PN-ABG-843

BIOTROPICA 22(2): 114-118 1990

Decline of Teak Yield in Northern Thailand: Effects of Selective Logging on Forest Structure[1]

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ABSTRACT

Teak harvest in Northern Thailand in 1985 was only one-tenth that in 1971. The dramatic decrease has been attributed by some authors to loss of trees through shifting cultivation and intensification of modern agriculture. This study examined the possibility that previous removal of large trees during selective logging is also a reason for present low yields of teak. In a selectively logged mixed deciduous forest, most of the remaining teak was concentrated in diameter size classes less than 50 cm. In contrast, most of the teak stumps were larger than this diameter. The large trees had been removed by logging. Reduction of teak production in Thailand to the point where sustainable, profitable yield is no longer possible may have resulted from over-intensive harvest of large trees.

TEAK (*TECTONA GRANDIS* LINN.) IS ONE of the most valuable timber species in the world. It occurs naturally in tropical Asia, mainly between 12° and 25° N. latitude, and 75° and 104° E. longitude, in India, Burma, Laos, and Thailand (Kaosa-ard 1977).

Teak has been the most economically important forest species for Thailand. In 1985, teak exports produced 255,867,183 Baht (U.S. $10,034,007) in foreign currencies (Royal Forest Dept. 1985). However, teak production has been decreasing rapidly. Between 1971 and 1985, annual production fell from almost 300 m³ to less than 40 m³ (Table 1). Decreasing teak yields have been attributed in part to disappearance of the native forests in Northern Thailand due to clearing for shifting cultivation, and for intensive modern agriculture (Myers 1980, FAO 1982). The percentage of total area remaining in forest declined from 67.0 percent to 49.6 percent between 1973 and 1985, as determined from Landsat photographs (Table 2).

Although teak production decreased by 80 percent between 1973 and 1985, forested areas in Northern Thailand decreased by only 26 percent. This suggests that there may be other important factors besides deforestation for agriculture which contributed to the decline of teak production. One possibility is that the decrease has resulted from selective logging in the mixed deciduous forests where teak occurs. Selective logging could result in the elimination of much of the marketable teak, yet the change in the forest canopy might not be detectable by remote satellite imagery. The purpose of this study was to examine the possibility that declining teak production in Thailand has resulted in part from changes in structure and biomass in the forests, caused by selective logging of mature teak trees.

STUDY SITE

In Thailand, the natural habitat of teak is the mixed deciduous forest of the Northern and Central regions, although not all deciduous forests contain teak. Teak appears to grow best on the plateaus of mountainous areas up to about 1000 m above sea level (Loetsch 1957). The field work described here was done in a mature mixed deciduous forest with teak, about 40 km from Lampang, near the Lampang–Ngao highway, 18°35'N, 99°50'E. The area is in a high mountain valley (elevation 300–350 MSL). The site is close to the Pratupha Ranger Training Center of the Thai Army, and therefore probably little illegal logging had occurred. Any observed alteration of stand structure occurred through legal logging.

METHODS

The field study, carried out in September 1986, used the modified point-centered quarter method

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TABLE 1. *Teak harvest in Thailand from 1971 to 1985 (Royal Forest Department 1985).*

Year	Volume ($m^3 \times 10^3$) By license	Confiscated	Total
1971	132.7	166.1	298.8
1972	86.0	91.6	177.9
1973	165.9	28.2	194.1
1974	215.6	38.7	254.3
1975	144.0	72.2	216.2
1976	170.0	93.7	263.7
1977	112.2	25.8	138.0
1978	73.5	38.7	112.2
1979	146.6	32.9	179.5
1980	74.4	22.9	97.3
1981	65.8	7.5	73.3
1982	55.2	2.9	58.1
1983	54.8	3.3	58.1
1984	46.6	1.6	48.2
1985	36.6	2.6	39.2

(Cottam & Curtis 1956). Twenty points were located at 50 m intervals along a straight line transect through the forest. All trees larger than 4.5 cm DBH were measured and arranged into 5 cm DBH size classes. Data from 80 quarters were analyzed for mean distance between trees, average DBH, and absolute density per ha. Another transect with 25 points was run to determine the density and diameter of teak stumps remaining from a selective harvest of the forest.

Total biomass (stem, leaves, roots, branches) of trees in each size class was estimated from diameter measurements, with the use of allometric equations developed by Ogawa *et al.* (1967) in Northern Thailand in the same physiographic region as the study reported here. Stem volume of trees in each size class was estimated with the use of equations developed by Petmark and Sahunalu (1978) in a teak plantation near Lampang. Volume and biomass of teak previously harvested were estimated from diameter measurements at the top of remaining stumps. These had an average height of 94.8 cm.

The impact of selective harvesting was determined by comparing volume and biomass data of the existing forest with that of the forest before logging, as calculated from data on stumps.

RESULTS

Species composition of the forest is given in Table 3. Structure of the forest is given in Table 4. Data from the stump survey are also included in Table

TABLE 2. *Forest cover as a proportion of total area of northern Thailand, from 1973 to 1985. Total area of northern Thailand is 169,644 km².*

Year	Forested area (km^2)	Percent of total area under forest cover	Area deforested during interval (km^2)
1973[a]	113,595	67.0	—
1976[a]	102,327	60.3	11,268
1978[a]	94,937	56.0	7390
1982[a]	87,756	51.7	7181
1985[b]	84,126	49.6	3630

[a] Klankamsorn and Charuppat (1983).
[b] Royal Forest Department (1985).

4. Addition of data in "Total" column to that in "Stumps" column gives an approximation of what the structure was like before selective logging.

Teak is clearly the dominant species in terms of both density of individuals, and average diameter. A total of 303 teak trees were encountered. The 15–20 cm diameter size class contained 65 trees, more than any other size class. Number of individuals decreased with increasing size class above 20 cm, with the exception of a gap with no trees between 40 and 45 cm. Of the 303 teak trees, 266 (87.8%) were in size classes less than 40 cm. There were no other species with diameters greater than 25 cm.

Minimum diameter for teak harvest is 60 cm (Forest Industry Organization 1985). Selective harvest of teak reduced volume of trees greater than 60 cm from 100.7 m^3/ha to 9.5 m^3/ha. Total biomass of these trees was reduced from 155.35 *t*/ha to 14.46 *t*/ha.

Inclusion of values predicted from stump mea-

TABLE 3. *Species composition in a mature mixed deciduous forest with teak, Lampang, Northern Thailand.*

Species	Density (no./ha)	Percent of total no.
Tectona grandis Linn.	303	70.0
Xylia kerrii Craib & Hutch.	44	10.2
Careya arborea Roxb.	22	5.1
Diospyros mollis Griff.	16	3.7
Nauclea orientalis Linn.	16	3.7
Terminalia belerica Roxb.	16	3.7
Lagerstroemia sp.	11	2.5
Schleichera oleosa Merr.	5	1.1

TABLE 4. *Structural characteristics of mixed deciduous forest with teak, Lampang, Northern Thailand.*

Size class (DBH, cm)	Density (no./ha)			Stem volume (m^3/ha)			Total tree biomass (t/ha)		
	Teak	Total	Stumps	Teak	Total	Stumps[a]	Teak	Total	Stumps[a]
10–15	54	141	—	2.7	14.1	—	4.86	17.13	—
15–20	65	103	—	7.8	23.7	—	10.04	30.32	—
20–25	49	54	—	9.8	23.2	—	13.09	30.94	—
25–30	49	49	—	16.7	16.7	—	22.72	22.72	—
30–35	33	33	—	15.8	15.8	—	22.14	22.14	—
35–40	16	16	5	10.2	10.2	3.2	14.52	14.52	4.54
40–45	0	0	5	0	0	4.3	0	0	5.85
45–50	16	16	—	15.7	15.7	—	22.72	22.72	0
50–55	11	11	17	14.5	14.5	22.5	21.63	21.63	33.43
55–60	5	5	22	8.7	8.7	38.3	13.07	13.07	57.51
60–65	5	5	12	9.5	9.5	22.8	14.46	14.46	34.71
65–70	0	0	11	0	0	24.6	0	0	37.84
70–75	0	0	17	0	0	43.8	0	0	68.34
Total	303	433	89	111.4	152.1	159.5	159.25	209.65	242.22

[a] Volume and biomass of harvested trees are calculated from regressions using top diameter of stump as an approximation of DBH.

surements dramatically changes distribution of volume and biomass. Largest values are shifted to the largest diameter classes.

DISCUSSION

ECOLOGY.—Species composition of the forest conforms to the community type described by Smitinand (undated) as moist deciduous forest of Thailand. This community includes *Tectona grandis*, *Xylia kerrii* and 10 other species as the upper story; and *Terminalia belerica*, *Diospyros mollis*, *Careya arborea*, and 21 other species as the understory.

A comparison of our site with other forest types in Southeast Asia (Table 5) shows that at the time of the study, our mixed deciduous forest with teak had a lower biomass than moist or rain forests, but higher than savanna forests. However, calculations based on diameter of remaining stumps suggest that the biomass of the forest at our site before large teak was removed may have had a value higher than any other cited in Table 5. Total biomass (452 *t*/ha) was calculated as the sum of present total tree biomass (209.6 *t*/ha) plus estimated biomass of harvested teak trees based on stump measurements (242.2 *t*/ha) (Table 4). This may be a slight overestimate, because smaller trees may have recently increased their biomass as a result of the harvest of the larger teak.

Assuming this error is negligible, teak constituted approximately 89 percent of the biomass in the original forest. This value is much higher than that given for many of Thailand's teak forests (Myers 1980). Mature teak is a large tree, and the high proportion of old teak at our site resulted in a forest with high biomass and volume.

YIELD.—For teak to be marketable, it must have a minimum diameter of 60 cm, according to a 1978 rule of the Royal Forest Department of Thailand (Forest Industry Organization 1985). In the study site reported here, only five trees per ha qualify for harvest under this limitation. Most of the teak is in the smaller size classes. The data projected from stumps suggests that past logging has removed most of the marketable trees.

The lack of trees in the 40–45 cm diameter class of the existing forest may have resulted from an intensive logging operation at the site about 25 years ago. This operation could have damaged small seedlings that would be in this size class today. After logging ceased, reproduction began again, as evidenced by individuals in smaller size classes. Although there are stumps in the 40–45 cm diameter class, they might have grown out of this class, had they not been harvested.

The low number of large trees at the site indicates that the intensity of selective logging has been greater than can be sustained by the natural productivity of the forest. Logging must be abandoned until trees in smaller diameter classes grow to marketable size.

The annual DBH increment of teak in the study site was calculated to average 1.61 cm (Gajaseni 1988). If cutting in the forest stops completely, and remaining trees continue to grow at this rate, it will

TABLE 5. *Dry weight biomass of selected tropical forests.*

Forest and locality	Biomass (t/ha) Aboveground	Belowground	Author
Tropical rain (Thailand)	367.4	32.0	Ogawa *et al.* 1967
Evergreen seasonal (Kampuchea)	322.4	32.0	Hozumi *et al.* 1969
Dry monsoon (Thailand)	267.7	25.0	Ogawa *et al.* 1967
Monsoon-savanna (Thailand)	143.9	16.0	Ogawa *et al.* 1967
Dipterocarp savanna (Thailand)	69.7	10.0	Ogawa *et al.* 1967
Mixed deciduous with teak[a]	188.5	21.1	This study
Mixed deciduous with teak[b]	398.9	53.1	This study

[a] After selective logging.
[b] Before selective logging, based on stumps.

take 14.25 years for those trees in the 35–40 cm diameter class and above to reach marketable size. At that time, harvesting could be resumed, but a lower rate than presently employed would be required in order to sustain the yield.

Increasing world demand for teak has pushed up the price from U.S. \$155/m^3 in 1981 to \$221/m^3 in 1985 (Forest Industry Organization 1985). There is no reason to suspect that prices will not increase further in the future, as economic demand increases. Thus it behooves the managers of teak forests to gauge more carefully the rate of harvest, so that this valuable resource will not become depleted.

Overintensive planned harvests are not the only cause of teak depletion. Between 1984 and 1985, confiscation of illegally harvested teak increased again, after a previous decrease (Table 1). Illegal harvests also must be reduced.

There are other explanations besides legal and illegal selective harvests that might be suggested as causing the decline in teak yield shown in Table 1. One possibility is that the harvest effort has declined. This is unlikely, because the increase in price for teak would be expected to increase rather than decrease effort.

Another explanation could be that the teak remaining after harvest was of low quality. Howard (1948) points out "A great many of the trees are inclined to be very crooked, and the stems are often twisted and fluted, making the conversion difficult and costly. The best quality is considered to be that from Moulmein. Perhaps the Rangoon timber is slightly more crooked in the heart, while that from Bangkok is found to contain more bee-holes." However the data in Table 4 shows that *all* the trees in the largest size classes were taken, suggesting that size of tree was more important than shape or condition. The most probable reason that teak production in Thailand no longer appears sustainable at previous rates of cutting seems to be overintensive harvest of large trees.

ACKNOWLEDGMENTS

Field work carried out in conjunction with a study sponsored by the U.S. Agency for International Development, Grant No. DPE-5542-G-SS-8005-00.

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