1973, according to the government statistics, 35% of forested area of Japan and 33% of growing stock were man-made forests. Percentage of growing stocks of conifers in the man-made forests amounted to 99.1% and was very high compared to natural forests among which only 31.9% consisted of conifers.

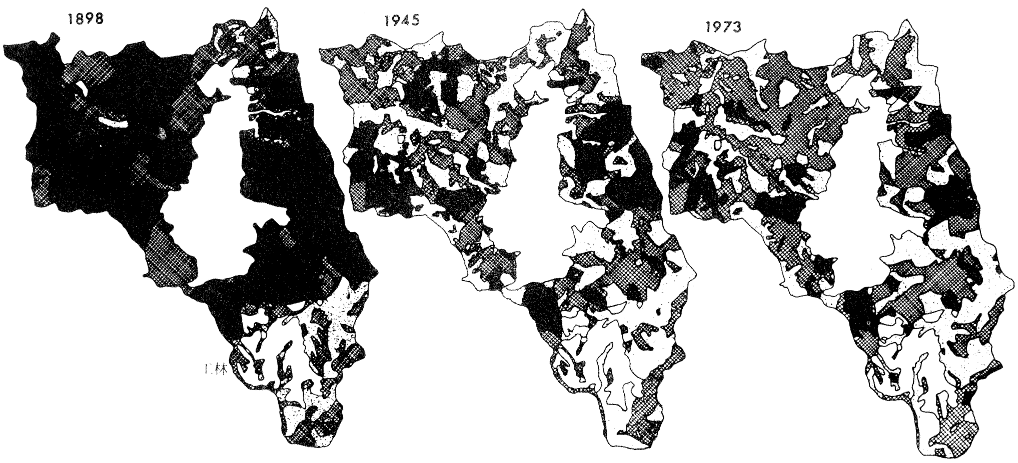

Fig. 1 Modifications in the composition and the form of forests in Tokyo University Forest in Tiba during the last 75 years (from Visitor's guide to the TUF in Tiba 1977)

black:	**natural forests of fir and hemlock with broadleaved trees, mainly coppice with standards.**
cross-hatched:	**broadleaved forests, mainly coppice.**
dotted:	**Plantations of *Cryptomeria, Chamaecyparis* and pines.**

Though planting of conifers experiences a decline at present, it still remains the main stream of forest regeneration. For example, in 1975, of 229,000 ha planted in Japan, 35% were covered with *Cryptomeria*, 30% with *Chamaecyparis obtusa*, 7.8% with pines and 24.7% with other conifers including larch and firs, and hardwood species represented only 2.5%. "Other conifers" were mostly planted outside the area occupied by *Cryptomeria* and *Chamaecyparis*. One fifth of the planted area corresponded to reforestation of cut-over conifer plantations and the rest consisted mostly of conversion of coppice stands and natural forest into conifer plantations. Conversion of coppice stands into conifer plantations chiefly resulted from the shift of energy sources for home use from wood to petroleum: fuelwood production which occupied 70% of total production of wood in Japan in 1935, decreased to a few percent in recent years. Regeneration by coppice declined drastically with the decrease in the demand for fuelwood. Regeneration by natural seeding has been tried on a rather larger scale since the 1920s mainly in the national forests, but such attempt was not particularly successful in spite of the abundance of ecological research related to this problem. Intensive systems for natural regeneration as seen in western Europe have not been developed.

In contrast to the poor development in regeneration by natural seeding, silvicultural technology of plantation forestry, especially of *Cryptomeria*, advanced considerably, as seen from the following examples, which may not be seen in the other parts of the world. In different regions different systems of control of stand density under the form of combinations of initial densities and thinning regimes were developed to meet the local demand for wood from the angle of dimension and quality. Initial planting densities varied from 800 to 20,000 trees per hectare and thinning regimes varied correspondingly. Tree improvement work by selection has been traditionally performed since a long time and many cultivars propagated exclusively by means of cuttings have been developed locally, especially in Kyusyu. The reason for this development is that wood of *Cryptomeria* has been deeply appreciated by Japanese people since time immemorial and used for building houses together with *Chamaecyparis obtusa*. It had also been used for many purposes though plastics and metals are now replacing wood in many cases.

Difficulties encountered in natural regeneration

In spite of the existence of well developed technology for plantation forestry, technology of regeneration by natural seeding lagged behind, and Japanese forestry developed chiefly by replacing natural forests by plantations of conifers.

With regard to climax forest vegetation of Japan, since the study carried out by Tanaka (1885), zonation according to temperature has been well recognized. Though further studies have been conducted and several modifications have taken place, the description of forest zones by Honda (1912) is still most popularly used. Honda divided Japanese forest vegetation into four zones: subtropical (annual mean temperature above 21°C, only in southern Okinawa and Ogasawara Islands), warm temperate (13—21°C, evergreen broadleaved), cool temperate (6—13°C, deciduous broadleaved), and subarctic and subalpine (below 6°C, coniferous) forest zones. In many of the broadleaved forests grow conifers like firs and hemlocks. *Cryptomeria* and *Chamaecyparis* belong to the conifers present in these broadleaved forest zones. Civilization of Japan started in the evergreen broadleaved forest zone, later followed by the deciduous forest zone, but coniferous forest zone has been far behind in this respect. These zones which are mostly differentiated by the temperature conditions, as there is no water deficiency, are characterized by a rich diversity of species, especially the broadleaved forest zone. Obata (1961) recorded 40 species of trees in a 0.471 ha sample plot of an evergreen oak forest in southern Kyusyu. Similarly Kitazawa et al (1959) counted 26 species among 335 trees in a sample plot of 20 × 100 m of evergreen broadleaved forest. In beech forests of northern Honsyu, Watanabe (1938) recorded 26 species of trees in a sample plot of 1.27 ha and 23 species in another sample plot of 1.85 ha, as the mean value for 13 plots averaging 1.5 ha in area was 14.6 species. These examples illustrate the diversity of species in temperate broadleaved forests. Subarctic forest zone which occupies the eastern half of Hokkaido also includes a mixture of many species of broadleaved trees. In subalpine forests of central Japan many pure coniferous forests exist and they regenerate themselves naturally, some of them following a pattern similar to shelterwood strip system. In a 20 × 20 m plot in a hemlock forest (*Tsuga diversifolia*) in subalpine zone of Titibu mountains, for example, 56 out of 63 trees were hemlock while the other 7 trees consisted of 4 species of conifers (unpublished data by Kashio). However, exploitation of subalpine forest zone is not justified in many cases.

The diversity of species in broadleaved forests, evergeen as well as deciduous, has for consequence a relative paucity of tree species of high economic value and even when forests are rich in the desired species, their regeneration is difficult because of competition from other vegetation. Besides, the wood of broadleaved tree species in these zones can not compete in its economic value with that of *Cryptomeria* and *Chamaecyparis* whose natural distribution and planting zones are similar to those of broadleaved forest zones. Some of the braodleaved trees in these zones are of high economic value only if they are of large dimension but smaller trees are of little value, while even trees of small dimension belonging to these two conifers are valuable if the quality is good enough.

Regeneration by natural seeding of conifer plantations once established is also very difficult in view of the silvicultural characteristics of tree species and luxuriant growth of natural vegetation, and not feasible ecologically. Drought resistance of these two species is very low (Satoo 1956) and regeneration by natural seeding on open ground is very difficult. Shade-tolerance is moderate and regeneration can not develop under dense canopy. When the canopy is opened to allow the development of regeneration, natural vegetation invades and grows so luxuriantly that young regeneration can not compete with it. Even under closed canopy, except for earlier stages after crown closure, natural vegetation invades. As seen from the examples given in Table 1, leaf mass of the natural vegetation penetrating under the canopy of some of the forests is very large, illustrating its vigor. Even if natural regeneration were possible, repeated felling of upper storey trees to meet the increasing demand for light of growing regeneration would be very difficult under the managerial degrees of freedom of present-day Japan, in most of the cases. Though natural forests of old ages covered with these species can be found in many areas, they are the products of a forest policy permitting local people to harvest only hardwood species for their own use so as to help enhance the growth of conifer regeneration. However, their establishment takes a long time. Process of natural regeneration is too slow in the framework of modern economy.

Table 1 Leaf mass of canopy and undergrowth (from Satoo 1973)

Canopy species	Canopy		Undergrowth		Number of samples
	Dry wt. t/ha	LAI	Dry wt. t/ha	LAI	
Larix leptolepis	3.6	4.3	0.53	1.61	1
Metasequoia glyptostroboides	4.3	8.5	0.37	0.88	1
Pinus densiflora	6.9	–	0.66	–	20
Chamaecyparis obtusa	14.6	–	1.28	–	2
Cryptomeria japonica	15.1	–	1.12	–	2
Abies sachalinensis	13.8	–	+	–	1
Thujopsis dolabrata	35.6	14.6	+	+	3
Betula ermanii	–	3.9	–	1.78	4
B. platyphylla var. *japonica*	–	4.4	–	1.44	2
Fagus crenata	–	4.9	–	0.88	3
Cinnamomum camphora	4.3	4.6	0.90	1.32	1

Agri-silviculture in Japan and its relation to the development of plantation forestry

Under these circumstances we have to depend on the system of planting after clear cutting. However, even in this system, control of competition from natural vegetation is a laborious undertaking. This system consists of harvesting of a forest by clear cutting, site preparation, planting, repeated weeding once or twice a year for several years, cleaning of weed trees at earlier stages of crown closure, repeated removal of climbers, thinning and pruning. Most of the work requiring a large pool of manpower without direct cash return is concerned with the suppression of natural vegetation. Prescribed burning had been used in site preparation though it is not used any longer. In Honda's textbook (1911) the method was described as one of the popularly used methods in that time. Prescribed burning was also used to suppress weed species in *Miscanthus* grasslands which are of little use nowadays. The use of herbicides was limited, because of the diversity of vegetation on the one hand and environmental concern on the other hand.

On the other hand, shifting cultivation for food production by burning broadleaved woodlands had been performed until recently. According to Matsushima (1973), an inquiry made by the Ministry of Agriculture of Japan in 1936 revealed that there were more than 77,000 ha devoted to shifting cultivation, while in a subsequent survey conducted in 1950 more than 9,000 ha were recorded. Matsushima also reported that in Tenryu area, in 1875, of 227 ha of holdings belonging to a family, 82% were covered with broadleaved woodlands used for shifting cultivation, 16% consisted of plantations of *Cryptomeria*, and only 2% were regular cultivated land. Of 476 ha of holdings in another family 97% were covered with woodlands for shifting cultivation, 2% were *Cryptomeria* plantations, and only 1% was regular farmland. These records clearly show that in this area shifting cultivation represented a very important means of living. Matsushima claimed that *Cryptomeria* forestry of Tenryu area, where the percentage of plantations in the forest area is very high now, developed as a new system of shifting cultivation by incorporating *Cryptomeria* trees into the crop rotations. Plantation of this tree species is regarded as the final crop of rotations in shifting cultivation or as a utilization of the fallow period of shifting cultivation and the age to harvest planted trees was influenced by the length of the fallow period. According to Ariki (1974), in a document dating back to the middle of the 18th Century, in Kito, Tokushima, it is stated that *Cryptomeria* trees were scheduled to be planted in the final stage of rotation in compensation for the permission of practising shifting cultivation in the woodlands belonging to the local feudal lord. This cultural system, which consists of harvesting of broadleaved woodland, burning, crop production for a few years and planting of timber trees, especially *Cryptomeria*, had been practised throughout Japan except Hokkaido. Tokugawa (1941) cited literature from the late 17th and early 18th Centuries describing this kind of system. According to Ariki (1974), 55.9% of the 77,000 ha devoted to shifting cultivation reported in the inquiry of 1936 included tree planting.

Even in a suburb of Tokyo, which is now within the city limit of Tokyo, planting of *Cryptomeria* as a part of crop rotation was performed until the earlier part of this Century (Tsutsui 1970). Shifting cultivation as a method of crop production showed lower productivity both per unit ground area and per unit input of labor as compared with regular agriculture (Ariki 1974). However, as a system of rotation including tree planting, productivity of labor input was not necessarily low, if the saving of the labor force for site preparation and weeding in tree planting is taken into account. Cereals like buckwheat, barnyard grass (*Echinochloa frumentacea*), Italian millet (*Setaria italica*), wheat and barley, beans like soybean and red bean (*Phaseolus angularis*), root crops like *Colocasia antiquorum* var. *esculentum*, sweet potato, radish and turnip, and perennial crops like paper mulberry (*Broussonetia kažinoki*) and *Edgeworthia chrysantha* for paper making, mulberry and tea were grown within the rotations. Combinations of these crops with trees for timber varied in time. Table 2 shows examples in Kito area, Tokusima. This system of tree planting is a form of agri-silviculture which is applied widely in the tropical countries for tree planting, and reminds of the taungya system. The author observed a similar system of establishing coconut plantations in Car-Nicobar Island in the Indian Ocean where the only tools for cultivation were iron sticks. Agri-silviculture has played an important role in the development of plantation forestry in Japan.

This system is not practised any more in Japanese forestry. Prescribed burning is under strict control of local governments by law (Forest Law, Art. 21-24) and most of the varieties of cereals produced do not any longer play an important role in the diet of the Japanese people presently. Socio-economic conditions also have been modified greatly. This system was mostly used and developed by peasants for their own small forestry but not in the large plantation programs planned by the government and large firms, presumably because of difficulties in the phase of organization.

Table 2 Examples of crop rotation and time when trees were planted in shifting cultivation as practised in Kito, Tokusima (modified from Ariki 1974)

Year	Crops											
1st	1	1	1	5	5	5	1*	1*	1*	1	1	1
							+	+	+			
2nd	2	2*	3*	4*	3*	2*	2+	3+	3+	4*	3*	2*
		+	+	+	+	+	+	+	+	+	+	+
3rd	3	4+	1+	1+	+	+	+	+	+	6+	1+	4+
		+	+	+	+	+	+	+	+	++	+	+
4th	*	+	+	+	+	+	+	+	+	++	6+	6+
	+	+	+	+	+	+	+	+	+	++	++	++
5th	+	+	+	+	+	+	+	+	+	++	++	++
	+	+	+	+	+	+	+	+	+	++	++	++
	+	+	+	+	+	+	+	+	+	++	++	++
Xth	+	+	+	+	+	+	+	+	+	++	++	++
•	+	+	+	+	+	+	+	+	+	+	+	+
	+	+	+	+	+	+	+	+	+	+	+	+
Yth	+	+	+	+	+	+	+	+	+	+	+	+
1st												

1: barnyard grass (*Echinochloa frumentacea*), 2: Italian millet (*Staria italica*), 3: red bean (*Phaseolus angularis*), 4: soy-bean, 5: buckwheat, 6: perennial crops (paper mulberry (*Broussonetia kazinoki*) *Edgeworthia chrysantha*, mulberry, or tea).

* the year to plant *Cryptomeria japonica* trees.

Xth year: year when perennial crop culture will be interrupted.

Yth year: year when *Cryptomeria* trees will be harvested.

Problems associated with clear cutting

Most of the lowlands in Japan are used for food production and industries or urban areas and only steep slopes are available for forestry. Even in flat countries harvesting of timber inevitably affects productivity of the land (Tamm 1969), the effect being more pronounced in clear cutting. Some of the examples of the problems associated with clear cutting will be analyzed briefly.

During the summer, a typhoon or a front may bring heavy rains, sometimes hundreds of millimeters in a day or two. Heavy rain which often occurs after the soil is saturated from previous rains sometimes causes mass movement of soil and landslides on steep hillsides. Landslides occur more often in conifer plantations than in coppice stands in which root system of the harvested trees continues to live. The soil of steep hillsides, which has been held by dense tangled roots, is released as the roots decay after trees were cut (Barrough and Thomas 1972, O'Loughlin 1974), and as roots of newly planted trees are not yet dense enough, landslides are more likely to occur in young plantations.

Productivity of forest soil is maintained by the turnover of organic matter and nutrient elements by decomposition of litter. With heavy and frequent rains, litter and fertile surface soils are washed away on steep terrains. Washing away of litter and surface soil may be accelerated by clear cutting (Sugiura et al 1967, 1968). Loss of organic matter and nutrient elements is greater after clear cutting and replenishment by natural cycling takes a long time (Tsutsumi 1963, 1964). Decrease in productivity as a result of repeated clear cutting over a period of time which leads to a decrease in soil organic matter is well demonstrated by Tsutsumi (1964). Burning will amplify these problems on steep slopes.

From late winter to early spring, cold dry winds mainly from the northwest prevail. They damage and kill unprotected young trees planted after clear cutting. Dry wind accelerates transpiration from leaves while water absorption through roots is low because the soil is cold. Consequently, absorption of water can not compensate for the loss of moisture by transpiration and leaves become dry and eventually die (Satoo 1962). Windkill occurs mostly on exposed sites and is sometimes very severe over larger areas exposed by clear cutting, mostly on slopes facing the north and northwest (Kaijo and Sunasaka 1971). To avoid this damage clear cut areas should have a forest stand to serve as a windbreak. Importance of surrounding stands for young plantations was stressed by Sai On as early as in 1737 and 1747.

After World War II, conversion of natural forest into plantations has been accelerated by increased demand for wood and the decline of requirements for fuelwood, and plantations have expanded into more difficult environments. On the other hand, mechanization of harvesting and modernization of transportation of timber brought about clear cutting over large areas. The larger the area, the more adverse the effect of clear cutting on forest. Change in the pattern of demand for domestic wood brought about shorter rotations which led to more clear cutting in a given period of time, and consequently, on a given land area.

Conclusion

In spite of the difficulties associated with regeneration system by clear cutting and planting, we have to keep this system. Maintenance of natural forest as a source of continued wood supply by natural regeneration may be ideal ecologically, but not feasible economically. To secure the supply of wood to meet the demands of society at reasonable prices, it is inevitable to have to depend on the system of clear cutting and planting. To reconcile the requirements of ecology and economy, we must try to keep the biomass of forest as large as possible. The environmental influences of forests such as water production, erosion control and amenity values are produced by large biomass and high productivity of forests, especially mass and production of leaves (Satoo 1974). For this purpose time and space with minimal biomass should be minimized through making the area of clear cutting as small as possible and the time interval of clear cutting or rotation period as long as possible. However, to realize these policies it is necessary to secure high managerial degrees of freedom. Wherever clear cutting involving a small area is not practicable it should be considered as "operational O-region". In such cases "doing nothing" is the right management decision. It is more urgent to enhance the managerial degrees of freedom than to expand the areas of plantation.

Thoughts about regeneration technology in the tropics from a forester living in the temperate zone

The development of technology of forest regeneration in the natural forests of Japan which is located in the temperate zone has been presented. Let us now think of regeneration technology in the tropics on the basis of the Japanese experience. The author himself has no practical experience in tropical forestry, but whenever he reads about natural regeneration of tropical rain forests (Normand 1971, for example), he can not understand why such method as the tropical shelterwood system is being used, mainly because of the difficulties experienced in Japan when trying natural regeneration, even though he understands that the problems accompanying clear cutting may be more severe there due to greater turnover rates. Diversity of species and profuse natural vegetation on the one hand and limited managerial degrees of freedom on the other hand make natural regeneration very difficult in Japan. Diversity and growth of natural vegetation must be even more extensive in the tropical rain forest where temperature conditions and water supply are more favorable than in Japan, while managerial degrees of freedom may not be much more favorable in most cases. If so, natural regeneration of tropical forests must be more difficult than in Japan. Is it not on the basis of the way of thinking of northern people that natural regeneration has been tried and practised in the tropics? Various methods of natural regeneration could be successful in the northern environment where natural vegetation is so simple as to allow the classification of site quality by ground vegetation (Cajander 1926) and its growth rate is very low, but could they be successful under the conditions of tropical rain forests which are more complicated in composition and structure? The author would be most happy if any comment and criticism on his thoughts were given to him by those who have ample experience and knowledge of tropical forestry.

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A postscript

After writing this article arrived the recent issue of a scientific journal in which Lowe [1] made the following statement, supporting the concept outlined in the last chapter of this article. Lowe states: "Nigerian tropical shelterwood system (T.S.S.) was a major management preoccupation of the Forest Service in western and mid-western Nigeria during the 1950s, and altogether about 200,000 hectares of forest were treated under this system." "The system was abandoned", "and during the 1960s the emphasis changed to artificial regeneration, particularly by 'taungya'". "It now seems that the system could not be economic because of the paucity of valuable regeneration and because of the relatively slow growth rates in natural forest. Silviculturally there was the difficulty of reconciling the need to open the canopy and yet at the same time to control growth of climbers and herbaceous weeds." (from his abstract, p. 193)

[1] Lowe, R.G. 1978. Experience with tropical shelterwood system of regeneration in natural forest in Nigeria. For. Ecol. Manage. 1: 193-212.

Discussion

Liew T. C. (Malaysia): I note that plantations are established on steep hills and mountains. As soil erosion is one of the main threats during the summer rains, is there any problem in constructing and maintaining the forest roads?

Answer: Roads have to be as narrow as possible and supported by carefully arranged auxiliary structures. Opposition stemming from the public against road construction out of concern about the environment is another difficulty. However, roads are needed for intensive management of the forest.

Glori, A. (The Philippines): Are there any pests or diseases in sugi plantations?

Answer: As far as pests and diseases are concerned, there are no serious problems in the *Cryptomeria* and *Chamaecyparis* plantations in Japan.