
TEAK (*Tectona grandis* L.f.) FORESTS IN JAVA, INDONESIA PLANTATIONS, MANAGEMENT AND POLICY

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ABSTRACT

This paper gives an overview of the environmental conditions, silviculture, distribution and area of teak forests in Indonesia. As Java is a densely populated island, the population pressure is also very high. Therefore specific forest management systems are applied. The tumpangsari (taungya) system as well as daily wage system are considered as having valuable social and economic aspects for people of the area surrounding the teak forests. This way they ultimately decrease further teak forests deterioration.

Indirect Government policies (such as family planning and transmigration) and policies aimed directly at the teak forests, such as application of the tumpangsari and daily wage systems, could maintain teak forests and teak production in Indonesia on a sustainable basis.

Key words : Teak (*Tectona grandis* L.f), Indonesia, sustainable management, tumpangsari (taungya) system, forest policy, population pressure.

1. INTRODUCTION

Teak (*Tectona grandis*) in Indonesia is native on the islands Java and Muna. It is generally considered as indigenous in Indonesia (De Veer, 1957; Departemen Kehutanan, 1986), although some suppose it was imported by the Hindus in the 7th century (Cart-haus, 1909; Altona, 1923; De Veer, 1957; Purwodidodo, 1991). In Indonesia teak forests are mostly found in Java, where a clear difference exists between dry and wet seasons. At present, almost all teak forests in Java are plantation forests, established after 1895. Nevertheless natural teak forests are still sporadically found in protected forests.

Teak together with other species, like the *Pinus merkusii*, the *Agathis loranthifolia*, the *Dalbergia latifolia*, the *Altingia excelsa*, the *Swietenia* spp. are the most important species in Java. Beside timber, there is also some production of non-wood commercial products like resin from the *Pinus merkusii* and the *Agathis loranthifolia* and cajeput oil from the *Melaleuca leucadendron*.

Teak is a rather heavy, hard and very hardwearing wood, which easily works : specific gravity 0.68, hardness class II and hardwearing class I-II (Perum Perhutani 1980 a, Departemen Kehutanan, 1992). According to its wood characteristics it can be grouped into four classes : lime teak with a light colored stem and lime concretions in the wood, oily teak with hard, heavy, shiny wood, wrinkled teak with wrinkled fibers and doreng teak with dark brown stripes in the wood. It is mostly used for furniture, construction wood, poles, flooring, etc. Owing to its good wood quality, it is called "commercial timber" since more than 100 years. Until 1969 teak was the most important timber species of Indonesia. After 1970 it was replaced by meranti (Dipterocarpaceae species) in both volume and value. Nevertheless teak is still very widely used either for domestic or export purposes. Export of teak mostly takes place to Europe, Middle East, other Asian countries, Australia and North America. It consists of sawntimber and products of integrated wood (like veneer, wall panels, mosaic parquet, solid doors, etc.), some 50 percent and 80 percent respectively.

Management of teak forests in Indonesia was introduced more than 100 years ago. Plantations of this valuable tree species are still extensive and produce large volumes of wood. Therefore since a long time, teak management has been recognized and applied in practice, beside the compelling need for permanent reservation of forest land for protecting forests, and regulation of the harvest on a sustainable basis.

Since teak forests are currently still very important, the Government of Indonesia c.q. Ministry of Forestry, exerts itself to the utmost to manage these forests as sustainable as possible. However it is not easy to realize this objective, as Java, where teak forests are concentrated, is extremely densely populated. So population pressure is very high. Nevertheless several silvicultural systems have been designed and are applied to manage teak forests on a sustainable basis.

This paper mainly deals with the area of teak in Indonesia, general silvicultural aspects and policy towards sustainable management of teak forests in Indonesia.

2. AREA OF TEAK PLANTATIONS

Java, with a total area of 13.2 million ha, covers 2.99 million ha of natural forest and forest plantations (23 % of the total land area). Production forest takes up 68 % of the forest area, whereas protection forest represents almost 24 % and nature and recreation forests some 8 %. These forests play a very important role both from the ecological and from an economical point of view. Eventhough Java covers only 7 % of the total area of Indonesia, it is occupied by more than 100 million people (more than 60 % of Indonesia's population). With an average of 814 people per km², Java has one of the highest population densities. Most of these people are living in the vicinity of forests. This situation, however, often interferes with forest management. On the one hand people need land for settlement, agricultural activities, woods and other daily needs, while on the other hand the Government tries to protect some forest areas and to extend forest plantations.

Forest management in Java occurs under the authority of Perum Perhutani (State Forest Enterprise). It distinguishes three management units, namely Unit I (Central Java), Unit II (East Java) and Unit III (West Java) (table 1).

Table 1 : Forest area on Java according to management units.

Unit	Total forest area (ha)	Production forests		Protection forests		Nature and recreation forests	
		ha	%	ha	%	ha	%
Unit I	655.681	579.255	88,3	74.818	11,4	1.608	0,3
Unit II	1.364.441	872.166	63,9	334.274	24,5	158.001	11,6
Unit III	968.100	567.030	58,6	321.996	33,3	79.074	8,1
Total	2.988.222	2.018.451	67,5	731.088	24,5	238.683	8,0

Source : Perum Perhutani 1980a.

Note : Unit I : Central Java

Unit II : East Java (including Madura)

Unit III : West Java

Unit II has the biggest forest area while Unit I has the smallest one. Unit I has the highest percentage of production forest. The area of protection forest ranges from 25 to 33 % in Units II and III, while in Unit I the protection area is reduced to 11 % and the nature and recreation forests have almost completely disappeared. The latter forest types are under the jurisdiction of the Directorate General of Nature Reserve and Forest Protection.

The production forests mainly exist of a very small number of tree species, namely teak, pine, mahogany, rose wood and *Agathis* (table 2).

Table 2 : Production forests and tree species distribution in Java in 1989.

Commercial name	Latin name	Area	
		Hectares	%
Teak	<i>Tectona grandis</i> L.f.	1,050,572	52
Pine	<i>Pinus merkusii</i> Jungh. et de Vriese	539,009	27
Mahogany	<i>Swietenia</i> spp.	86,950	4
Rose wood	<i>Dalbergia</i> spp.	49,893	2
Agathis	<i>Agathis loranthifolia</i> Salibs	83,287	4
Other species		208,042	11
Total		2,017,753	100

Source : Perum Perhutani, 1989.

Teak occupies more than 50 % of the production forests in Java. Nowadays it is still mostly planted in the forest plantations in Java, followed by pine.

Since forest area in Java is very limited and teak wood is an important export commodity, management of these forests must be done properly and improved through several policies in order to conserve the forest as well as to sustain the production.

3. GENERAL SILVICULTURAL ASPECTS

In order to discuss the silvicultural aspects of teak, it is necessary to have an insight into the ecological aspects of this tree species (distribution, site conditions and climate).

3.1. Ecology

3.1.1. Distribution

In Indonesia teak forests are found in Java, Bali, Nusa Tenggara and Sulawesi (Departemen Kehutanan, 1992). In Java teak covers an area of some 1.05 million hectares, while in the other islands it covers less than 50, 000 hectares. The distribution of teak forests is strongly related to well determined ecological conditions, such as soil and climate.

3.1.2. Site condition

Teak can grow up to 500 m above sea level (a.s.l) (De Veer, 1957), but Beekman (1949) says it could grow up to 700 m a.s.l. Teak grows well on several soil types in Java. Although most of the teak forests occur on tertiary lime and marl formation, it is not proven that teak prefers these sites (Beumee-Nieuwland, 1922; Beekman, 1949). It grows also on volcanic and alluvial soils of various origin (Beekman, 1949).

The chemical composition of the soil is not of great importance to the growth of teak. It seems that, without human influence, teak would occur only on the lime and marl soils, while on the usually more favorable red soils (volcanic or lime in origin), teak would not compete with the natural tree species (Beumee-Nieuwland, 1922). Physically teak need permeable soils, fresh and well aerated. Very permeable sand soils, rather impermeable clay-soils and shallow soils are not favorable (Beekman, 1949). The capacity of the soil to retain water is very important. If it is too high or too low plant growth will be hampered. However for many teak sites, the drainage of the soil seems often to be the most decisive factor for productivity. The drainage of the second layer is of particular importance for the upper soil layer. In good soils, good drainage of the second layer safeguards good drainage of the first layer. While on bad teak sites, the amount of water in the second layer during the growing period will be much too high to transport water from the upper layer quickly enough downwards. Too much water in the second layer

maybe the reason that sometimes older teak stands do not thrive so well. The main reason for poor drainage in the lime and marl soils is the occurrence of the insoluble lime carbonates in the soil. Lime carbonate will be more soluble if sufficient CO₂ can penetrate into the soil. Also clay illuviation may be a second reason for poor drainage of the soil. A third factor, causing a decrease in the physical soil condition, is the presence of readily soluble calcium salts, which are not neutralized (Beumee-Nieuwland, 1922). Therefore soil fertility should be maintained, i.e. by a dense undergrowth of deep rooting, evergreen trees which prevent soil erosion, facilitate infiltration and evaporation of water, and contribute to the nutrient cycle (Anonymous, 1930).

Teak is a light demanding species (Van Ravenswaay Claasen, 1910; Becking, 1940). Therefore crown mixing of teak with other dense crown species is unsatisfactory (Anonymous, 1930). The silvicultural characteristics of teak can be compared with those of the *Quercus* sp. in temperate regions (Becking, 1940).

3.1.3. Climate

Teak requires a typical monsoon climate with a periodic dry season, with an annual precipitation ranging between 1250-3750 mm and four to seven dry months with less than 60 mm precipitation. The optimal mean annual temperature is 22-27°C, with extremes of 15 and 30°C (Beekman, 1949; Perum Perhutani, 1993). For its normal growth, teak prefers areas with a significant difference between dry and wet seasons.

3.2. Silvicultural systems

Of more than two million hectares of production forest in Java, more than 50 percent consist of teak plantation. Its cultivation is entirely artificial. Although De Veer (1957) states that in many countries the most usual silvicultural system is selective cutting, followed by natural regeneration, this system can not be generalized and applied to teak forests of Java. It has been proved that clear cutting, followed by artificial regeneration, is the most adequate silvicultural system for Java teak forests, at least from the economical and technical point of view. We have to realize, however, that such a system implicates a lot of ecological risks, like soil erosions, loss of several nutrients, disturbance of pedofauna-activities, etc. Therefore it must be improved in the future by viz. careful plantation and exploitation, undergrowth of deep rooting, evergreen trees, small scale clear cut areas and lengthening of rotation period.

3.2.1. Site suitability

Teak requires specific site conditions to attain a normal growth and wood of high quality. When it is planted on unsuitable sites, it will display either too slow or too fast growth with undesirable stem forms and wood quality. The most suitable areas for teak are only located in Java, covering not more than 800, 000 ha (Perum Perhutani, 1993). This means that some 250, 000 ha are located in unsuitable areas.

As already mentioned, teak in Java is planted in cutting-over areas. However repeated planting of teak on the same site, without soil fertility improvement, causes site deterioration, indicated by slow growth, badly shaped stems and light crowns.

Improvement of soil fertility in teak plantations is done by indirect fertilization due to application of the tumpangsari. Fertilizers for agricultural crops during the tumpangsari are Urea, Three Super Phosphate (TSP) and KCl. These fertilizers are added in a dosage depending on the soil condition and the kind of agricultural crops. Beside that, on the area without the tumpangsari application, nitrogen-fixing tree species such as the *Dalbergia latifolia*, the *Cassia siamea*, the *Leucaena leucocephala*, the *Schleichera oleosa*, etc. are used to improve the soil fertility.

3.2.2. Provenance trial, progeny test and propagation

Provenance tests of teak have been studied since 1930's using different ecotypes, namely Indian, Burmese, Thai, Vietnamese, Munamese and Javanese. It was found that Javanese and Burmese teak give the best growth performance. At present, teak cultivation in these areas still uses these both provenances.

Perum Perhutani (1993) mentions that progeny test of teak have conducted since 1988 to seeds from selected plus trees, using latin square design. Seeds are directly planted at the spacing of 3 x 3 m in plots of 10 x 10 m. Observations indicate that the germination percentages of the seeds range from 60 to 90 percent, and the growth of the seedlings is relatively faster than the one originating from seeds of non-plus trees.

In order to establish teak clone banks, since 1983 grafted seed orchards have been established by the Perum Perhutani. The total area already covers some 500 ha. The first fruiting occurred in 1989, producing less than 1 kg per tree (Perum Perhutani, 1993). Beside that, teak propagation by tissue culture techniques has also been elaborated. Some seedlings, produced by this method, have already been planted in the field.

3.2.3. Plantation and stand maintenance

The forest plantations, carried out by Perum Perhutani, consist of the replantation of cutting-over areas, of non-productive areas and of bare lands. The cutting-over areas are logged before plantation activities, while non-productive areas are occupied by several weeds, such as the *Imperata cylindrica*, the *Eupatorium malabathricum*, etc. Bare lands are areas without vegetation cover.

Plantation activities are done by applying the tumpangsari system, in which the local people are employed as a laborer and farmer. It is carried out in a generative way through seed planting, directly in the field as well as through nurseries from which the stumps will be planted later in the field.

By direct seeding, spacing of 2x1 up to 3x1 m is used. This provides a fast closure and favorable youth development. In order to secure a growing seed at each marking stick, 5-8 seeds are planted together (Wirjodarmodjo and Soebroto, 1983). Finally, from these 5-8 seedlings, growing at each marking stick, only one is left and kept growing. The rest must be cut or drawn out. Seedlings from nurseries, after having sufficient roots, are directly planted in the field. Both systems are applied in the beginning of the rainy season (October).

A study by Klop and Van Ogtrop (1985) indicated that site preparation during teak forest establishment should be carried out from April to September. In this period land clearing is done and the soil is tilled several times. In July and August the paths, rises and ditches are constructed. In the following month sticks are placed at the planting site, along the contour lines. Then planting is done in October. When the planting of the main tree species is finished, it should be followed by interplantings and by hedge-plantings, using non-teak species (mostly nitrogen-fixing species/leguminous trees). These are carried out before the end of December. Interplanting with leguminous trees is very useful as an alternative for soil improvement and erosion control.

Around the area, along the roads, mostly secang (the *Caesalpinia sappan*) are planted to form a hedge. The hedge planting mostly combined with interplanting of crops like kemlandingan (the *Leucaena leucocephala*) or the *Acacia villosa*. Other non-teak species, like mahoni (the *Swietenia* spp.), sonokeling (the *Dalbergia latifolia*) or johar (the *Cassia siamea*) are also planted in the first and last teak rows (figure 1).

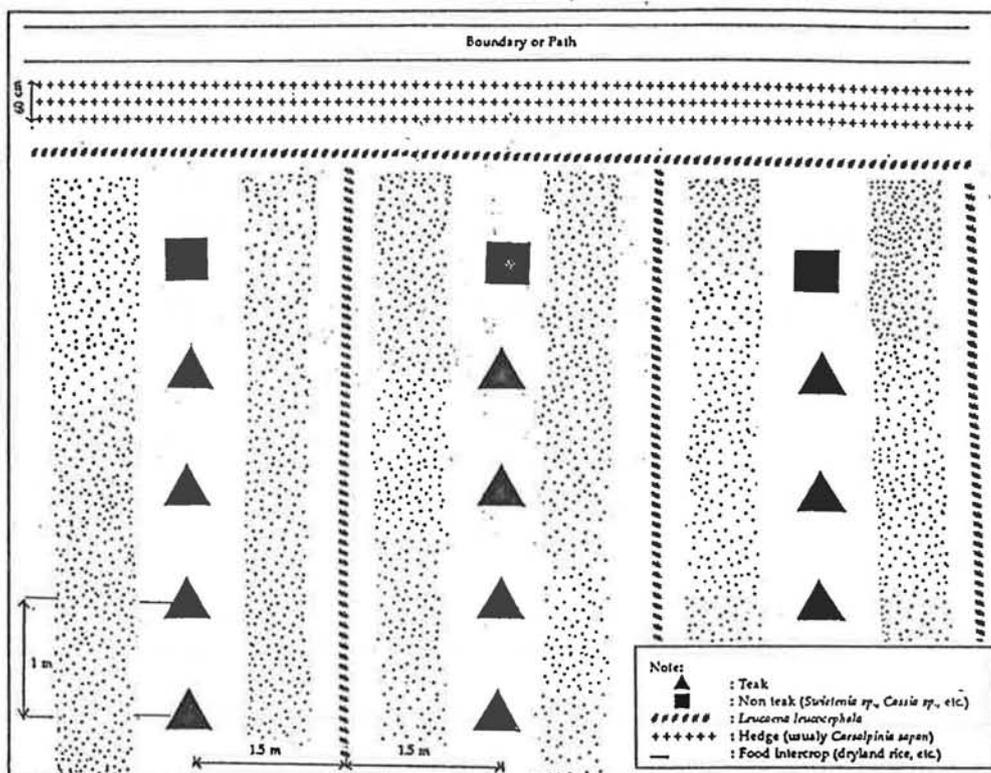


Figure 1 : Lay out of the tumpangsari teak plantation (after Yunus, 1976).

The hedge-plants are especially important to protect the teak plantation from disturbances caused by cattle (cows, sheep, etc.) from nearby villages. In addition, local people could use hedge trees either for fodder or firewood.

In the tumpangsari system, the local farmers are admitted to plant food crops among the rows of the main tree crops and the inter-crops, with the obligation to maintain both the main and inter-crops. In this way support for fertilizers and pest control is performed by the Perum Perhutani in many cases.

The local farmers start to plant agricultural crops (mostly maize and rice) in October of the first year. For maize the first harvest is in January and the second one in March or April. Other agricultural crops, which are allowed to be planted, are pepper, peanut, soybeans etc. In some places, cassava, climbing legumes, sweet potatoes, banana and potato are forbidden, because it could disturb the development of the main trees. The tumpangsari period mostly lasts five years. Presently, shadow tolerant species for medical crops like the *Zingiber* sp., the *Cucurma domestica*, the *Cucurma xanthorrhiza*, the *Lenguas officinarum*, etc. can also be planted under the old stand.

In the second year the interplanted crops like the *Leucaena* sp. or the *Acacia* sp. are already pruned, i.e. in March and April, to faster a closed canopy between the interplanted trees, so that erosion can be minimized. Later on the interplanted crop is pruned every six months. The pruning waste is put along the rows in order to eliminate water competition between teak and interplanted trees during the dry season.

If necessary blankfilling is repeated in November of the second year or in March of the third year. The planting period is over in April of the third year.

In order to obtain a high output, both in volume and quality of the wood, at the end of the rotation, several maintenance tasks must be done, viz. weeding, pruning, thinning, protection against pests, diseases and other disturbances, like grazing, fire, thievery, etc.

Weeding is important to protect the young plants from water, nutrient and radiation competitions. Weeding is necessary up to the age of 2 year. At that time teak saplings have a height of some 3-6 m.

Pruning is done to stimulate the height growth and to produce high quality timber. In plantations already overgrown with the *Imperata cylindrica*, pruning of the side branches helps the teak to overgrow the *Imperata cylindrica*.

Thinning attempts to maintain a high and uniform diameter on the select stems while promoting good form and rapid branch shedding (White and Cameron, 1971). If the thinning is delayed the quality of the wood will suffer from it (Anonymous, 1986). The first thinning occurs at the age of 5 year. Later on, until the age of 30 year, a thinning is carried out every five years, while afterwards the interval is lengthened up to 10 years.

Thinning reduces stands from their initial stem number of 3000/ha to the final stand with 100 - 200 good formed trees/ha.

Protection against pests and diseases is necessary, especially for the young trees. It is applied by using several kinds of insecticides and pesticides. Beside pests and diseases, wood thievery and grazing sometimes occur, especially in areas where the people in the surrounding forests are very poor.

Illegal grazing in teak forest leads to a negative impact both on the stand and the soil. Utomo and Widiarso (1992) mention that teak forests must be protected against illegal grazing by i.e. :

1. hedge crop planting;
2. formations of cattle foremen;
3. assignment of grazing ground;
4. cattle stabling, etc.

Wood thievery in teak plantation happens everywhere, but especially in these areas where the rural people surrounding the forests are living in poor economic conditions and suffer a high degree of unemployment. Therefore the Perum Perhutani endeavor to involve these people in forestry activities, i.e. through tumpangsari activities, labor in reforestation, etc.

3.2.4. Rotation and Harvesting

The rotation of teak plantations is based on financial considerations. As local conditions must be taken into account, the presently used rotation ages vary from 40 to 80 years.

To meet market demands for smaller sized logs and to improve the financial return, there is a tendency to shorten teak rotation to 40 years (Davis, 1989). Shortening the rotation period is an alternative to design forest stands capable to compromise between the pressure on the teak plantation and the forest land.

In teak forest stand there is currently a tendency to overcut the older (bigger) trees and to leave the younger age classes (Sumitro, 1992). The crucial undertaking is maintaining the younger age classes to the maturity with little risk and cost. The shorter the rotation the less risk involved, therefore the shorter rotation is considered only on the risky areas (Simon, 1991 as cited in Sumitro, 1992). Shortening of rotation could give beneficial economical results, but from the ecological point of view it presents several risks. Short rotations generally affect directly the soil condition, i.e. by accelerating soil erosion, and hence declining soil quality. Besides, short rotations also lead to shorter times for soil self-recovery; too often harvesting, especially by using mechanical technique, cause soil compaction. Regarding to these processes the soils gradually deteriorate. Long rotation periods, on the contrary, viz. 80 years are maybe economically not so beneficial, but

have ecologically a positive impact, like a high possibility of soil recovery, high species diversity (either plant or animal species), etc. This way, the soil ecosystem becomes relatively stable, which ultimately improves a sustainable use of the teak forests. Considering the local conditions, however, adjustment should be made in order to compromise between the daily need of the surrounding people and the ecological need for the continuity of the ecosystem. Therefore further research on more appropriate rotation ages should be done.

Harvesting of teak in Java is done manually and plays an important role in the employment of local people. Clear cutting systems are applied, with low energy input, to maintain the sustainability of forest production.

Two years before felling, teak trees are girdled, in order to reduce water content and to improve the wood quality. It becomes lighter, hence transport and handling are cheaper. The processing in the factories is better as the wood is more durable and does not split as easily, etc. The branches, fallen before felling, are collected by people from the surrounding areas for fuelwood. These collecting activities have to be done very carefully in order to avoid disturbance of the plantation and the surroundings.

The annual production of teak logs and fuelwood is relatively constant, around 800,000 m³ and 200,000 m³ respectively (Perum Perhutani, 1993). This production originates both from final fellings in mature stands and from thinning areas. The area of felled mature stands is about 5,000 ha, with an average of 100 m³/ha and a mean annual increment of 1.25 m³/ha/year over rotations varying from 40-80 years (Davis, 1989). These figures are considered very low. According to Purwowidodo (1991) the teak increments range from 4-6 m³/ha/year. But in some cases due to the local conditions, these figures can not be reached. According to FAO (1981) the mean annual increment of teak in Java is about 2 m³/ha/year. This is the most agreeable value rather than the other values mentioned above. Since thinnings happen each five year up to 30 year old, and later on every 10 years up to mature stands of 80 year, the thinning frequency is 10. So yearly some 100,000 ha are thinned.

3.2.5. Regeneration

Regeneration of teak could be done either in a natural or in an artificial way. In Indonesia natural regeneration of teak was applied up to the end of 19th century (Departemen Kehutanan, 1986). Natural regeneration under a dense canopy of trees, bushes or herbs is not possible (Kramer, 1932). Nevertheless, natural regeneration could be stimulated (Spaan, 1912) :

1. Girdling the old stand should be done when the trees are left; so the seed will be smothered by the falling leaves.

2. When a thick layer of dry leaves is lying on the ground, it must be burnt as it is difficult for seeds to germinate in this layer. Burning has to be done at the end of the east monsoon, i.e. in August or September, to protect the soil against insolation as long as possible.
3. Felling should be done in long narrow strips, so that the trees of the old stand, bordering the felling area, may contribute to regeneration.

According to Joesoef (1982), there are three important steps of teak artificial regeneration development in Indonesia :

1. till 1880 regeneration was conducted by planting teak seeds or by sowing the seeds on former felling fields;
2. from 1880-1907 the intercropping system was developed; the tumpangsari system was carried out for the first time by Buurman in the Pekalongan area (1883);
3. 1907 up to now, the tumpangsari system is combined with kemlandingan (the *Leucaena leucocephala*) as catch-crop in intercropping areas.

It is obvious that natural regeneration of teak gives relatively slow growth (Perum Perhutani, 1993). Moreover it seems that, at least an economical and technical point of view, natural regeneration is also less favorable than artificial regeneration.

By natural regeneration, germination has several difficulties due to the teak seed characteristics. As mentioned by Kramer (1935) teak is a light-demanding species, and so natural regeneration under bushes or herbs is not to be expected. Artificial regeneration, in combination with the tumpangsari system, produces better results in terms of standing stock volume and better quality of stems. The method also creates employment for the local people (Kartasubrata, 1992; Sumitro, 1992).

Considering that teak plantations in Indonesia mostly occur in densely populated areas, artificial regeneration has been tried out to increase job opportunity for people of the surrounding teak plantations. Clear fellings with artificial regeneration are still applied.

However it is important to note that natural regeneration systems prevent soil deterioration, as there is less soil treatment than with artificial regeneration.

3.2.6. Problems and constraints in relation with teak forest management

Teak forest management is often faced with several problems and constraints, mostly related to pests and diseases, site suitability, population pressure etc.

Pests and diseases

Several pests and diseases have already been observed in teak plantations (table 3).

Table 3 : Pests and diseases in teak plantations of Indonesia.*

Pests	Diseases	Symptoms
<i>Neotermes tectonae</i>		stem damage
<i>Lepidiota stigma</i>		root damage
<i>Hyblaea parea</i>		defoliation
<i>Pyralusta machoeralis</i>		leaf-destruction
<i>Xyleborus destruens</i>		stem damage
<i>Duomitus ceramicus</i>		stem damage
<i>Monohamus rusticator</i>		stem damage
<i>Valanga nigricornis</i>		leaf-destruction
<i>Phases damar</i>		stem damage
<i>Xyleborus destruens</i>		leaf-destruction
	<i>Pseudomonas solanaceae</i>	withering of the young trees

* Compilation of data from Suratmo (1989), Hardi and Intari (1990).

Destruction by pests are relatively higher than diseases. Nevertheless if control is done properly, its impact can be kept low.

Among others pests, the *Neotermes tectonae* gives a serious problem in teak plantations. It is a flying termite laying eggs in little cracks in the stem. Hardi and Intari (1990) point out that this termite starts to attack 3 year old plantations, but the symptoms are only recognized on 6 year old plantations. The damage can easily be observed from outside. It is indicated by a swollen stem and results in low wood quality or stem break by wind. At the first sign of attack, the tree concerned should be felled and burnt because no effective insecticide has yet been found. This measure leaves open space for a rather long time, before the crowns of the surrounding trees close together (Perum Perhutani, 1993).

Others, like the *Lepidiota stigma* destroy the rooting system in young plantations (1-2 year old). These population increases during the rainy season. Unlike the *Hyblea parea*, the *Pyralusta machoeralis*, the *Xyleborus destruens* and others which do not explode so often. Up to now the causes of their explosion are not yet known. There is a trend that during the rainy season, pests will explode easily (Suratmo, 1989).

It appears that a good maintenance of the plantations is the best way to prevent pests and diseases. Therefore, diversification of the ecosystem by a combination of agricultural crops with tree species could be done. This way the diversity and stability of the ecosystem increases, certainly in comparison with monoculture systems. But also humidity, light intensity, microclimate, etc. have to be managed by silvicultural treatments like thinning, pruning, or spacing between trees. Ultimately it creates an environment which is unfavorable for development of pests and diseases.

Research concerning the most appropriate silvicultural system in relation with the appearance of pests and diseases is very urgent.

3.2.7. Population pressure

Increasing population provokes some problems in teak plantation forests. The Perum Perhutani efforts to expand the existing teak forests, but people of the areas surrounding the forests need land either for settlement, agricultural activities, production of firewood, etc. It leads to illegal cuttings and destruction of teak plantation for staple food planting (such as : maize, rice etc.), grazing, etc.

4. FOREST POLICY TOWARDS SUSTAINABLE MANAGEMENT OF TEAK FORESTS

4.1. Sustainable management of teak forests

Forest products are very important for Indonesia. After oil and gas they provide most of the necessary revenues for its development. Beside that, Indonesia's forests do also play an important ecological role, e.g. as habitat for flora and fauna. Therefore the forests should be used on a sustainable basis.

Teak forest plantations, as well as other forest plantations, are very valuable. They both fulfil productive and protective roles. The former relates to wood and non-wood products which are necessary either for domestic or export uses. Up to now, by applying the above silvicultural system, the sustainability of teak production could be maintained. However, the question must be put how long the site potential can be kept intact. The latter relates to environmental issues, e.g. soil protection. Forest plantations have to be managed in such a way, that they help to stabilize and to improve the environment. This should be realized by a proper planned plantation system.

ITTO (1993) states that conservation of local plant and animal species and of ecosystems and ensuring an ecological stability at the landscape level require complementary actions within integrated land-use and development plans. The protective role of teak forests can be fulfilled considerably, as teak is one of local tree species. Teak forests are the habitat of some local animal species and its cover protects the soil against erosion.

Challenge of the existence of teak forests is caused by population pressure. It increases the need for land for agriculture, settlement, woods, etc., leading to environmental degradation as well as depletion of the natural forest. Planned forest plantation is expected to ensure the maintenance of natural forests as well as sustainable wood production. These forest plantation plans have to be synchronized within integrated landuse and development plans. By doing so, sustainable teak forest management is expected to be achieved.

According to ITTO (1991) guidelines, sustainable forest management is the process of managing permanent forest land to achieve one or more clearly specified objectives of management with regard to the production of a continuous flow of desired forest products or services without undue reduction of its inherent value and future productivity, and without undue undesirable effect of the physical or social environment.

Concerning the teak forest on Java, its management could be judged as relatively sustainable. True, Sumitro (1992) point outs that in Java there were reductions in value and productivity of teak forests, but there were also counter actions to balance them. And next to the undesirable effects, there were also compensating actions, which might not be always in the same forms and/or quality. This statement can be achieved when we accept the dynamics of the process. So that finally it could be stated that teak management is relatively sustainable. This opinion is also supported by the statement of Earth Summit (UNCED, 1992) and Principle ITTO Guideline (1993).

In the Basic element 6 (UNCED, 1992) it is clearly stated that a broad spectrum of forest management objectives should meet the need of the people for energy, industrial raw material which should be promoted and recognized. In the management of teak forest it is easy to find statistics, indicating the continuous contribution of the teak forests to the government revenues, local employment and industry. There are also many activities to overcome the undesirable effects resulting from forest utilization (terracing, agrosilviculture, social forestry, etc.). The extent and the distribution of the stands are also reported (Sumitro, 1992). According to Departemen Kehutanan (1986), until the year 1900 the extent of natural teak forest was some 650, 000 ha and in 1929 due to plantation activities, the total teak areas increased to 785, 000 ha. Up to the end of 1989 it is reported to be more than 1 million ha. Therefore the forest extent and the distribution are still sustainable, provided the stands can be in different form and quality, but not necessary of lower productivity and poorer quality.

Owing to the local condition of people of the areas surrounding the teak plantations, the success of the sustainable teak forest management will depend mostly on the success of the tumpangsari system and on employment approaches for the local people. This is conform with the Principle 2 of the ITTO Guidelines for the establishment and sustainable management of planned tropical forests states, namely that provisions for the establishment and sustainable management of planted forests must be considered in the context of an integrated land-use plan for national economic and social development. Thus, planted forests should normally only be established on lands which are known to be capable of supporting all aspects of their long-term management and utilization without land degradation. The creation of plantations must be balanced with the needs for protection of the site and the environment, the conservation of biological diversity of all types, the needs and aspirations of the people present and the potential demands of future generations (ITTO, 1993). It is realized that wet tropical regions, such as Indonesia, have very strong rain erosivity. Hence on certain areas, due to their specific conditions, soil and landscape protection has to be done, otherwise the ecosystems will deteriorate. With respect to the conversion of biological diversity, flora and fauna species have to be inventarized and interesting areas have to be protected.

In the teak plantation development, the aspirations of the people surrounding forests have to be taken into consideration in the maintenance and the development of the teak forests. Silvicultural systems should be created to accommodate the people's aspirations and to involve the people in the management of teak forest plantations. All these aspects have to be considered in forest policies. Therefore law enforcement by the National Government is necessary.

4.2. Forest policy on the management of teak forests

Aware that tropical forests have an important role, the Government of Indonesia c.q. Ministry of Forestry always tries to improve the policy to conserve the tropical forests in Indonesia as well as possible. Teak forest plantations in Java, for example, are tried to be managed on a sustainable basis.

Teak forest management has been introduced more than 100 years ago. The purpose was to replace successively indigenous teak forests by more productive stands (Departemen Kehutanan, 1986). Nowadays, not only the management of teak forests is more intensive but also the region of teak plantations forests is more extended. This way, it is intended to prevent environmental degradation and to maintain teak wood production on a sustainable basis.

The management of state production forests in Java is entrusted to the Perum Perhutani. On the other hand the other forests, namely protection forest and nature conservation forests, are under the jurisdiction of the Directorate General of Nature Reserve and Forest Protection.

The Perum Perhutani is charged with all kind of activities, starting from the establishment of forest plantations, to the protection, exploitation, product processing and its marketing. Due to the specific problems in Java, especially concerning population pressure, the philosophy of Perum Perhutani in managing Java forests, aims at :

1. pursuing maximum utilization of forest land;
2. sustaining the forest resources and environment;
3. increasing the welfare of the population, especially those people living in and nearby the forests.

To support sustainability, a well determined planning has been made for teak forest plantations as well as other forest plantations. Herewith a distinction has been made between the general plan, the long and short term plans and the annual technical plan.

The general plan (Rencana Umum Perum Perhutani) is made at the level of the Directors (President Director, Director of Production, Director of Marketing and General Director) for a period of 20 years. It describes broad policies, strategies and goals for use of forest lands. These broad policies are expressed in the long term plan (Rencana Pengaturan Kelestarian Hutan) which outlines sustained yield regulations and relates to the management of forest concessions and other related industries. The broad policies of forest plantations, especially the teak forest plantations and their related regulations are prepared by the Planning Bureau under the head of the Perhutani unit. The follow up of the long term plans (Rencana Karya Lima Tahunan) is explained in the short term plans. These explain the state forest cooperation's objectives in more detail and defines the subdistricts and police districts that will be the target of different forestry programs during a 5 year period. This plan is produced by the Rayon personnel in consultation with personnel from the Planning Bureau. Finally, the annual technical plan (Rencana Tehnik Tahunan) is made every year by the Head of the District Forest Areas. It deals

with the planned field activities in their district area, such as planting, replacing, weeding, pruning, thinning, protecting, girdling and felling. Every year an evaluation report on the practiced management of the forests is made. All these plans aim at ensuring the sustainability of forest management. Nevertheless constraints always appear, mostly related to forest disturbances due to people living in surrounding forests.

Population pressure in Java is the main constraint of forest management. Specific reasons are the poor economical situation of the people surrounding the forest and the high degree of unemployment. Hence people tend to illegal exploitation of forest products, which ultimately causes forest deterioration. For these reasons, the Perum Perhutani tries to increase the welfare of people of the areas surrounding the teak forest plantations, through several planting systems. Two main planting systems are applied, namely :

a. Tumpangsari (taungya system)

The tumpangsari system has already been introduced for more than 100 years. However, the application of this system is nowadays more systematic and intensive. In this system, the people surrounding the forest (of which most are farmer) are allowed to grow food crops in teak plantations during a period of two up to five years. The Perum Perhutani also assists these forest farmers with food crop seeds, fertilizers and insecticides in order to increase the food production of the peasants.

b. Daily wage system

This system is applied in areas where the tumpangsari system cannot be applied due to the lack of peasants or to the poor soil conditions. In this system, people of the areas surrounding the teak forest plantations are involved in the plantation maintenance, like weeding, pruning, thinning, etc. They will receive a daily wage as a laborer in the plantations.

Tumpangsari system in Java has been developed for the first time in 1883 by the forest officer Buurman Van Vreeden on a teak plantation at Pekalongan. After that the method was used almost everywhere in Indonesia whereas natural regeneration was applied on a diminishing scale (Bruinsma, 1927). Presently the system is still used for more beneficial results to both the forests and the local people.

In this system people are able to work as farmer in the forest. Beside some financial support, they can keep the harvest of agricultural products. They should take enough care of the young trees and be aware that the forest soil cannot be considered as an agricultural soil. Attention should not only be paid to the food crops, but also to the forest. This cultivation system means an important social element for people of the areas surrounding the forest. It can be considered as an appropriate system in overcrowded areas where many people do not possess land. However attention to and intensive supervision of the farmer during the layout are necessary.

The application of the tumpangsari system corresponds to Principle 27 of the ITTO Guidelines (1993) for the establishment and sustainable management of planted tropical forest. Indeed this principle mentions that management of planted forests should implement a traditional multiple-use principle in order to produce multiple benefits.

5. DISCUSSION

Teak in Indonesia appears in Java, Bali, Nusa Tenggara and Sulawesi. Central and East Java are considered as the centra of teak forests. This is due to the fact that these regions have the most favorable environmental conditions, such as climate and soil for the teak forests.

According to the classification system of Schmidt and Ferguson (1951), Central and East Java mainly have climatic types C and D, while the Northern coast of East Java and Blambangan Peninsular mainly have E type. Those climatic types have distinct wet and dry seasons. In always wet places, such as West Java, teak grows too fast, resulting in lower wood quality, characterized by thick sapwood and thin and light color heartwood (Perum Perhutani, 1993). Distinct wet and dry seasons provide better quality of wood in terms of color, hardness, etc. Therefore Central and East Java are the best places for teak plantations.

Naturally teak grows on lime and marl soils. So teak forests in these regions are mostly concentrated on soils developed on limestone and marly parent material. But it has been found that the composition of the soil (limestone or marly parent material) is not the most important soil characteristic for teak. Indeed the most determinating parameters are obviously soil texture, permeability, drainage, soil depth and fertility. Medium soil texture, good permeability and good drainage and, at least, medium soil depth seem to be the most favorable soil characteristic for teak forests. Teak also need relatively fertile soils.

Due to the above mentioned site requirements teak forests do not only appear on limestone or marly soils, but could also grow on other types of soils, provided suitable soil physical characteristics are present. If needed, chemical characteristics could be improved with fertilizers. It explains why teak forests in Indonesia are also extended on other soil types such as volcanic soils, alluvial soils, etc.

Population pressure is likely to be the most important problem in Indonesia, especially in Java. With only 7 % of the total land area, Java contains more than 107 million of people or 60 % of the total population. Pressure of the population on the forest of Java, including the teak forests, occurred since a long time, as people need land either for agriculture, grazing or settlement. Illegal forest conversions into other land-uses, without proper soil management, lead in these regions to erosion and degradation of watersheds. To solve and to avoid those problems, efforts have been made by government through several policies such, as :

1. family planning to decrease the population growth;
2. transmigration to move poor farmers from Java to the other less densely populated islands in order to improve their prosperity by activating agriculture. This way, not only the pressure on Java's forest decreased, but also the centra for the further development of outer islands were established.
3. programs for people, surrounding forests, involve them in forest maintenance and production, such as the tumpangsari system, the daily wage system, etc.

The tumpangsari system allows people of the areas surrounding the forests to perform agricultural activities in the forest at the early stage of the teak forest development. Beside their agricultural activities, farmer have to take care of the young forest trees. This system is considered to have an important social aspect for the people, because it gives the opportunity to the people to produce food stuffs to support their daily life. The system diminishes not only the poverty of the people but ultimately also the forest deterioration. Hence a positive interaction between the forest and the surrounding people is developed.

The Perum Perhutani applies a daily wage system to people of the areas surrounding the forest plantation for certain jobs in forest maintenance, such as weeding, pruning, thinning etc. This system provides additional income to the people and decreases also the population pressure on the forest.

Tumpangsari system in Indonesia is not only used in the teak plantations, but also in plantations of the *Pinus* sp., the *Agathis* sp., the *Altingia* sp., the *Swietenia* sp., etc. Herewith, beside agricultural crops, other tree species like the *Leucaena leucocephala*, the *Calliandra calothyrsus*, the *Gliricidia sepium*, etc. are used as inter-planting. Those green manuring crops are aimed to restrain the development of wild vegetation, to prevent surface run-off, etc. This system is especially favorable in overpopulated areas, like Java, where the people do not possess land. By using it, both ecological and socio-economical benefits can be achieved.

Diversification of plant species favors a more stable ecosystem. By this, destruction by pest and diseases can be avoided. Besides, in young teak plantations, several weeds like the *Imperata cylindrica*, the *Eupatorium* sp., etc. can be eliminated by agricultural activities.

The socio-economic advantages of this system are explained by the relatively low costs, because the tree-crop gets two years free maintenance, until it is large enough to survive weed-growth. Meanwhile people of the areas surrounding the forests are able to work as a plantation laborer/farmer in the forest, so that, beside harvest of agricultural products, they receive some financial support.

By applying tumpangsari system or other systems, in which people directly enjoy the benefits from the forest land, a sense of responsibility among the people is stimulated, leading towards a sustainable forest management.

In order to succeed, the collaboration of the local people is needed. Involvement in planning and establishment is necessary to motivate them for permanent cooperation and to increase their income and quality of life. Anyway the decision making system "bottom ---> up" is more appropriate than "up ---> bottom" system.

Government of Indonesia tries to manage teak forests on a sustainable basis by indirect policies, pursued on the national level, such as family planning and transmigration, and policies aimed directly at the teak forests, such as application of the tumpangsari and the

daily wage systems. It is expected that by working this way, the teak forests could be improved, both in quality and quantity.

Since there is still a population growth in Indonesia, the population pressure on the teak forests is still increasing. Therefore, forest management systems, which involve the surrounding people in forest development and maintenance should be improved and encouraged from time to time to increase the involvement of the people, without any destructive impact on the teak forests. Besides, timber harvesting area should be adjusted to the existing potential, so that destruction can be relatively minimized. A guideline concerning the sustainable management of teak forest should be developed. Researches supporting the guideline development are needed, especially concerning : impact of site preparation, regeneration, scale of cutting areas, importance of interplanting and its impact on the ecosystem, plantation systems, best rotation period, socio-economic influences, etc.

6. CONCLUSIONS

Teak forest products are very important for the development of Indonesia. Therefore intensification and extensification of those forests areas are necessary.

Teak is an indigenous species in Indonesia, distributed in Java, Bali, Nusa Tenggara and Sulawesi.

In former times it was believed that teak only grew on lime or marly soils. Later, it has been realized that the teak grows well in soils with medium texture, good permeability, good drainage and, at least, medium soil depth. The chemical factors can be managed by fertilizers application. Teak needs distinct wet and dry seasons.

Although the population density of Java island is very high, teak forests should be maintained on a sustainable basis by Governmental policies, which are indirectly and directly related to them. The former refers to transmigration and family planning, while the latter deals with silvicultural systems such as the tumpangsari and daily wage. Both systems are believed to have a positive social and economic impact on people of the areas surrounding the teak forests, as well as a positive ecological impact on the existing teak forests.

Forest management systems, which involve people of the areas surrounding the plantation, in forest maintenance, like the tumpangsari system, have to be adapted from time to time in order to anticipate on the increasing population pressure and to ensure the sustainability of forest and their wood production.

Some attention must be paid to the management of teak forest plantations, especially with respect to the principle of sustainable management and biodiversity. Research is still needed to improve the existing methods, in order to fulfil continuously the wide range of always changing human forest needs.

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