Potential of Commercial Fast-growing Tree Plantations in Thailand

เอกสารหมายเลข 3
(เอกสารอ้างอิง)

Potential of Commercial Fast-growing Tree Plantations In Thailand

เอกสารประกอบการสัมมนา

"ป่าเศรษฐกิจ : จริง หรือ ฝัน"

วันที่ 23 กุมภาพันธ์ 2532

ห้อง เพลินจิต โรงแรมอิมพีเรียล ถนนวิทยุ

สถาบันวิจัยเพื่อการพัฒนาประเทศไทย

POTENTIAL OF COMMERCIAL FAST-GROWING TREE PLANTATIONS IN THAILAND

MANAGEMENT OF NATURAL RESOURCES PROJECT

FEBRUARY 1989

RESEARCH TEAM

Project Director	Dr. Dhira Phantumvanit
Principal Investigator and Project Coordinator	Dr. Ruangdej Srivardhana
Co-principal Investigators	Dr. Bunvong Thaiutsa
	Dr. Chaipan Pongtanakorn
	Ms. Jerapan Jirananda
Research Associates	Khunying Suthawan Sathirathai
	Ms. Sirima Suwanwat
	Mr. Songpol Jetanavanich

ACKNOWLEDGEMENTS

This research was conducted as part of the Management of Natural Resources Project (MNRP) funded by the Canadian International Development Agency (CIDA). Under MNRP, a steering committee was established to supervise all its activities. The authors are grateful to members of this committee for their support. The following individuals, in particular, are instrumental in directing the operations of MNRP :

Mr. Pravit Ruyabhorn	Secretary-General, National Environment Board
Khun Sunthad Somchevita	Deputy Secretary-General, National Environment Board
Ms. Usa Kiatchaipipat	National Environment Board
Khun Kosit Panpiemras	Deputy Secretary-General, National Economic and Social Development Board
Khun Kirasak Chancharaswat	Director, Natural Resources Development Coordination Division, National Economic and Social Development Board
Ms. Rosalind Coleman	Counsellor, CIDA
Mr. David Yasui	First Secretary, CIDA
Mr. Jim Stanley	Consultant, CIDA

For typing the numerous versions of the manuscript and for general administration assistance, the authors are thankful to Ms. Chuchitt Sombunthawong and Ms. Kwancheevit Pinyakul.

CONTENTS

Page

LIST OF TABLES

Potential of Commercial Fast Growing Tree Plantations in Thailand

1. RATIONALE

1.1 Background

The fact that deforestation in Thailand has been severe is well known. To illustrate the situation, data in Table 1 present the forest status of Thailand at different times from 1961 to 1985.[1/] It is clear from the figures that deforestation has taken place quite rapidly all over Thailand but the rates differ among the five regions of the country, with the Northeast the most critical region. Deforestation takes place as a result of complex human activities, but only four major causes are indicated here

----

1/ The latest figures which can be confirmed are derived from remote sensing analysis conducted in 1985. Current estimation of forest land is incomplete pending the on-going assessment of the Royal Forest Department.

Table 1 Natural Forest Areas in Various Regions of Thailand, 1961, 1973, 1976, 1978, 1982 and 1985

(rai)

Region	Total Land Area	Natural Forest Area 1961	1973	1976	1978	1982	1985
North	106,027,680	72,671,875	70,996,875	63,954,375	59,335,625	54,847,500	52,578,750
		(68.54)	(66.96)	(60.32)	(55.96)	(51.73)	(49.59)
East	22,814,063	13,226,875	9,397,500	7,894,375	6,898,125	5,000,000	4,993,750
		(57.98)	(41.19)	(34.60)	(30.24)	(21.92)	(21.89)
North-East	105,533,958	44,315,000	31,669,375	25,933,750	19,513,125	16,178,750	15,140,000
		(41.99)	(30.01)	(24.57)	(18.49)	(15.33)	(14.35)
Central	42,124,189	22,287,812	14,981,250	13,641,250	12,766,250	11,572,500	10,767,500
		(52.91)	(35.56)	(32.38)	(30.31)	(24.47)	(25.56)
South	44,196,992	18,516,250	11,521,875	12,586,875	11,001,875	10,276,250	9,678,125
		(41.89)	(26.07)	(28.48)	(24.89)	(23.25)	(21.90)
Whole Country	**320,696,882**	**171,017,812**	**138,566,875**	**124,010,625**	**109,515,000**	**97,875,000**	**93,158,125**
		(53.33)	**(43.21)**	**(38.67)**	**(34.15)**	**(30.52)**	**(29.05)**

Notes: All data were derived from LANDSAT except for the 1961 data which came from aerial survey.
Values in parentheses are percentages of the total land area in each region.

Source: RFD, 1985a, p. 20-24.

They are:

(i) Rapid population growth;

(ii) Traditional and unproductive agricultural production techniques;

(iii) Illegal logging; and

(iv) Destruction of forest by hilltribes.

Rapid population growth has expanded the Thai population from 18 million in the early 1960s to approximately 54 million today, a triple increase within less than three decades. This increasing population requires more agricultural land to produce food and fuelwood for energy consumption and historically, both agricultural lands and fuelwood have been obtained through the destruction of forests.

The second cause of deforestation in Thailand is the dependence of the poor rural sector on traditional agricultural production practices. The majority of Thai farmers depend upon traditional ways of production with minimal application of modern technology. Overall agricultural production in Thailand is extensive rather than intensive and has been possible only through agricultural land expansion. In fact, yield per rai in Thailand is much lower than the regional average. For rice, the average yield in Thailand in 1986 was 1,916 kg/ha compared with 3,125 kg/ha for Burma, 3,979 for Indonesia, 2,694 for the Philippines, 2,884 for Malaysia, and 6,303 for the Republic of Korea.

The expansive nature of Thailand's agricultural production is confirmed by the land-man ratio which is defined as the "ratio" of agricultural land over agricultural population. In 1964, 1971, 1978 and 1983 the ratios were 3.12, 3.48, 3.74, and 3.70, respectively. Historically, increased agricultural land in Thailand was made possible only through the conversion of forest land. Table 2 illustrates, for example, that during the period 1980-1984, about 8.7 million rai of forest land was cleared; out of this, 6.8 million rai was turned into agricultural land. It is obvious that, as long as Thai farmers rely on traditional agricultural practices, the pressure on our forests will continue.

Table 2 Trends in the Use of Agricultural Land

	1960		1975		1980		1984	
	1,000 rai	%	1,000 rai	%	1,000 rai	%	1,000 rai	%
Total Cultivated Land	62,980	19.6	112,211	35.0	119,000	37.1	125,757	39.2
Rice	37,106	58.9	71,239	63.5	73,563	61.8	74,913	59.6
Upland crops	7,449	11.8	19,953	17.8	25,758	21.7	29,169	23.2
Tree crops[a]	9,739	15.5	10,413	9.3	11,142	9.4	12,378	9.8
Perennial crops	8,686	13.8	10,606	9.4	8,537	7.1	9,297	7.4
Forest Land	187,526	58.5	130,762	40.8	103,419	32.3	94,696	29.5
Others[b]	70,192	21.9	77,725	24.2	98,279	30.7	100,245	31.3
Whole Country	320,698	100	320,698	100	320,698	100	320,698	100

Notes: a. Including para rubber, oil palm, and horticulture
b. Including grazing land

Source: Agricultural Statistics of Thailand, Crop Years 1960, 1975, and 1984, Center for Agricultural Statistics, Office of Agricultural Economics.

Illegal logging as a result of the requirement for agricultural land or due to unscrupulous timber operations, is the third important cause of deforestation. It is obvious among forest professionals that illegal logging plays a major role in reducing forest cover. In Thailand, which has been relying on selective cutting practices, indiscriminate cutting on concessional plots and on nearby areas can be considered as another illegal logging operation which magnifies the deforestation problem.

The last cause of deforestation is the destruction of forests, particularly in headwater areas, by hilltribes who presently number approximately 500,000 (TDRI, 1986). It is estimated that each year between 250,000 and 312,000 rai of prime watershed forest is lost due to shifting cultivation, still being practised on the hills. Moreover, the prevailing high hilltribe population growth rate of 2.5% per annum indicates that this practice will continue to be a prime cause of future forest destruction.

Despite all efforts, the government has only reached about 250,000 hilltribe people, the rest roam at will. The mobile nature of these people, migrating back and forth across the Thai and neighboring borders, has made attempts to regulate their shifting cultivation practices infeasible. In fact, reliable information on the exact size of their population, race, and migratory patterns is still not available.

1.1.1 Deforestation in Perspective

Clearing of forest can bring both benefits and adverse effects to the society. It cannot be denied that, historically, forest land has greatly contributed to the economic development and livelihood of the Thai people. Forest products, until recently, constituted a high percentage of the country's export share. Up to 90% of the energy required by the rural sector came from forest fuelwood and, in the past, the Thai people were able to use quality wood at relatively low price without interruption in supply. It is also the land reclaimed from the forest that has sustained the 4-5% growth rate in the Thai agricultural sector up to the present time; and it is this reclaimed land which accommodates an increasing number of Thai farmers.

Excessive use of the forest, as shown in Table 1, gives another dimmer picture, however. In 1985, with only 29.05% of Thailand's total land area still covered with natural forest, the Thai people felt the impact of losing their forests. Thailand, having once been a wood exporting country, now has become a net wood importing country, imports more than 2,000 million baht worth of wood and wood-related products annually.

From an environmental perspective, massive deforestation, as still being practiced, creates damage to the society at large. Soil erosion, which undermines both on-site and off-site soil fertility, is a result of deforestation. Deforestation, as taking place in the watershed areas of the North (Ping, Wang, Yom and Nan watersheds) has changed the river flow patterns and, hence, adversely affects agriculture downstream. The conversion of about 17 million rai of land in northeast Thailand to saline soil between 1960 and the present time can be attributed to excessive deforestation in that region. Also, flash flooding and mud slide which took place and cost more than 370 lives and 6 billion Baht in property damage in southern Thailand recently were caused by excessive forest clearing.

At present, there is nothing to reassure us that the existing 29% of natural forest-covered land will be preserved. On the contrary, many factors seem to suggest that, in the future, the forest area will continue to shrink. Even though the overall population growth rate has declined to approximately 1.5% per annum, Thailand already has a large population base. Almost one million people will be added to this base annually and they require additional land for living. If the Thai population is unable to change from traditional to more productive ways of agricultural production -- it is certain that more forest land will be converted to agricultural land. Hilltribes will likely continue to add to the destruction of watershed areas and aggravate the deforestation situation. It is probable that the natural forest area will continue to decline, placing greater stress on natural ecosystems.

1.1.2 National Forest Policy

On paper, the Government has always recognized the importance of Thailand's forests. In the 1960s, it was proclaimed that 50% of the nation's total land would be put under forest reserves. The forest-covered area has dwindled through time, however, and the target was altered to the lower figure of 40% in the 1970s. In 1985, with only about 29.05% of the country's total land area still covered with natural forest, "National Forest Policy" was set in December, with the same target, 40% forest land. Indeed, the nation's forest experts believe that this amount of forest area is sufficient to meet the wood and forest product requirements of the country. This percentage is further broken down into two kinds of forest areas: conservation forest (15%) and economic forest (25%). Conservation forest areas include watershed areas, national parks, wildlife sanctuaries. Economic forests are those areas which are mainly destined for private plantations. National Forest Policy, therefore, yields to deforestation and accepts the continuing reduction of natural forest (from 29.05% to 15%) This policy is quite realistic, however, because without effective measures to protect natural forests from continuing population expansion, more forest is expected to be encroached upon, nonetheless.

At present, about 31,505,000 rai of natural forest land has been proclaimed national parks, wildlife sanctuaries, and non-hunting areas. By law these areas are protected and subject to strict enforcement. It is still feasible to expand the territory of these protected areas to 48 million rai, or about the size of the 15% target set by the national forest policy.

National forest policy also spells out the role that economic forest should play. This completely changes long-established administrative practices which historically treated forest resources as social goods for which decisions were mostly made by public agencies. Following these long-established practices, the private sector has had a very limited role in the development of forest resources. What private enterprise has done in the past was to replant trees, after cutting, on concessional lands. These efforts were trivial compared to the overall amount of illegal cutting. Moreover there had been little incentive for private investors to reforest or make use of abandoned land. The concept of "economic forest" and the role of private enterprise in accelerating reforestation is, indeed, a new approach to the management of Thailand's national forest resources.

1.1.3 Reforestation: an Insurmountable Task

Although the national forest policy envisages an important private sector role in improving deteriorated forest resources, it also foresees difficulties in encouraging the private sector to invest. This is due to the nature of forest investment itself. The gestation period for forest investment is long. Forest plantation is subject to fire and other natural hazards; Also, waiting through a long gestation period, investors risk the perils of price fluctuation. As is indicated in Table 3, up to 1985 (which covers a period of about 70 years), the total accumulated reforested land was only 3,375,507 rai. This figure is about a half of one year's deforestation at its peak. In other words, it took 70 years to undo what it took only six months to do.

Table 3 **Reforestation by Government Agencies and Concessionaires', 1961-1985**

(rai)

	up to 1980	1981	1982	1983	1984	1985	Total
Afforestation in Forest Villages	1,002,644	94,713	56,281	56,094	56,450	66,330	1,332,422
Watershed Reforestation	394,625	87,250	48,750	46,925	56,575	63,300	697,425
Reforestation of Degraded Forests	375,706	89,781	30,600	30,100	32,575	48,200	606,962
Concessionaires' Reforestation	361,569	69,400	74,981	96,569	67,244	68,875	738,638
Total	**2,134,544**	**341,144**	**210,612**	**229,688**	**212,844**	**246,675**	**3,375,507**

Source: RFD, 1985a, p. 29.

The national forest policy's economic forest target is therefore ambitious. If the 1985 natural forest-covered area of 29.05% were to be maintained, reforestation on 10.95% of the country's total land would be required to meet the 40% national target. This amounts to 35 million rai. However, if the approximately 15 million rai of para-rubber tree and other replantation areas already in existence are deducted from 35 million rai, about 20 million rai is still left to be planted with "economic" trees. In the more likely case (in which the natural forest is expected to shrink to 15% of the nation's forested area) reforestation of 25% of the country's total area needs to be undertaken to meet the 40% forest land requirement. This would involve approximately 80 million rai. If 15 million rai under rubber and other commercial trees are deducted, approximately 65 million rai must still be reforested.

1.2 Objectives

With the background as specified in the foregoing section, the objectives of this study are : -

1. The identification of fast-growing tree species most appropriate for commercial plantation. Many fast-growing species grow well in Thailand's climate and soil. This study suggests the most suitable tree species to serve projected requirements in wood commodities.

2. An evaluation of the role of commercial fast-growing tree plantation in national forest policy. This study will also estimate the forest replantation areas necessary to meet the local demands plus potential export.

3. Incentive policy. Some wood commodities such as pulp have enjoyed protection privileges for a number of years, while others such as paper, have incurred burdens resulting from these protective measures. Furthermore, the burden is passed to consumers who pay higher prices for wood products. Tax measures, while benefiting some local wood industries, create undesirable effects to others and to consumers at large. The study on the tax policy for the pulp industry is an attempt to develop an

appropriate policy to induce more investment in the local wood-related industry which may lead to the expansion of commercial reforestation area.

1.3 Scope of the Study

This research focuses on "economic forest". As stated earlier, the critical issue here is the monumental task of reforestation. Indeed, to meet the national policy objective, between 20 to 80 million rai of the country's total land must be reforested and maintained.

To encourage continuous and permanent reforestation so that the required percentage of land will always be covered with forest, there must be a continuous and sufficient demand for output from reforested areas. Priority thus is given to serving the demands from wood industries
which use the wood of fast-growing trees as raw material.

1.3.1 Definition of Fast-Growing Tree

Fast-growing plantation is defined by Jaakko Poyry Oy (1987) as "a plantation with a mean annual increment exceeding 12-15 m^3/ha/yr., measured under bark and grown on short rotation." Forest trees can be divided on the basis of growth rate into five groups as follows:

1. Very fast-growing tree, a tree having an annual increment of girth at breast height (gbh) of over 5 cm;
2. Fast-growing tree, a tree having an annual gbh increment between 4-5 cm;

3. Normal-growing tree, a tree having an annual gbh increment between 2.5-4 cm;

4. Rather-slow-growing tree, a tree having an annual gbh increment between 1-2.5 cm; and

5. Slow-growing tree, a tree having an annual gbh increment below 1 cm.

Based on these criteria, Corvanich (1982) identified trees having 100-cm gbh in less than 10 years of age as very fast-growing trees, while those reaching the same size of gbh in 15, 20, 25, and 30 years were classified as fast-growing, normal-growing, rather-slow-growing and slow-growing trees, respectively.

However, aside from growth rate, fast-growing criteria may vary with planting site, wood utilization objectives, and rotation length as well. A given tree can be considered fast growing only at a particular planting site for a certain purpose. Teak, for example, may be considered a very-fast-growing tree if it is planted on deep, well-drained soils derived from limestone. But it definitely is slow-growing from the wood utilization and rotation-length standpoints.

Rotation is the planned number of years between planting and felling, i.e., the period of time a tree is allowed to grow. It is an important tool in controlling tree size--the longer the rotation the larger the tree. But rotation length also markedly affects yield, profitability, and end-use products.

For industrial plantation applications, though the species chosen must yield a marketable commodity at a competitive price, almost all plantation development involves long-term investment which increases the burden of interest charges. Hence, short rotation is the most important factor.

Thus, it can be concluded that "a fast-growing tree for industrial use" is defined in this paper "as a tree having a rotation length of not more than seven years."

Fast-growing trees selected for consideration in this study are : -

	Latin Name	Common Name
1.	Eucalyptus camaldulensis	Eucalyptus
2.	Leucaena leucocephala	Kratin Yak
3.	Azadirachta indica	Sadao
4.	Casuarina equisetifolia	Son Talae
5.	Rhizophora mucronata	Kong Kang
6.	Casuarina junghuhniana	Son Pradipat
7.	Acacia auriculiformis	Kratin Narong
8.	Acacia mangium	Kratin Tepha
9.	Melia azedarach	Lian
10.	Pinus kesiya	Son Khao
11.	Bamboo	Pai

1.3.2 Contents of the Study

Chapter 2 identifies high potential wood products. Since this study is confined to commercial forest products sold in the market, continuing and successful reforestation will depend on the market potential of wood products from reforested areas. The analysis of available data on production, export, and import of important wood products will be conducted. Future projected demands for those wood products identified earlier will then be attempted by using the FAO COMFOP model. (A description of the model is provided in Appendix I of this report.) COMFOP is an economic model illustrating the relationship between the demand for wood products and other factors of production in the economy. Future demands for prospective wood products can then be simulated.

The final analysis will convert the wood product requirements into specific sizes and types of reforested areas. The potential of commercial plantation, in terms of its contribution to expanding the total area under forest can then be assessed.

Chapter 3 emphasizes the tax study for the pulp industry. A tax on imported pulp could protect the local pulp industry which, could serve as an important source of demand for wood of fast growing tree plantations. On the otherhand, an inappropriate tax measure could disrupt the industry and hence impairs the badly needed reforestation effort.

Conclusion and recommendations are presented in Chapter 4. There are 3 appendixes to this report. Appendix 1 provides the details of the FAO COMFOP Wood Utilization Estimation Model, which is used throughout this study in projecting future trends. Appendix 2 contains information on the nature and property of fast-growing tree species under study. Finally, details of the domestic resource cost study illustrating the comparative viability of the local pulp industry, is contained in Appendix 3.

2. POTENTIAL OF COMMERCIAL FAST-GROWING TREE PLANTATIONS IN THAILAND

In this study, the term "potential", implies good market prospects for a particular wood product, with a stable, growing demand in either the domestic or foreign market. Hence, analyses of export, import, and domestic demands for wood products will be attempted. A stable and increasing commodity export trend reflects good prospects -- in terms of foreign requirements -- for that commodity. On the other hand, an increasing import trend indicates the economy's dependency on that particular commodity, which may lead to an import substitution industry requiring fast-growing woods for production. Increasing and stabilized trends in both wood commodity export and import, hence, may indicate a strong future demand for fast-growing trees.

The magnitude of domestic wood product consumption is another important indicator of wood requirements. The domestic consumption of plywood, for example, is mostly supplied by local industry and plywood imports are being discouraged by heavy import taxes. Obviously, the industry can not compete in the world market; hence, export and import data alone do not reflect the significance of this industry. However, since the industry does provide enough plywood for the country's needs, it is considered a stable industry and can guarantee a stable demand for fast-growing trees. However, such potential should be judged against the actual utilization under practice in Thailand. In this case, only hardwoods from teak and dipterocarps are being employed for local plywood production. This issue will be further scrutinized in the following sections.

2.1 Wood Related Commodity Exports

Data in Table 4 illustrate trends of wood-related commodity exports between 1982 and 1986. To give a whole picture of all wood - related commodity export, data of all related commodities were presented. Boxes and other paper products were excluded from further analysis since they were not directly made of woods. Teak veneer was not counted in the study either since it was made from teak which was not considered fast growing tree in this study. Hence, three wood commodities namely wood charcoal, parquet, pulp, and hardboard emerge as prospective wood products. They indicated either voluminous amounts of export or increasing export trends. Thus from the export figures, wood charcoal, parquet, hardboard and wood pulp are considered as our potential wood products which may induce commercial plantations.

In addition to the above, we learned that two other wood commodities i.e. wood chip and cement-based board have attracted foreign importers. Though exporting these commodities has just started (1987), their export prospects are promising. We thus added these two commodities as potential wood products and included them in the study.

Table 4 Exports of Major Fast-Growing Trees Related Commodities 1982-1986

	1982		1983		1984		1985		1986	
Wood Charcoal										
Total (Kg, Mill. Baht)	64,744,257	83.80	70,276,727	94.10	54,703,907	75.90	47,178,749	82.50	39,311,185	65.60
Other Veneer Sheets, Sheets for Plywood										
Total (CU.M., Mill. Baht)	361	16.90	31,410	20.00	825	20.80	63,381	17.10	235	18.60
Parquet										
Total (Kg, Mill. Baht)	2,448,220	83.50	2,699,095	75.70	4,599,913	117.40	7,728,961	207.10	13,209,537	302.40
Pulp										
Total (Kg, Mill. Baht)	305,084	2.57	914,174	12.10	2,432,486	36.22	5,495,970	74.20	26,542,454	264.20
Paper, Paperboard & Boxes										
Total (Kg, Mill. Baht)	6,200,233	156.61	3,813,481	110.10	2,920,220	84.71	5,308,967	359.00	10,295,518	532.30
Fibreboard (Hardboard)										
Total (Kg, Mill. Baht)	6,962,131	37.10	10,805,314	55.50	14,258,762	67.20	17,272,324	86.50	24,336,360	114.20
Particle Board										
Total (Kg, Mill. Baht)	459,927	20.80	397,285	12.00	568,523	23.10	122,141	5.10	1,353,007	22.60
Sum of Major Fast-Growing Trees Related Commodities										
Total (Mill. Baht)		401.28		379.50		425.33		831.50		1,319.90
Value of Wood Related Commodities										
Total (Mill. Baht)		1,825.46		1,821.03		2,139.01		2,990.73		4,244.69
Percentage of Major Fast-Growing Trees Related Commodities										
(%)		21.98		20.84		19.88		27.80		31.10

Sources : Data in this table are derived from a series of Department of Customs' Foreign Trade Statistics of Thailand, 1982-1986

2.2 Wood Related Commodity Imports

Table 5 contains import data of wood related commodities from 1982-1986. Data in the Table show that Thailand has been and still is dependent on various kinds of imported pulp. Each year more than one thousand two hundred million baht worth of pulp is imported. Another major import item shown is "newsprint" (a subitem classified under Paper, Paperboard and Boxes), of which another one thousand one hundred million baht worth is imported each year. This is not surprising since Thailand has never produced newsprint for its own use and all newsprint paper has to be imported. It was dropped from our further analysis however, since it is not directly produced from woods. The import figures of plywood are incredibly low despite it being a popular construction material. This can be explained by the simple fact that a tax wall has been imposed on imported plywood to protect local industry. Hence, from the import viewpoint, only wood pulp was identified as the source of substantial demand for a reforestation project.

2.3 Local Demand for Wood Products

Local demand for wood products is another major demand-creating sector for the wood of fast-growing tree species. It is obvious that wood charcoal is and will continue to be an indispensable energy source for the rural Thais. Also, the requirement for parquet and particle board is expected to grow with the expansion of the economy and the country's construction sector.

Table 5 Imports of Important Fast-Growing Trees Related Commodities, 1982-1986

	1982		1983		1984		1985		1986	
Other Veneer Sheets & Sheets for Plywood										
Total (CU.M., Mill. Baht)	4,302	11.02	3,120	2.69	53	1.61	2,658	0.72	65	4.81
Household Utensil of Wood										
Total (Kg, Mill. Baht)	10,340	0.36	39,943	1.36	2,293	0.22	59,445	2.29	130,965	5.19
Pulp										
Total (Kg, Mill. Baht)	92,152,173	918.91	124,143,514	1,226.20	68,645,784	823.15	125,946,924	1,208.98	105,420,944	1,200.55
Paper, Paperboard & Boxes										
Total (Kg, Mill. Baht)	117,033,238	1,481.07	170,129,891	1,814.71	141,604,725	1,672.63	165,183,732	2,232.73	136,283,466	1,848.10
Particle Board										
Total (Kg, Mill. Baht)	822,069	12.96	437,336	9.00	335,049	9.58	463,949	9.76	317,531	10.88
Sum of Important Fast-Growing Trees Related Commodities										
Total (Mill. Baht)		2,424.31		3,053.95		2,507.20		3,454.48		3,069.53
Value of Wood Related Commodities										
Total (Mill. Baht)		5,894.57		7,284.05		6,838.90		8,007.82		7,327.46
Percentage of Important Fast-Growing Trees Related Commodities										
(%)		41.13		41.93		36.66		43.14		41.89

Sources : Data in this table are derived from a series of Department of Customs' Foreign Trade Statistics of Thailand, 1982-1986

In Thailand plywood and veneer are traditionally made from hardwood of trees with large trunks, particularly teak and dipterocarps. However, tree species which have been used to produce plywood and veneer have recently dwindled in supply. The abolishment of concessional forests, as a result of new forest policy after the flood and mud slide in southern Thailand, could undoubtedly aggravate the supply situation. Although new technology which requires fast-growing trees as inputs for plywood production was introduced to Thailand, producers, at least at this stage, have neither been convinced nor have accepted it. Plywood and veneer were therefore dropped from further analysis.

It is obvious that <u>wood pulp</u> is a potential wood commodity. At present, per capita paper consumption in Thailand is still low, only 15 kg per capita per year; however it may be assumed that the figure will increase as the country becomes more developed. Considering that <u>wood pulp</u> is the necessary raw material in producing paper and Thailand imports a substantial amount of <u>wood pulp</u> each year, the commodity is regarded as vital.

Since any supply of woods from natural forest is limited, it should be optimally consumed. Wood commodities which can be produced from wood residuals thus are worth promoting. For this reason, <u>fibre board</u> was added to this study.

Hence, from the perspective of local requirements, <u>charcoal</u>, <u>parquet, particle board, and wood pulp and fibre board</u> were considered as prospective wood products.

Prospective wood products from all three categories can therefore be listed as follows:

1. wood charcoal
2. parquet
3. hardboard or particle board
4. wood pulp
5. wood chip
6. cement-based board
7. fibre-board

2.4 Estimating Future Demands

In estimating future demands for fast-growing tree plantations, the COMFOP computer model of FAO was used. The methodology calls for grouping the seven wood products selected in the earlier sections into four categories, namely those with export potential only, those intended mainly for domestic markets, wood products with potential for both export and local consumption, and finally those in demand for local consumption which will require inport.

2.4.1 Commodities for Export Only

Wood Chip. Wood chip has recently become an important wood product, especially for export. The overseas market for this product (which include Taiwan, Japan, and Korea) are very promising and the demand is expected to increase. Since the product itself has just come into the local market, export data were obtained from a sole market producer. Its 1987 export amounted to approximately 20,000 tons. Future export growth naturally depends upon the supply of sawn eucalyptus woods, which in turn is dependent upon the total size of plantation areas. Due to the continuing interest of foreign companies to import wood chip from Thailand, the growth rate of 20% per annum was assumed in our computer simulation.

Parquet. Parquet is an important export wood product item. Its export volume increased from 3,787 tons in 1981 to 7,728 tons in 1985 and its value also jumped from 122 million baht to 207 million baht during the same period. Based on data between 1981 to 1985, export growth rate for parquet was estimated based on a semi-log regression, projecting a 20.5% per annum growth. The figure may be overvalued in the long run, since it is difficult to sustain such a high growth rate.

It is well known that a high percentage of parquet is used locally. Home produced parquet in the past was generally made of hardwood which is not concerned in this study. However the possibility of parquet produced from fast-growing trees is now widely accepted. It was assumed that fast-growing wood parquet will be aimed at the export market, while hard wood parquet will be for local consumption.

Wood Charcoal. Most wood charcoal was produced by using hardwoods.A high percentage of the raw materials used to produce charcoal was collected from natural forests. However, wood charcoal can also be produced from fast-growing trees such as eucalyptus, casuarina, and rhizophora.

From the above rationale, the model employed in this study would only cover the export portion of charcoal making, using fast-growing trees. Relying on the export level in 1985 of 47,178 tons as the base year, the growth rate of 3% per annum was applied.

2.4.2 Commodity for Local Consumption Only

Particle Board. In the export analysis, the particle board's export values had shown a rising trend but the values were trivial comparing to those of domestic consumption. The model under consideration therefore emphasized particle board produced for local consumption. Based on projected GDP and income elasticity, the COMFOP model estimated the future local consumption requirements.

2.4.3 Commodities for Local Consumption and Export

Fibreboard. Fibreboard is used in Thailand as a construction material. In 1988 there was only one firm producing this product with the capacity of 4.8 million pieces a year. Although the product has market potential, total production is limited by the shortage of supply of raw material. Export of this wood commodity expanded at 30% per annum between 1981 and 1985. In this study, the above export expansion rate of 30% was followed, and it was believed that the industry was capable to expand at this rate.

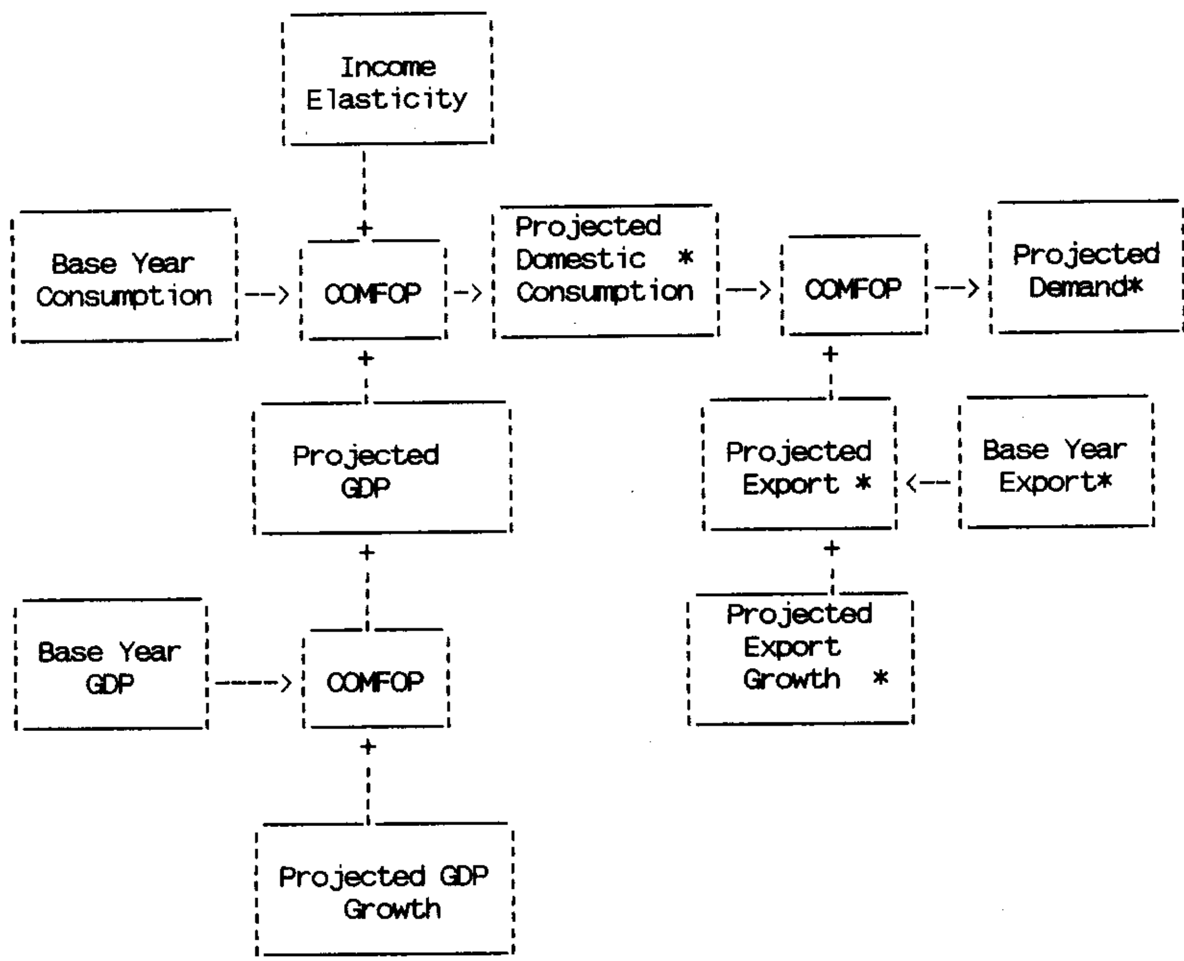
The COMFOP model first estimated the future local consumption demands which were then integrated with the export expansion to derive at the overall demand for fibreboard.

Cement-Based Board. This product is rather new on the market. In 1988, there was only one firm producing this product. Its major use is for construction, especially for low cost housing.

At present, the domestic market consumes about 60 per cent of the total production, while the remaining 40 per cent is for export. It was anticipated that this proportion will hold in the future.

In this study, the production of cement-based board was assumed to reach the capacity of 9,000 m^3/year within the next few years as envisaged by the local producer. In addition, it was assumed that no new factory would be set up in the foreseeable future.

The following diagram indicates how future demands for fibreboard and cement-based board were estimated.



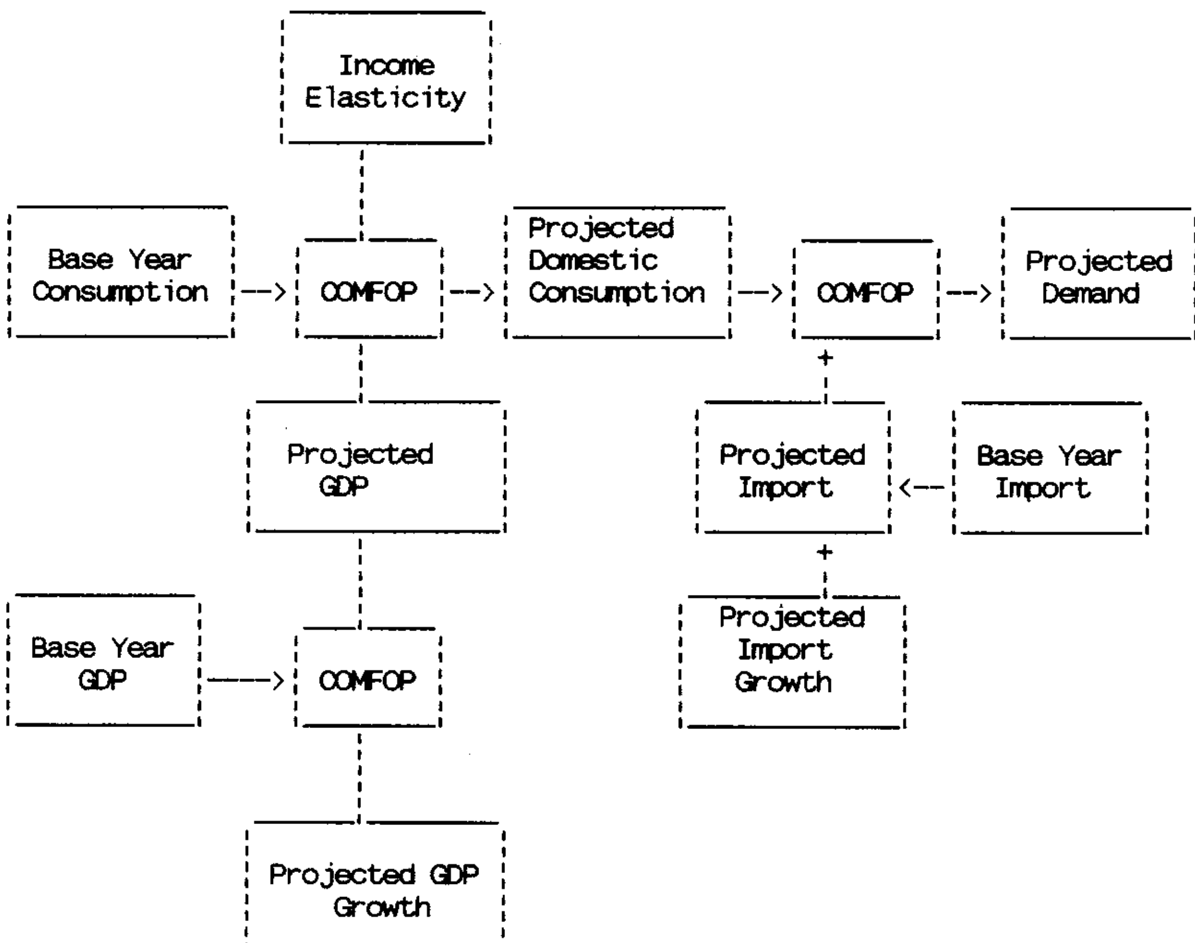
Note: 1) All steps are required for fibreboard estimation.

2) Only steps with * marks are required for cement-based board estimation.

2.4.4 Commodity for Local Consumption and Import

Wood Pulp. As in the case of fibreboard, wood pulp is required for both local consumption and export. However, the export portion, as indicated in Table 4, was insignificant compared to the local demand. On the other hand, import of pulp, as indicated in Table 5, has continued to be substantial.

The local requirement was first estimated by COMFOP's algorithm. The import figures, derived from existing trends, were then subtracted from the local requirements to derive at the local production estimates. The following diagram indicates how future production of wood pulp was estimated.



2.5 The Results

As stated earlier, export demands were applied for parquet, wood chip and charcoal based on given growth rates. For other commodities, their total demands were estimated from past consumption patterns. In estimating local consumption, population and grass domestic product (GDP) projections were used as input. Tables 6 and 7 show projected figures for population and GDP respectively. Further details of COMFOP are provided in Appendix I. Results of computer simulation are tabulated in Table 8, providing proposed demands for local production, import, export and total demands for all seven wood commodities.

Table 6 Thailand's Population 1985-2005

Year	Population (millions)
1985	52.78
1990	58.90
1995	64.43
2000	69.65
2005	74.70

Note : Calculated by using growth rate estimates from TDRI

Table 7 Thailand's GDPs 1985-2005

Year	GDP (million baht) at 1972 Price
1985	373,869.0
1990	477,145.1
1995	628,234.4
2000	801,018.7
2005	1,023,456.5

Note : Calculated by using growth rate estimates from TDRI

Table 9 Estimated Demands for Wood Related Commodities

	1981	1985	1990	1995	2000	2005
Pulp (1000 tons)						
-Production	38.00	26.00	118.00	196.00	288.00	406.00
-Import	92.00	126.00	89.00	35.00	80.00	75.00
-Export	0.00	0.00	0.00	0.00	0.00	0.00
-Total	130.00	152.00	207.00	231.00	368.00	481.00
Particle Board (1000 cu.m.)						
-Production	29.00	32.00	30.00	195.00	425.00	327.00
-Import	0.00	0.00	0.00	0.00	0.00	0.00
-Export	0.00	0.00	0.00	0.00	0.00	0.00
-Total	29.00	32.00	30.00	195.00	425.00	327.00
Fibreboard (1000 cu.m.)						
-Production	33.00	49.00	61.00	76.00	93.00	114.00
-Import	0.00	0.00	0.00	0.00	0.00	0.00
-Export	8.00	22.00	28.00	36.00	46.00	58.00
-Total	25.00	27.00	33.00	40.00	47.00	56.00
Parquet (1000 cu.m.)						
-Production	5.41	13.74	34.90	99.66	225.24	572.20
-Import	0.00	0.00	0.00	0.00	0.00	0.00
-Export	5.41	13.74	34.90	99.66	225.24	572.20
-Total	0.00	0.00	0.00	0.00	0.00	0.00
Wood Chip (1000 tons)						
-Production	-	-	25.62	42.87	69.04	111.20
-Import	-	-	0.00	0.00	0.00	0.00
-Export	-	-	25.62	42.87	69.04	111.20
-Total	-	-	0.00	0.00	0.00	0.00
Charcoal (1000 mt)						
-Production	-	45.00	39.00	34.00	29.00	25.00
-Import	-	0.00	0.00	0.00	0.00	0.00
-Export	-	45.00	39.00	34.00	29.00	25.00
-Total	-	0.00	0.00	0.00	0.00	0.00
Cement-based Board (1000 cu.m.)						
-Production	-	-	4.12	6.14	9.00	9.00
-Import	-	-	0.00	0.00	0.00	0.00
-Export	-	-	1.61	2.45	3.60	3.60
-Total	-	-	2.51	3.69	5.40	5.40

2.6 Requirements for Greenwood and Plantation Areas

Data in Table 8 are crucial in estimating greenwood and plantation area requirements. However, before the estimations could be undertaken, a few preceding steps would be necessary. First of all, we need to know the most appropriate tree species to produce the identified wood products. Secondly, we need to know the greenwood requirements of the prospective products, both in dry weight and green weight. Finally we must be able to translate the greenwood requirements into areas required for fast-growing tree plantations.

2.6.1 Species Selection

It is not simple to identify the most suitable single tree species for a given commodity. Wood characteristics alone cannot be used as the only criterion of species selection. Selection of tree species to match a given commodity extends beyond the silvilculture point of view. This is because each tree species matures best in a particular environment. Teak, for instance, grows well on well-drained soil derived from limestone. The yield at 30 years of age on the best site in Lampang Province is 39.41 m^3/rai. This is 7.7 times higher than on the adjacent site in which the soil is of lower quality (Thaiutsa, 1987). For further details, characteristics of significant fast-growing tree species are presented in Appendix II.

Eucalyptus camaldulensis also strongly responds to site factors. Productivity in terms of total above-ground biomass of a four-year-old eucalyptus planted with a density of 100 trees/rai was found to be 12.11 kg/tree in Suphan Buri, 12.42 kg/tree in Kanchanaburi, 20.90 kg/tree in Ratchaburi (Taweesuk et.al, 1987), 35.4 kg/tree in Kalasin (Jamroenprucksa, 1987), and 77.93 kg/tree in Sisaket (Petmak and Chakrapholwararit, 1985).

Besides site factors, growth and yield of fast-growing trees also vary with genetic variation, normally refered to as seed source. It is obvious for planting Eucalyptus camaldulensis in Thailand that the two best Australian seed sources are Katherine and Petford. Another important factor influencing growth and yield of plantation trees is silvicultural practice. This parameter includes preparation of the planting site, spacing, and such intermediate treatments as frequency of weeding, fertilizer application, pruning, and thinning. For a certain species of fast-growing trees, "among" tree variations in growth and yield may be less than "within" tree variations, resulting from different silvicultural treatments. Similarly, the difference in productivity of a given species may be more than double on a proper planting site with proper spacing in comparison to the productivity of the same species grown on an adjacent site.

On the basis of growth and yield, in combination with the wood properties required for the specified prospective commodities, the best two species most suitable for each commodity are recommended as follows :

Wood charcoal	:	Eucalyptus camaldulensis Casuarina equisetifolia
Wood chip	:	Eucalyptus camaldulensis Acacia mangium
Particle board	:	Eucalyptus camaldulensis Acacia mangium
Cement-based board	:	Eucalyptus camaldulensis Melia azedarach
Fibreboard	:	Eucalyptus camaldulensis Casuarina junghuhniana
Woodpulp	:	Eucalyptus camaldulensis Casuarina junghuhniana
Parquet	:	Acacia auriculiformis Azadirachta indica

Since planting costs and yields per rai of all fast-growing trees recommended above are fairly similar, selection of tree species for a particular commodity listed above should then be based on suitability of species and habitat matching rather than on the species itself. Acacia mangium is not suitable to an area where the amount of annual rainfall is below 1,500 mm. Melia azedarach should be planted only on deep and well drained soil. The principal disadvantage of Casuarina equisetifolia and Casuarina junghuhniana is their inability to coppice. Taking all mentioned factors into consideration, only Eucalyptus camaldulensis is the best choice for all products -- except parquet, which is best produced from either Acacia auriculiformis or Azadirachta indica.

2.6.2 The Dry Weight - Green Weight Ratio

To know the amount of land required to grow fast-growing trees to produce wood commodities, we need to know -- the ratio of the final product's dry weight and the roundwood's green weight. For almost all wood products which use Eucalyptus camaldulensis, this ratio is about 1:2.5. But for woodpulp this ratio is approximately 1:4.4.

The following are the ratios of the various products used in this study :

Charcoal	1 : 2.5
Wood chip	1 : 2.5
Particle board	1 : 2.0
Cement-based board	1 : 2.5
Fibreboard	1 : 2.0
Woodpulp	1 : 4.4
Parquet	1 : 3.0

2.6.3 The Green Weight - Area Requirement Ratio

Based on Chadbunchachai's investigation (1985), the cost of a private eucalyptus plantation on a five-year rotation, planted in Chachoengsao province, was about 2,677 baht/rai per year. It is almost the same for other fast-growing tree investments, except Casuarina junghuhniana which costs 3,705 baht/rai (Thuammali, 1987). Also, the average yield per rai at a given planting site in terms of both volume and dry weight production, are relatively close for most species. The annual increment of stem-ovendry biomass is about 1.5 tons/rai for a moderately managed plantation. The commercial yield of a five-year rotation plantation weighed at the factory gate (green weight) is about 15 tons/rai (Thaiutsa and Taweesuk, 1987). This figure was used to estimate plantation size.

2.6.4 Projected Demands for Wood Products and Greenwood Requirements

The future demand for each wood product was estimated using the COMFOP model. Table 9 shows the estimated demand for each wood commodity from 1990 to 2005. To convert from dry to greenwood requirement, the conversion factors discussed in section 2.6.2 were applied, with the results as shown in Table 10. The last row of Table 10 indicates the annual total requirements for greenwood by all selected wood commodities from 1990 to 2005. It can be observed that the demand for greenwood jumps from 1,042,000 tons in 1990 to 4,883,730 tons in 2005, an increase of almost five times in 15 years.

2.6.5 Estimation of Plantation Land Requirement

Given the relationship between area (in rai) and greenwood yield, in terms of yield per rai, the total land requirement for fast-growing tree plantation per year could then be calculated. With a five-year rotation and a conversion factor of 15 tons of greenwood per rai, the requirement for land to grow fast-growing trees in the period 1990 to 2000 are given in Table 11.

Table 9 Estimated Future Demands for Wood Products (1.000 tons)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Pulp	118.00	133.60	149.20	164.80	180.40	196.00	214.40	232.80	251.20	269.60	289.00	311.60	335.20	358.80	382.40	406.00
Particle Board	52.76	59.22	84.67	100.13	115.58	131.04	161.95	192.86	223.78	254.69	285.60	353.07	420.54	488.01	555.48	622.94
Fibreboard	61.49	64.51	67.54	70.56	73.58	76.61	80.04	83.46	86.89	90.32	93.74	97.98	102.21	106.44	110.68	114.91
Parquet	24.43	31.96	39.49	47.01	54.54	62.06	81.19	100.30	119.43	138.54	157.67	206.24	254.81	303.39	351.96	400.54
Wood Chips	26.62	29.87	33.12	36.37	39.62	42.87	48.10	53.34	58.57	63.81	69.04	77.47	85.90	94.34	102.77	111.20
Charcoal	56.00	55.20	54.40	53.60	52.80	52.00	51.20	50.40	49.60	48.80	48.00	47.50	47.20	46.80	46.40	46.00
Cement-Based Board	5.03	5.50	5.96	6.43	6.90	7.37	8.05	8.74	9.43	10.12	10.80	10.80	10.80	10.80	10.80	10.80

Table 10 Demand for Green Wood (1.000 tons)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Pulp	519.20	587.84	656.48	725.12	793.76	862.40	943.36	1.024.32	1.105.28	1.186.24	1.257.20	1.371.04	1.474.88	1.578.72	1.682.56	1.786.40
Particle Board	107.52	138.43	169.34	200.26	231.17	262.08	323.90	385.73	447.55	509.38	571.20	706.14	841.08	976.01	1.110.95	1.245.89
Fibreboard	122.98	129.02	135.07	141.12	147.17	153.22	160.07	166.92	173.78	180.63	187.49	195.96	204.42	212.89	221.36	229.82
Parquet	73.29	95.87	118.44	141.04	163.61	186.19	243.55	300.91	358.29	415.63	473.00	618.72	764.44	910.16	1.055.88	1,201.62
Wood Chips	66.55	74.68	82.80	90.93	99.05	107.18	120.25	133.35	146.43	159.53	172.60	193.68	214.75	235.85	256.93	278.00
Charcoal	140.00	138.00	136.00	134.00	132.00	130.00	128.00	126.00	124.00	122.00	120.00	119.00	118.00	117.00	116.00	115.00
Cement-Based Board	12.57	13.74	14.91	16.08	17.25	18.42	20.13	21.84	23.58	25.29	27.00	27.00	27.00	27.00	27.00	27.00
Total Greenwood	1.042.11	1.177.58	1.313.05	1.448.54	1.584.01	1.719.48	1.939.27	2,159.07	2.378.90	2.598.70	2.818.49	3.231.53	3.644.57	4,057.53	4.470.67	4.883.73

Table 11 : Land Requirement for Commercial Plantation, 1988-2000

(1,000 rai)

Year	Land Requirement
1988	389.25
1989	437.69
1990	482.84
1991	533.62
1992	590.02
1993	652.05
1994	719.69
1995	792.96
1996	879.11
1997	978.15
1998	1,090.06
1999	1,214.86
2000	1,352.54

3. VIABILITY OF THE PULP INDUSTRY

As a country progresses to a higher level of economic development, paper consumption per capita will increase. At present, per capita paper consumption of the Thai people is approximately 15 kilograms per year. This figure is quite low compared to those of other developing countries such as Malaysia (30 kg/year) and Taiwan (70 kg/year). Given the current high economic growth rate of the country, with GNP increase of more than 10 per cent in 1988, paper consumption will definitely grow in the foreseeable future.

Paper is produced from pulp which is generally divided into two categories: long fibre pulp (which is made of soft wood from the pinus family) and short fibre pulp (which is normally made of hard wood or non-wood materials such as rice straw and bagasse). Since Thailand has a limited supply of pinus wood, because of its geographical location, long-fibre pulp production is infeasible in this country, and is not considered in this study.

Paper can also be produced from waste paper. Each year, in addition to domestic supply, a substantial amount of waste paper has to be imported. Though it can be considered a substitute raw material in paper making, waste paper cannot completely replace pulp because the pulp content is lost in the recycling process. This loss does have an effect on the paper quality. Also since bleaching cannot eliminate all colors in waste paper, the final product is not of the best quality. Pulp, therefore, is still an indispensable raw material for the paper industry.

Table 12 illustrates Thailand's future demand for paper and paperboard.

Table 12 : Consumption of Paper and Paperboard, Thailand 1982-1991.

(Tons)

Year	Capacity	Consumption
1982	428,100	474,640
1983	475,550	617,826
1984	540,575	597,896
1985	585,750	628,462
1986	645,750	630,860
1987	720,250	689,500
1988	784,450	731,000
1989	784,450	782,500
1990	784,450	834,500
1991	784,450	829,000

Source : Thai Pulp and Paper Industries Association, 1987

3.1 Thailand's Pulp Production History

Table 13, shows the actual pulp production in Thailand, vis-a-vis its capacity, from 1974 to 1986.

The first pulp mill was founded in 1945 as a state enterprise. The raw material used by the mill was primarily rice straw. The mill's production capacity was 9,000 tons per year which was not adequate to meet the country's demand; thus, a large amount of pulp was imported each year.

Table 13 : Pulp Production in Thailand, Supply and Capacity.

(Tons)

Year	Production	Capacity
1974	30,600	NA
1975	21,200	NA
1976	26,300	NA
1977	32,600	39,000
1978	37,200	39,000
1979	37,200	39,000
1980	24,200	36,000
1981	16,400	32,000
1982	38,674	104,500
1983	68,100	104,500
1984	78,682	104,500
1985	92,317	104,500
1986	117,002	104,500

Source : Thai Pulp and Paper Industries Association, 1987.

Thailand began to modernize since early 1960s with the inauguration of the first National Economic and Social Development Plan in 1961. However, not much attention by the government and the private sector was given to the pulp industry during this initial phase of economic development. The paper industry, on the other hand, which produced paper from imported pulp, did attract local investors. Six paper factories had been established by 1972, with imported pulp as their main raw material. From 1973 until the end of the decade, there was a pulp shortage resulting in a rise in the price of paper in the local markets. The situation had indicated the need to produce pulp locally to avoid being dependent on foreign import. During this period many paper producers added pulp to their production lines; pulp was thus produced for the paper factory's own consumption rather than for sale. Because building a pulp factory is expensive and planning and construction does take a number of years, commercial pulp production was quite stable between 1977 and 1981 with a marked increase in the total production capacity from 32,000 tons/year to 104,500 tons/year in 1982. (See Table 13)

Beginning in 1982 some firms have produced pulp to sell in the local market. It should be noted that, in the past, the pulp industry depended on non-wood raw materials such as bagasse, rice straw, grass weed, and bamboo; hence only short fibre pulp was produced locally. While the demand for pulp kept on increasing, there were signs of shortages of these raw materials. Not only was the supply of bagasse and rice straw limited, the number of bamboo trees had also dwindled due to over-exploitation. In the case of bagasse, yearly limitation in supply hindered the expansion of production capacity. In addition, the pulp industry must compete for the limited amount of bagasse with other industries. It can be concluded that bagasse and other non-wood raw materials cannot serve as reliable sources of raw material. The Thai pulp industry will have to depend more on the wood of fast-growing trees as the main production input.

3.2 Pulp Promotion and Protection Policies

Commercial pulp production in Thailand began when the world economy was confronted with a depression and, in 1982, just as Thailand's pulp industry emerged the world price of pulp began to decline. This troublesome period was not supportive to Thailand's nascent pulp industry. Unless protected, cheap pulp from abroad could easily undercut the local production. The government thus passed two protective measures as follows:

1. An increase of import duty for pulp from 1% to 10% of the c.i.f. price. This measure took effect in August 1982 and is still being applied.

2. The imposition of a surcharge, in addition to the import duty, of 20% of the c.i.f. imported price. The first surcharge was imposed during November 24, 1982 to November 23, 1983; the second between December 23, 1983 to December 22, 1984; the third from January 9, 1985 to January 8, 1986; and the fourth and final surcharge was levied from January 9 to April 30, 1986.

Generally, surcharge is used to protect local pulp industry from dumping. It is usually levied for a one-year period but can be extended for another year if necessary. The surcharge rate normally is within the range of 1 to 50 per cent of the c.i.f. value. To protect the local pulp industry, a rate of 20% was applied.

Table 14 illustrates how the duty and surcharge protect the local pulp industry. Without protection, the price of locally produced pulp cannot be competitive.

Table 14 : Prices of Locally Produced Pulp, C.I.F. Prices, and C.I.F. with Import Duty Prices.

Year	c.i.f. price[1] (Baht)	c.i.f. and Protection[2] (Baht)	Price of Local[3] Pulp (Baht)
1982	9,299	12,272	8,333
1983	9,033	11,921	10,075
1984	10,675	14,088	12,175
1985	11,335	14,959	11,400
1986	12,060	15,916	12,750

Sources : 1) c.i.f. prices are obtained from the Customs Department

2) data in this column are based on the c.i.f. prices plus 10% import duty and 20% surcharge

3) local prices are obtained from Pheonix Pulp and Paper Company Ltd.

In addition to import tax and surcharge, the pulp industry also benefits from privileges provided by the Board of Investment, in particular these are :

1. Exemption of import duty and business tax for imported machineries and parts.

2. Exemption of corporate income tax for three to eight years after the company starts to earn income. Such company is also allowed to carry losses that may occur during exempted period and may deduct these losses from its annual revenue for a period of five years beyond the exemption period.

Pulp companies are relatively large-scale, relying on imported machineries and equipment, Privileges as granted by the Board of Investment thus enabled them to save substantially.

3.3 Effects of the Protection Policy

Both import duty and promotional privileges helped establish the Thai pulp industry. While promotional privileges encouraged investment, the import duty provided security to the local industry. This study dealt with import duties only.

In theory, import duty is levied on a commodity for the following reasons:

1. To protect a young industry, that is to say, to encourage import substitution.

2. To generate revenue for the government.

3. To discourage importation of undesirable goods and commodities. This would naturally lead to foreign exchange savings and an improvement in the balance of trade.

4. To save the local market for local producers.

5. To expand local employment and consumption of local raw materials.

On the other hand, import duty as an instrument that protects the local industry could have adverse effects, such as :-

1. The import duty could distort the allocation of the country's resources. Since the duty helps a weak industry survive through protection, some resources are bound to be directed to the production of disadvantageous commodities when the resources could have better been used for other more productive purposes.

2. Protection directly affects consumers, forcing them to pay higher prices or consuming sub-standard commodities.

3. An import duty levied on intermediate goods definitely raises the production cost of the final product. An import duty on pulp, for instance, does increase the raw material cost in producing paper, the burden of which is spread between paper producers and consumers.

4. Protection could lead to monopoly which generally is not desirable to the local economy in the long run.

5. With a secured position protected against foreign competitors, the local producer might lose the incentive to improve its management and technological skill.

3.4 Effectiveness of the Import Tax Policy

To measure the effectiveness of the fiscal policy adopted to protect the local pulp industry as elaborated earlier, indicators were analysed, namely :-

(1) production quantity;

(2) capacity utilization rate;

(3) import quantity; and

(4) export quantity.

Details of the analysis are presented below.

3.4.1 Production Quantity

The imposition of an import duty and a surcharge on imported pulp, initiated in August 1982, certainly has had a direct impact on local pulp production. As a result, domestic pulp production has expanded from 38,674 tons in 1982 to 117,002 tons in 1986. Before 1982, domestic pulp production fluctuated within 40,000 tons per year. After 1982, local pulp production went up steadily. (Table 13) It is believed that this increasing trend will continue, perhaps at a faster rate, due to several favorable factors which will be discussed more thoroughly in subsequent sections.

3.4.2 Capacity Utilization Rate (CUR)

The rate of capacity utilization is another indicator of local pulp industry performance. CUR is the ratio of actual production capacity used to the total production capacity of that industry in a certain year. In theory, those industries whose capacity utilization rates approach 100% produce desirable outcomes for society. After 1982, the capacity utilization rate steadily increased, from 37% in 1982 to 100% in 1986. At present, the capacity utilization rate is over the designed 100%.

3.4.3 Import Quantity

Before the import duty was imposed in 1982, the growth rate of imported pulp (between 1974 to 1982) had averaged 358.4% per annum. After 1982, imported pulp shows an average declining trend of 8.8% per annum between 1982-1987. The dramatic change in trends of the two periods led to the conclusion that the import tax did establish effective protection for the local pulp industry and effectively lessened the country's dependency on imported pulp.

3.4.4 Export Quantity

The quantity of pulp exported increased from 305 tons in 1982 to 27,267 tons in 1986, an average growth rate of 221.9% per annum during the period. Before 1982 all domestic pulp produced was consumed locally, but in 1986 about 23% of domestically produced pulp was exported. To a certain extent, the ability to export reflects the strength and maturity of the protected industry, in this case pulp, to compete successfully in the international market.

It can be concluded then that tax measures, to a very large extent, contributed to the establishment of the Thai pulp industry. However, the import tax and surcharge are not permanent protection measures and must be withdrawn at an appropriate time. The question thus becomes, "Will the industry survive without these protective measures?"

In addition to trade barriers, many other factors help sustain the pulp industry's survival. Promotional measures (including tax exemption on imported machineries and corporate income tax holidays) reduce the industry's burden and make it market competitive. Also, the price of imported pulp is another determining factor. In the case of Thailand, the surcharge which accounted for 20% of the c.i.f. price, was finally lifted and, hence the degree of protection was lessened. Without surcharge, the local pulp industry still proves to be viable. This is due to the fact that the price of imported pulp has been steadily rising and continues to exceed the price of domestically produced pulp.

3.5 Gains from Protection

It can be concluded, that the import tax and the surcharge were important factors in protecting the local pulp industry; however, other factors, especially the continuing rise in the world price of pulp, also contributed to the industry's competitive position. In quantitative terms, these protective measures benefited Thailand in the following ways :-

1. Government revenue generated by import tax and surcharge. Since the time when the import duty was raised from 1 to 10% of the c.i.f. price in 1982 and the surcharge was imposed in November 1982 (and removed in April 1986) government revenues generated between 1982 and 1987 averaged 82.9 million baht per year from these two schemes. (Table 15)

Table 15 : Revenues Generated from the Increase in Import Tax (from 1 to 10%) and the Imposition of the 20% Surcharge on Imported Pulp, 1982-1987.

(000 Baht)

Year	Value of Imported Pulp	Revenue Generated From Import Tax	Revenue from Surcharge	Total Revenue
1982	428,644	38,578	7,144 (1)	45,722
1983	486,465	43,782	97,293	141,075
1984	326,225	29,361	65,245	94,606
1985	425,146	38,264	85,029	123,293
1986	414,639	37,318	27,643 (2)	64,961
1987	307,697	27,693	- (3)	27,693
Total	2,388,816	214,996	282,354	497,350
Average	398,136	35,833	56,470 (4)	82,891

Notes (1) Based on an imported pulp average of 35.7 million baht per month. The surcharge in 1982 was effective only in December.

(2) The surcharge was effective from January to April. Hence, only one-third of the overall annual value of imported pulp was used in calculating the value of surcharge.

(3) No surcharge was in effect in 1987.

(4) The figure is a five-year average.

Table 15 shows that the revenue generated from the rise in import tax totalled 214.9 million baht, or the average revenue per year of 35.8 million baht. The revenue accrued from the surcharge imposed for five years was 282.4 million baht, with an average revenue per year of about 56.5 million baht. The total revenue from both categories was therefore 497.4 million baht for the six-year period. On the average, the import tax and surcharge on imported pulp generated about 82.9 million baht to the Thai government each year from 1982-1987.

2. Employment Generation. The pulp factory is a large enterprise which requires a wide range of personnel. On the average, each pulp factory employs no less than 500 employees. The factory also provides employment opportunities for upstream and downstream enterprises.

3. Foreign Exchange Saving. Since Thailand has to produce paper for local consumption, the country needs substantial quantity of pulp each year. Without local production, all pulp has to be imported. The value of domestically produced pulp -- the import substitute -- valued at the c.i.f. price, therefore, represents the foreign-exchange value Thailand can save. In Table 16 the foreign exchange saving was estimated at 4,272.2 million baht during the 1982-1986 period.

Table 16 : Local Pulp Industry Foreign Exchange Savings

Year	Locally Produced Pulp (ton)	c.i.f. Price (Baht/ton)	Value of Foreign Exchange Saved (000 Baht)
1982	38,674	9,299	359,630
1983	68,100	9,033	615,147
1984	78,682	10,675	839,930
1985	92,317	11,335	1,046,413
1986	117,002	12,060	1,411,044
Total	394,775		4,272,164

3.6 Drawbacks to Protection

Despite benefits mentioned in the preceding section, the import tax and surcharge imposed on imported pulp have had some undesirable effects on the economy. By establishing the import and surcharge taxes, local producers could raise the price of locally produced pulp to match the price (plus tax) of imported pulp. Table 17 illustrates how the locally produced pulp price caught up with the price the consumer had to pay for imported pulp. The data indicate how the c.i.f. price rose from 1983 to 1986; and it is believed that this trend will continue. While the price of locally produced pulp was very low in 1982, it almost caught up with the protected price (column 3). Note that prices of locally produced pulp surpass c.i.f. prices from 1983 to 1986.

Table 17 : The Relationship between the Prices of Locally Produced and Imported Pulp

Year	c.i.f. Price (Baht)	c.i.f. and Protection (Baht)	Locally Produced Commodity Price (Baht)
1982	9,299	12,272	8,333
1983	9,033	11,921	10,075
1984	10,675	14,088	12,175
1985	11,335	14,959	11,400
1986	12,060	15,916	12,750

Source : C.i.f. prices are obtained from the Customs Department

Table 17 also suggests unnecessarily high raw material cost of producing paper since the paper producers could produce paper for less without protective measures. In other words, if imported pulp was allowed in without duty, paper producers could acquire cheaper (imported) pulp than that produced locally. As a result of protection, the consumer must bear the burden of higher prices.

The import duty and surcharge, if used for too long, clearly support inefficiency. Import duty is normally imposed to protect local industries during their inception period, while the surcharge is usually considered as an effective instrument to protect local industry from foreign dumping. Both the import tax and the surcharge, therefore, should not be continued indefinitely because, under them, local industry continues to enjoy privileges and may become uncompetitive in the world market. As a result, consumers unnecessarily have to pay high prices for the final product.

Inefficiency and resource misallocation co-exist. If, from an economic perspective, it is not efficient to produce pulp within the country, then it should be imported. This statement does not apply to a short-term protection policy to help establish a domestic industry. After a period of protection, an industry should be able to stand on its own feet, and the protection should be lifted. If protection is extended indefinitely, then local resources would be directed to an inefficient industry at a high cost to the entire society -- in the sense that resources are not employed most efficiently.

It is evident that import tax and surcharge played a significant role in the survival of the local pulp industry. We also discussed how the rise in the world price for pulp made the local industry more competitive (although an import tax of 10% is still in effect). It would be of interest, therefore, to determine the real competitive position of the local pulp industry so that appropriate tax policy can be established. In particular, we need to know if the local pulp industry could survive without the remaining protection of the 10% tax.

3.7 The TDRI Domestic Resource Cost Study

A domestic resource cost (DRC) study sheds light on whether it is advantageous or not to produce a particular commodity locally in comparison to the foreign exchange cost for importing it. A country is said to have comparative advantage in the production of a given commodity if the cost of producing it is lower than the cost of foreign exchange, measured at the shadow exchange rate saved or earned from its production.

Appendix III provides the full details of the domestic resource cost study undertaken. The study attempted to evaluate whether the local pulp industry, as an import substitution industry, has comparative advantage now and whether it will continue to be the case in the future. It was assumed that Eucalyptus camaldulensis were the main fibrous raw material used in pulp production. This assumption departed from past industry practices since, non-wood raw materials such as bagasse, rice straw, jute, and bamboo have always been the main raw materials used. It, however, corresponds to the present trend because the industry can no longer depend on these conventional raw materials as their supply has become increasingly limited.

Bagasse, for instance, is a by-product of sugar production. Hence, its yearly supply is a direct function of the annual sugar production. Further bagasse is a versatile raw material with many applications. It is burned to produce energy in sugar mills and this use competes with the pulp making industry. Hence, the supply of bagasse is rather limited.

The same situation prevails regarding the supply of the other two indigenous raw materials - jute and bamboo. In the future, the country's pulp industry must turn to a more dependable source of raw material; and Eucalyptus camaldulensis will likely become the main choice. Thus, eucalyptus wood was used in the DRC study as the raw material.

Detailed results of the study appear in Appendix III. If the price of eucalyptus wood is 600 baht/ton and the capital opportunity cost is 12% per annum, the DRC ratio(1) of the industry as a whole is 0.94. When we assume the same price for eucalyptus wood and use only 8% per annum as the capital opportunity cost, the DRC ratio becomes 0.90. But if the eucalyptus wood price is raised to 800 baht/ton, to reflect environmental costs and the capital cost is kept at 12% per annum, the ratio becomes 1.04 (the case in which domestic production does not have comparative advantage and it is more desirable to import. However, with a price for eucalyptus of 800 baht/ton at 8% per annum for capital opportunity cost, the ratio is reduced to 0.95.

---

(1) The DRC ratio is defined as the ratio of domestic resource cost and the official exchange rate (OER). If this ratio is one, it roughly means that there is no difference, from the resource allocation viewpoint, between producing a commodity domestically for consumption and importing that particular commodity. Producing that commodity locally does not create advantage nor disadvantage over importing. When the ratio is greater than one it means it is favourable to import, rather than to produce locally. On the contrary, a ratio of less than one means a comparative advantage in producing locally. The comparative advantage increases as the DRC ratio moves closer to zero.

In all cases except one in which the eucalyptus price is 800 baht/ton and the capital opportunity cost is 12% per annum, the DRC ratios were below one. Thus it should be obvious that the Thai pulp industry does have comparative advantage. This means that from the resource allocation viewpoint there is no need to maintain the import duty on pulp to protect the pulp industry. Only when there were irregularities in the world trade might some protection be needed.

3.8 Future Scenarios

Though it has been shown that the local pulp industry now has comparative advantage, it would be even more important from the policy viewpoint to predict the future situation. The analysis is based on a regression equation established from historical c.i.f. prices. (1977 to 1987). Table 18 shows the results projecting the c.i.f. price to 19,007 baht/ton in year 2000. The figures may be undervalued, however, since the pulp market will continue to expand. In June 1988 the world's major pulp producers (in Scandinavia, Canada, and the U.S.) were offered US $655 - 700 (17,193 - 18,375 baht) per ton of kraft pulp.(1) This corresponds very well to the c.i.f. price of US $620 (16,275 baht) in the final quarter of 1987 resulting from this exercise.

---

(1) "Far Eastern Economic Review", June 9, 1988, P. 93

Table 18 : Expected c.i.f. Price of Imported Pulp, 1988 - 2000

Year	c.i.f. Price (Baht/ton)
1988	13,055
1989	13,551
1990	14,047
1991	14,543
1992	15,039
1993	15,535
1994	16,031
1995	16,527
1996	17,023
1997	17,519
1998	18,015
1999	18,511
2000	19,007

Note : All figures are derived from the estimated equation

price = 7103 + 496 TI (TI = year)

where

R^2 = 0.635

No. of Observations = 11

Degree of Freedom = 9

The c.i.f. prices which appear in Table 18 therefore can be looked at as low-end c.i.f. values. One interesting result of the study was that with the eucalyptus wood price of 600 baht per ton and a capital opportunity cost of 12% per annum, the c.i.f price of imported pulp must come down to 11,515 baht per ton to make the DRC ratio equal one -- the case in which there is no difference, from the resource allocation viewpoint, between importing pulp and producing pulp domestically for local consumption. The c.i.f. must be reduced to only 11,203 baht per ton to create the same indifference if the capital opportunity cost is reduced to 8% per annum. (See Appendix III Table A 3.6). Since the c.i.f. figures in Table 18 are all well above those two figures, the study clearly shows the future comparative advantage of the Thai Pulp industry.

The preceding analysis has demonstrated the future comparative advantage of the Thai pulp industry as a result of increase in the world price of pulp. Since the world price of pulp is expected to rise at a high rate, there is no need for an import duty to protect the mature import-substitute pulp industry. The remaining 10% duty on imported pulp actually has no real effect on protection since local production costs are already far below the world prices. Hence the duty can be totally abolished. The government may loose the revenue it used to receive from the 10% import duty, but this will be compensated by the revenue generated through the corporate income tax the pulp company will have to pay when its tax-holiday privilege is over. As long as the world price of pulp increases more rapidly than local production costs, the Thai pulp industry will continue to maintain its comparative advantage; there is no need for protection measures because the local industry could survive under these favorable market conditions.

The following are a few examples of real-world phenomena in support of the foregoing statement. Although it is probable that the import duty protecting local industry will be totally lifted in the near future, many investors still plan to expand production. Siam Pulp and Paper Co. Ltd. plans to add another 50,000 tons of pulp per annum to its present capacity. The Soon Hua Seng Group, a major trader of agricultural commodities, plans to invest at least 12 billion baht to add 330,000 tons of pulp to the country's existing capacity. Both groups indicate their desire to use eucalyptus wood to produce pulp. In addition, the Shell Company plans to grow eucalyptus trees to produce wood chips (a venture which could turn into a pulp industry,) on 125,000 rai in Changwat Chantraburi. This expanding trend obviously indicates the very secure status of the local pulp industry.

The foregoing discussion indicates a very secured position of the local pulp industry, even without protection. The continuing increase in the world price of pulp and the abundant local market are the two main factors which ensure the viability of the Thai pulp industry.

Hence, the survival of the local pulp industry is not at risk. As an import substitution venture, the industry still has an enormous local market while the world pulp price continues to rise. With a higher world market price local pulp producers may choose to export. In a free enterprise economy like Thailand there is no absolute barrier to trade, and the pulp companies are aways eligible to export. Problems may arise when the world pulp-price is so high that it attracts pulp exportation to such an extent that a domestic pulp shortage occurs; hence, a probable future problem of the pulp industry is no-longer how to protect it. The industry's import substitution era has passed with a high degree of success; from now on, attention must be given to this industry from the export side.

4. CONCLUSION

4.1 Conclusion

From the preceding chapters, it can be concluded that:-

1. There are many wood products with good market prospect. Among them are wood pulp, wood charcoal, wood chip, cement-based board, parquet, fibre board and particle board. These are permanent sources of demand for fast-growing trees.

2. Many fast-growing tree species are suitable for the production of the seven wood commodities identified above. These are Eucalyptus camaldulensis, Casuarina equisetifolia, Acacia *mangium*, Melia *azedarach*, Casuarina junghuhniana, among others. Among these choices, Eucalyptus camaldulensis stands out as the prefered species of the buyers. At present, it is the fact that supply of eucalyptus woods can not keep up with demand.

3. One of the main results arising from this study is that to respond to increasing population and the economic growth which would induce more consumption of wood products, the total plantation area of fast-growing trees is required to expand up to 1.35 *million rai by the year 2000*. It should be observed that the total land required is rather marginal representing only 0.42 per cent of the total land area of the country.

4. More land *requirement for fast-growing* tree plantations will likely come from the export market. Counting all the known demands for fast-growing tree plantations, the total land

requirement will still be only 3.6 million rai or about 1.1 per cent of the total land area of the country.

5. However, if the present policy of maintaining 25 per cent of the total land area of the country under "economic forest" is to be taken seriously, the target set calls for replantation area of as large as 20 to 60 million rai. Therefore it is indisputable that commercial fast-growing tree plantations in Thailand will not be a major factor contributing to the fulfillment of national "economic forest" policy.

6. Past records confirm that commercial reforestation in Thailand is relatively new and the government is trying to catch up with new requirements of the private sector. To date only 150,643 rai of degraded forest land has been approved by the Royal Forest Department for private commercial plantations. Details of the approved areas and tree species by region are given in Table 19.

Table 19 Degraded Forest Areas Already Approved by the Royal Forest Department for Private Fast-Growing Tree Commercial Plantations.

Region	Province	Area(rai)	Tree species*
North	Chiang Mai	1,660	Paulownia
	Chiang Rai	4,370	Aau.,Csi.,Eca.,Lle.
	Kamphaeng Phet	3,378	Eca.,etc.
	Lampang	2,637	Etc.
	Phayao	7,596	Aau.,Csi.,Eca.,Lle.
	Phrae	21,666	Aau.,Cju.,Eca.,Lle., Maz.,Tgr.
	Tak	1,000	Eca.,Lle.
Northeast	Buri Ram	2,255	Ama.,etc.
	Nakhon Ratchasima	2,306	Cju.,Eca.,Lle
	Surin	2,000	Ect.
Central	Chachoengsao	15,301	Eca.,Gar.,etc.
	Chanthaburi	8,435	Cju.,Lle.
	Chon Buri	943	Cju.,Lle.
	Kanchanaburi	2,076	Etc.
	Phetchaburi	9,527	Ain.,Eca.,Lle.,Rap.
	Prachuap Khiri Khan	12,637	Ain.,Aau.,Ceq.,Cju.,Eca.
	Ratchaburi	11,484	Aau., Ceq.,Cju.,Eca.,Lle.
	Saraburi	7,500	Cju.,Eca.,Lle.
	Suphan Buri	1,200	Bamboos,etc.
	Trat	4,712	Cju.,Rap.,etc.
South	Chumphon	7,552	Etc.
	Nakhon Si Thammarat	3,000	Ceq.,Rap.
	Surat Thani	17,435	Ceq.,Cju.,Rap
	Total	150,643	

Note :

Aau.	:	Acacia auriculiformis
Ain.	:	Azadirachta indica
Ama.	:	Acacia mangium
Ceq.	:	Casuarina equisetifolia
Cju.	:	Casuarina junghuhniana
Csi.	:	Cassia siamea
Eca.	:	Eucalyptus camaldulensis
Gar.	:	Gmelina arborea
Lle.	:	Leucaena leucocephala
Maz.	:	Melia azedarach
Rap.	:	Rhizophora apiculata

Source : Division of Forestland Management, RFD (Personal contact, April 1988).

Another 257,431 rai of degraded forest land is being requested by private enterprises for commercial plantation (details in Table 20).

Table 20 : Degraded Forest Areas Requested by Private Enterprises for Commercial Plantation

Region	Province	Area (rai)
North	Chiang Mai	1,135
	Chiang Rai	600
	Kamphaeng Phet	1,454
	Lampang	11,162
	Phayao	24,187
	Tak	23,619
	Sukhothai	568
Northeast	Buri Ram	10,893
	Khon Kaen	1,000
	Nakhon Ratchasima	1,710
	Roi Et	18,431
Central	Chanthaburi	130,762
	Kanchanaburi	1,000
	Lop Buri	500
	Phetburi	4,379
	Ratchaburi	2,107
	Rayong	2,830
	Saraburi	7,900
	Trat	13,194
South	-	-
	Total	257,431

Source : Division of Forest Land Management, Royal Forest Department. (Personal contact) April, 1988.

7. There is no lack of new interest from the private sector to invest in forest plantations. Major companies such as Siam Pulp and Paper, Shell, and the Oji Paper Company of Japan, all have publicly expressed their interest to invest. Some have gone through the process of seeking promotional priveleges from the Board of Investment, while others have already applied for governmental land. At least one company is facing a lamentable problem when it found that the allocated land has already been encroached upon by squatters. Statistics confirm that there is an abundant supply of land with poor soil in forest reserves which is suitable for fast-growing trees. However most of the land is occupied by illegal settlers. This has become the single major obstacle to large-scale plantation, not the shortage of investment fund, nor the lack of governmental policy.

In dealing with tens of thousands of poor farmers, the private sector can not be expected to come up with solutions by itself.

Although there are successful cases in the private sector - farmer partnership in other arena of agricultural development, the case of fast-growing tree as an agricultural commodity requires special attention, due to its long gestation period. Thai farmers are known for their adaptability, ready to switch to new crop which may provide better income. However, investing in fast-growing trees for sale is a new venture in which most of them are still not familiar with. It would require the government to take the lead in providing viable solutuions.

8. Finally, for long-term viability, new markets for forest products should be explored. It is clear from the pulp domestic resource cost study that it is comparatively advantageous for Thailand to produce short fibre pulp for domestic use. This is because Thailand has favorable climate in growing fast growing trees. Also the Thai labor cost is relatively cheap when compared with those of industrialized countries. These factors will continue to exist in the foreseeable future and the Thai pulp production will likely remain competitive in the international market. Though the import duties and surcharges which were imposed on imported pulp to protect the local pulp industry during 1982-1986 were essential for the survival of some local pulp factories then, they may not be necessary now. A 10% import duty is still imposed on imported pulp. This measure is no longer essential since the world price of pulp has recovered at a rapid rate. The remaining 10% import duty can now be totally abolished.

References

Ahmed, Sadiq. *Shadow Prices for Economic Appraisal of Projects : An Application to Thailand*, World Bank Staff Working Paper Number 609, 1983

Bhumiphamon, Suree, 1986. *The Status of Multipurpose Trees in Thailand*, National Research Council.

Bruno, Michael. *Domestic Resource Costs and Effective Protection : Clarification and Synthesis*, in Journal of Political Economy, (January/February 1972).

Bunyavejchewin, S., B. Puriyathorn, and B. Boontawee. 1986. *Aboveground biomass, firewood and charcoal production, nutrient and energy of five tree species*, RFD Div. of Silviculture, Silvicultural Report, pp. 367-380.

Chadbunchachai, N. 1985. *Cost and return on investment of private Eucalyptus camaldulensis plantation in Chachoengsao province*, Master thesis, Chulalongkorn University. 158 p.

Chakrapholwararit, C, 1985. *Yield-density Effect of Eucalyptus camaldulensis*, Dehnh. Plantation. Master thesis, Kasetsart University. 93 p.

Chamroenprucksa, M. 1987. *The Production of Eucalyptus Camaldulensis*, Dehnh. Established under the Agroforestry Scheme. Thai J. For. 6 : 268-278.

Corvanich, A. 1982. *Fast-growing trees*, Forestry Association of Thailand, Bangkok. 227 p.

Dao Mongkolsamai and others, 1986. *Current Situation of Pulp and Paper Industry in Thailand*, paper presented in the Seminar on Pulp and Paper Industry Development in Thailand, organized by the Thai Industry Association.

Dasgupta, P.S., A.K. Sen and S.A. Marglin. *Guideline for Project Evaluation*, UNIDO, 1968.

Evans, J. 1983. *Plantation forestry in the Tropics*, ELBS and Clarendon Press, Oxford. 472 p.

Hyde, William F. *Forestry Sector Intervention : The Impacts of Public Regulation on Social Welfare.*

Jaakko Poyry Oy, 1987. *Fast-growing plantation*, Helsinki. 171 p.

Jaakko Poyry Oy, 1987. *Fast-Growing Plantations Impacts on the International Market Pulp, Linerboard and Woodfree paper Business.*

Lorchirachoonkul, Vichit and Thirapong Vikitset. *Thailand Power Tariff Structure Study*, National Institute of Development Administration (NIDA), September, 1986.

Pearson, Scott and Ronald W. Meyers. *Comparative Advantage Among African Coffee Producers*,in American Journal of Agricultural Economic, Vol. 56 (1974)

Petmak, P. and C. Chakrapholwararit, 1985. *Planting Eucalyptus in Agroforestry System*, A paper presented at the Eucalyptus Seminar, Royal Forest Department, Bangkok. pp. 125-141.

Phantumvanit, Dhira and Khunying Suthawan Sathirathai, 1987. *Pressure on Forests--the Thai Experience.*

Rao, *Eucalyptus in Some Aspects*, FAO.

Rativanich, T., A. Abhijatabutr, S. Sonthivanich, P. Atiwannapat and R. Mormanee, 1987. *Suitable Ages of Eucalyptus Camaldulensis Dehnh. for pulping*, Thai J. For. 6 : 414-436.

Sahasakul, Chaipat. *Features of Tax System in Thailand*, Thailand Development Research Institute (TDRI), December 1987.

Sanitprachakorn, Montri, 1986. *Development of Pulp and Paper Industry's Raw Materials*, Paper presented in the Seminar on Pulp and Paper Industry Development in Thailand, organized by the Thai Industry Association.

Sathirathai, Suthawan, 1987. *Preliminary Profile on Large Scale Commercial Reforestation by Private Sector.*

Spangenberg, Magnus, 1986. *World Pulp and Paper Industry and Its Reflexion on Thai Industry*, paper presented in the seminar on Pulp and Paper Industry Development in Thailand, organized by the Thai Industry Association.

Squire, Lin and G. Van der Tak. *Economic Analysis of Projects*, World Bank, 1975.

Taweesuk, S., S. Kachonsrichon, L. Tawornwong and S. Srilueng, 1987. *Eucalyptus surveys in Ratchaburi, Kanchanaburi and Suphan Buri provinces*, A report sumitted to Siam Pulp and Paper Co. Ltd. 197 p.

Thaiutsa, B., 1987. *Applicability of Silviculture to Improve Demonstration Forest*, A paper presented at Seminar on Management Guidelines of Demonstration Forest, Lampang. 17 p.

Thaiutsa, B. and S. Taweesuk, 1987. *Eucalyptus Plantation in Thailand*, Thai J. For. 6 : 437-443.

Thuammali, T., 1987. *Economic of Causuarina Plantation (Casuarina junghuhniana Mig.) in Changwat Chachoengsao.* Master thesis, Kasetsart University. 44 p.

Tingsabadh, Charit, 1987. *Culture and Environment in Thailand*, paper presented at the Siam Society Symposium in August 1987.

U-Boureaproy, Chalermporn, *Import Substitution Industries : A Case Study of Audio-Visual Industry*, A Master Degree Thesis, Faculty of Economics, Thammasart University, May 1986.

Wisuthachinca, Dhavit. *Customs Tariff of Thailand*, 1986.

Bank of Thailand. *Bank of Thailand Monthly Bulletin*, December 1987.

Department of Customs. *Foreign Trade Statistics of Thailand, December 1986*, 1987.

Department of Public Welfare. *Economics of Forest Sector in Three Land Settlements in North and Northeast Thailand*, Thai-German Land Settlement Promotion Project.

FAO, IBRD, WRI, UNDP. *The Tropical forestry Action Plan.*

IFCT. *Comparative Advantage of Electronics and Wood Processing Industries in Thailand*, 1981.

IFCT. *Economic Analysis of Projects*, August 1984.

International Science and Technology Institute, Inc., 1986. *Evaluation of Renewable Non-conventional Energy Project, Thailand*, Washington, D.C.

National Energy Administration, Thailand, 1984. *The Village Woodlot : Its Implementation in Thailand.*

NEB, 1987. *Thailand Natural Resources Profile*, prepared by Thailand Development Research Institute.

NESDB, 1985. *Rural Energy in Thailand Issues and Policy Directions.*

Office of Agricultural Economics. *Agricultural Statistics of Thailand Crop 1986/87*, Ministry of Agricultural of Co-operatives, 1987.

Office of the National Economic and Social Development Board (NESDB), *National Income of Thailand, 1986 edition.*

Royal Forest Department, 1985. *The National Forest Policy.*

Royal Forest Department, 1985. *The Private Forest Cultivation, A Survey Report*, Planning Division.

Royal Forest Department, 1986. *Utilization of Fast Growing Trees in Thailand*, Office of Private Reforestation and Extension.

Royal Forest Department, 1986. *You Ask-We Answer, Practical Problems on Reforestation* , Office of Private Reforestation and Extension.

Royal Forest Department, 1987. *Expenditure Data on Eucalyptus Cultivation*, Office of Private Reforestation and Extension.

Royal Forest Department, 1987. *Fast-Growing Tree Plantation with Agro-forestry System for Rural Development*, Office of Private Reforestation and Extension.

Royal Forest Department, 1987. *Forest Statistics of Thailand 1986*.

Royal Forest Department, 1987. *Impacts of Eucalyptus Camaldulensis on the Ecology in Thailand*, Office of Private Reforestation and Extension.

Royal Forest Department, 1987. *Policy of Reforestation in Thailand*, Office of Private Reforestation and Extension.

Royal Forest Department, 1987. *Utilization of Eucalyptus Camaldulensis*, Research Division.

Thai Pulp and Paper Industries Association, 1987. *The 1987 Directory*.

Thailand Development Research Institute (TDRI). *Clean Technologies for the Pulp and Paper Industry, The Textile Industry and Metal Coating and Finishing in Thailand*, February, 1986.

Tribal Research Institute (TRI), 1986. *The Hilltribes of Thailand*, Bangkok, Thailand.

UNDP/World Bank, 1986. *Northeast Region Woodfuels Supply Pre-investment Study*, A Joint UNDP/World Bank Energy Sector Management Assistance Program.

Appendix I

The FAO COMFOP Wood Utilization Estimation Model

The FAO's COMFOP model was originally developed for Camaroon, a country in Africa. It was designed to estimate future demands for wood products of that country. Since the estimated value is dependent on a set of independent variables reflecting the socioeconomic situation of that country, it can be used to predict wood product demand of any country, provided that acceptable independent variables are used with the model. Moreover there is room to add some additional forest related calculations into the model.

The COMFOP model was based on the methodological approach called "system approach" which covers the study of system under view to determine its salient features and components, and to discover their relationships and modes of behavior. From the constructed relationships, as a result of the system study, the approach could facilitate simulations of consequences of different assumptions concerning the economy's future development. There are major strengths and weaknesses of the approach with respect to economic research. The approach can deal with the dynamic situation, given certain model assumptions. In addition, the model developed with this approach could be used to deal with risk and uncertainty in the real economic situation. Furthermore, this approach normally does not have a predefined analytical structure, thus, it incorporates flexibility into the model. It has some weaknesses, however. There is no standard statistical or mathematical test for the validity of results.

Additionally, it requires knowledge of an overall system or various interrelationships within the system. Although this approach has some weaknesses, the model derived from it can certainly shed some light on the future demands for wood products.

Developed within the framework of "system approach" the COMFOP model is therefore different from a general econometric model.

The model was developed for a personal computer on spreadsheet program, "LOTUS 1-2-3". After setting up the computer, the user simply enters data into predesigned forms which are displayed on the computer screen. An interactive electronic spreadsheet program also allows the modification of the model to fit specific country conditions. A special advantage is its simplicity and rapid handling of sensitivity analysis.

The model's structure is consisted of 20 tables. Table 1-10 (T.1-T.10) are used as the space for input tables. The rest of the tables, table 11-20 (T.11-T.20), are those of outputs. The relationships among each table is presented in figure A.1. Descriptions for these tables are as follows :-

Table 1	B1...F26	Input data on GDP and Population
Table 2	B34...G50	Income elasticity for wood products, 5-year period
Table 3	B61...G95	Projected import
Table 4	B103...G131	Projected apparent consumption in the case of manual projection

Table 5	B138...G164	Export projection
Table 6	E170...E182	Conversion factor for roundwood to processed product (m^3)
Table 7	E180	Percent of residues
Table 8	B197...I209	Paper/pulp/wood matrixes
Table 9.1	B219...G243	Forest products 3 period for production and import
	B249...G256	Apparent consumption
Table 9.2	B266...D303	Production and trade figures
Table 10.1	B211...G345	Expected apparent consumption and export projection 1985-1995
Table 10.2	B353...G387	Expected apparent consumption and export projection 1995-2005
Table 11	B396...D398	Economic projection
Table 12.1-12.2		Demand projection by wood products
Table 13.1-13.2		Demand projection for paper and paper board
Table 14.1-14.2		Demand projection roundwood equivalents
Table 15		Demand projection fuelwood and charcoal
Table 16		Demand projection (roundwood summary)
Table 17		Demand projection (required Production)
Table 18		Demand projection (residues)

Table 19.1-19.2	Demand projection (quality distribution)
Table 20	Demand projection (aggregated required production)

In Table 11, the population and GDP are estimated at every five-year interval, as the following:

$$\text{Projected population} = \left[\frac{\%\ \text{Growth}}{100} + 1\right]^5 * \text{Base Year Population}$$

$$\text{Projected GDP} = \left[\frac{\%\ \text{Growth}}{100} + 1\right]^5 * \text{Base Year GDP}$$

Options are provided for calculating apparent consumption as "manual" or "automatic" in Table 12 as shown in figure A.2. In addition, an option for including or not including exports is also included as shown in Figure A.3.

In estimating future demand for wood products the model requires a set of variables. These are the present level of consumption, income elasticity (I.E.) and the projected gross domestic product (GDP) of that projected year. Income elasticity is defined as a percentage change in consumption (of a particular wood product) with respect to a change in GDP and the estimation of future GDP is based on regression technique and historical data.

Relationship between the estimated future consumption or demand for wood product and a base year's consumption can be illustrated through the income elasticity concept as the following:

$$I.E. = \frac{C_2 - C_1}{Y_2 - Y_1} * \frac{Y_1 + Y_2}{C_1 + C_2} \qquad (1)$$

Where C_1 = base year consumption or demand

C_2 = subsequent year consumption

Y_1 = base year GDP

Y_2 = subsequent year GDP

Equation (1) can then be rearranged to become a function of projected consumption C_2 as shown in the following equation.

$$C_2 = \frac{C_1 * [(I.E.*Y_1) - Y_1 - Y_2 -(I.E.*Y_2)]}{[(I.E.*Y_2) - (I.E.*Y_1) - Y_2 - Y_1]} \qquad (2)$$

Thus C_2 can be determined by substituting the values of parameters on the right hand side of equation (2).

Income elasticity is estimated from the relationship between consumption and gross domestic product (GDP). The relationship is:

$$C = f(GDP)$$

The value of I.E. is derived from the derivative of double log regression equation as follows :

$$\ln C = a + b \ln (GDP)$$

Where a and b are estimated coefficients.

Taking derivative of the above equation with respect to ln GDP, we have

$$\frac{d \ln C}{d \ln GDP} = b$$

The estimated coefficient b, thus, is the estimated I.E. This procedure was used in deriving income elasticity of all products.

Other data which are required for the model's prediction such as GDP and population growth rates are obtained from the TDRI macroeconomic projection (TDRI, 1986 and TDRI, 1987). The production and trade figures of wood products were found from various issues of Forest Statistics of Thailand and Export Statistics respectively.

Values of I.E. of some wood products which are required for the estimation of future demands are given in table A.1.

Table A.1 Estimated Values of Income Elasticity of Some Wood Products.

Wood Product	Value
Pulp	1.1
Particle Board	3.0
Fibreboard	0.7

Note : For wood charcoal, wood chip and parquet, only export demands are considered in this study. Cement based board is also limited by the industry's capacity. Hence there is no need for the I.E. values for the estimation of their future demands since no domestic consumption or demand is relevant for these products.

From the relationships established in the model and the parameters given in table A.1 the quantities of wood products required in the future can be estimated, given that the values of estimated population and GDP are fed into the model. The model's outcomes thus have only direct relationships with exogeneous independent variables i.e. population and GDP which are determined outside the system. It does not incorporate endogeneous and significant variables such as the commodity's price in the model. This is the main drawback of the model.

The model's feature can be illustrated by means of figure A.4. This figure illustrates the market demand curves for a particular product. The vertical axis measures the price per unit of good, and the horizontal axis measures the quantity of good demanded per unit of time. Two things should be noted concerning figure A.4. First, the market demand curve for a good slopes downward to the right. In other words, the quantity of good demanded increases as the price falls. Second the market demand curve pertains to a particular period of time. From the figure, it is simple to determine the relationship between quantity demanded and price. Unfortunately, the figure which represents the present model does not incorporate the effect of price changes on the projected demand. It does take into account the effect of population and income changes on the quantity demanded, however. As a result the demand curve shifts to the right as either income or population increases as shown in the figure.

The Model's Result Reliability

Reliability of results, when a model is used to predict or estimate the future values, is always a major concern of a researcher. This study is no exception and there is an effort to check how accurate the model can predict. Since the model is based on the system approach and no statistical test can be conducted for the model's reliability, other approaches must be introduced. In the following paragraphs, tests of the model's validity by means of comparing the calculated outcomes and the values actually occured will be presented.

Because only three wood commodities i.e. pulp, particle board and fibreboard will be estimated, by means of the COMFOP model, for their future domestic consumptions or demands, reliability tests will be done for these commodities only.

Reliability Test for Pulp

Estimated figures by the COMFOP model and the actual level of pulp consumptions during 1983-1986 are given in table A.2.

Table A.2 Comparison Between Estimated and Actual Values of Pulp Consumption (1000 mt/year)

Year	Estimated	Actual	Diff	% Diff
1983	137.17	191.00	53.83	28.18
1984	144.73	144.00	-0.73	-0.51
1985	152.72	212.00	59.28	27.96
1986	161.15	175.00	13.85	7.91

Data in table A.2 indicate the highest 28% difference between the actual and estimated values in 1983 and the lowest 0.51% in 1984. The estimates were underestimated when compared with the actual values in most cases. The reason may be because during this period the growth of pulp consumption was higher than that of the GDP. However, based on the comparison, the lowest projection accuracy is about 70% while the highest is about 99%. Thus the predicting ability is quite acceptable. Another factor that could contribute to high percentage differences in 1983 and 1985 was unexpected jump of pulp importation in these 2 years, to more than 120,000 ton/year, from a normal imported quantity of less than 100,000 ton/year.

Particle Board

Demand for particle board usually depends on the construction industry. In this study, import and export factors are disregarded. A simulation for the 1983-1986 period shows that the model tends to give overestimated values with 37% difference between the estimated and actual values in 1985 as the highest and 1.17% in 1983 as the lowest. (Table A.3). A factor contributing to the divergency can be the failure to take substitution effects into the model.

Table A.3 Comparison Between Estimated and Actual Values of Particle Board Consumption (1000 m^3/year)

Year	Estimated	Actual	Diff	% Diff
1983	32.52	32.90	0.38	1.17
1984	37.82	33.10	-4.72	-14.26
1985	44.12	32.20	-11.92	-37.03
1986	51.73	43.50	-8.23	-18.93

Fibreboard

Table A.4 shows a comparison between estimated and actual demands for fibreboard. As expected, the model's result is overestimated. The reason may be due to overestimation of export demand by the model. The highest percentage difference between the actual and estimated demand is 26 percent in 1985 while the lowest is 8.11 percent in 1984. It is anticipated that the long-term demand projection by the model can be considered as the upper bound.

Table A.4 Comparison Between Estimated and Actual Demand for Fibreboard (1000 m^3/year)

Year	Estimated	Actual	Diff	% Diff
1983	42	50.1	8.1	16.17
1984	44	40.7	-3.3	-8.11
1985	49	39.6	-10.6	-26.77
1986	52	46.8	-5.2	-11.11

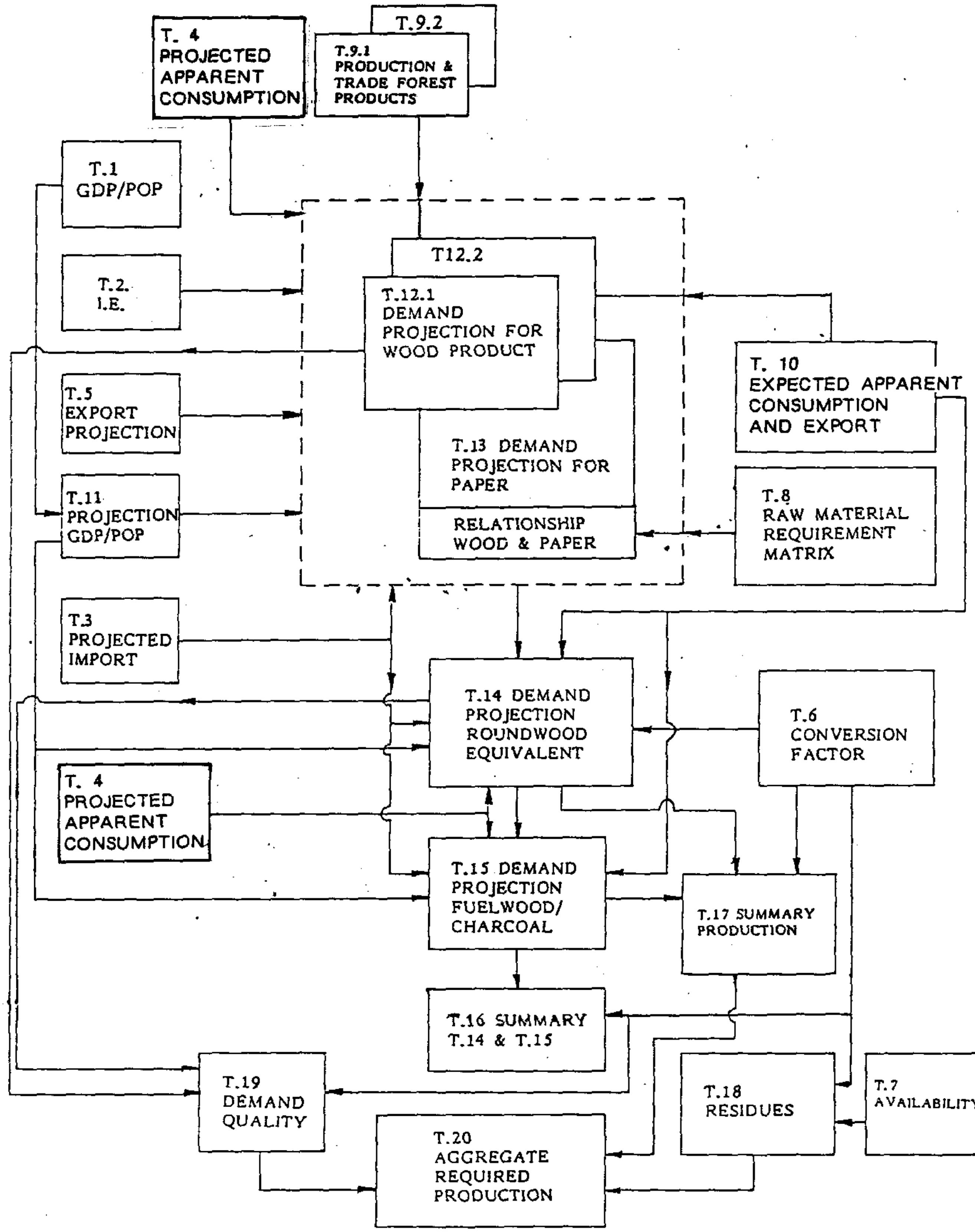
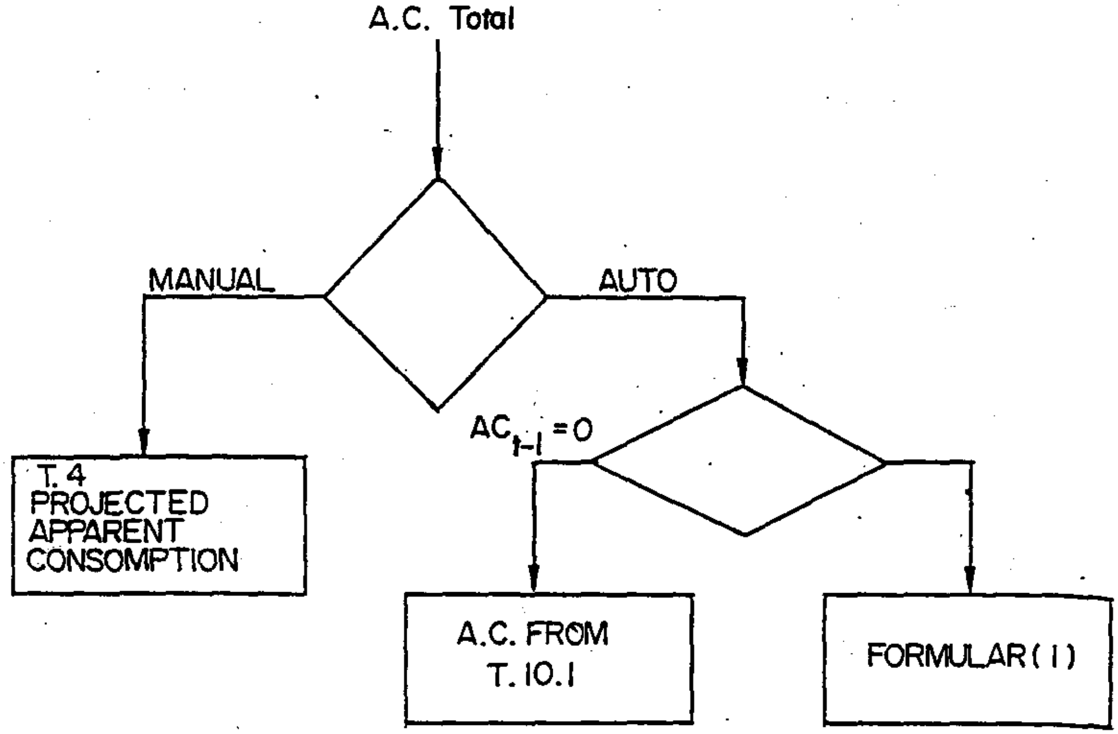


FIGURE A.1 : Relationships Among Tables



$$(1)\ \text{A.C.Projected} = \text{A.C.}_{t-1} \times \left[\frac{(\text{I.E.} \times GDP_{t-1}) - GDP_{t-1} - GDP_E - (\text{I.E.} \times GDP_E)}{(\text{I.E.} \times GDP_E) - (\text{I.E.} \times GDP_{t-1}) - GDP_E - GDP_{t-1}}\right]$$

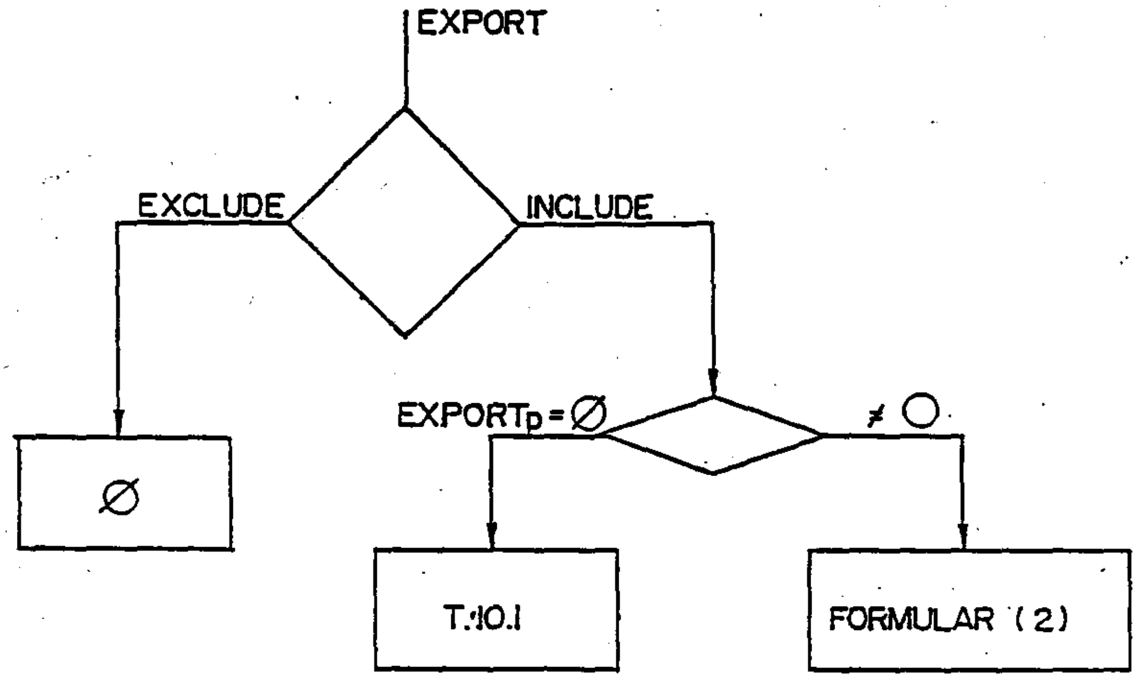
GDP_{t-1} : for the previous period (T.11)

I.E. : income elasticities at projected period (T.2)

GDP_E : expected GDP at calculated period (T.11)

A.C. : apparent consumption

FIGURE A.2 : Consumption Options



$EXPORT_p \neq \varnothing$: export value on the previous period $\neq \varnothing$

$$(2)\quad EXPORT_E = EXPORT_P \times \left[1 + \frac{\%\text{export growth}}{100}\right]^Y$$

% export (T. 5)

Y = number of years in the projected period

FIGURE A3 : Export Inclusion Options

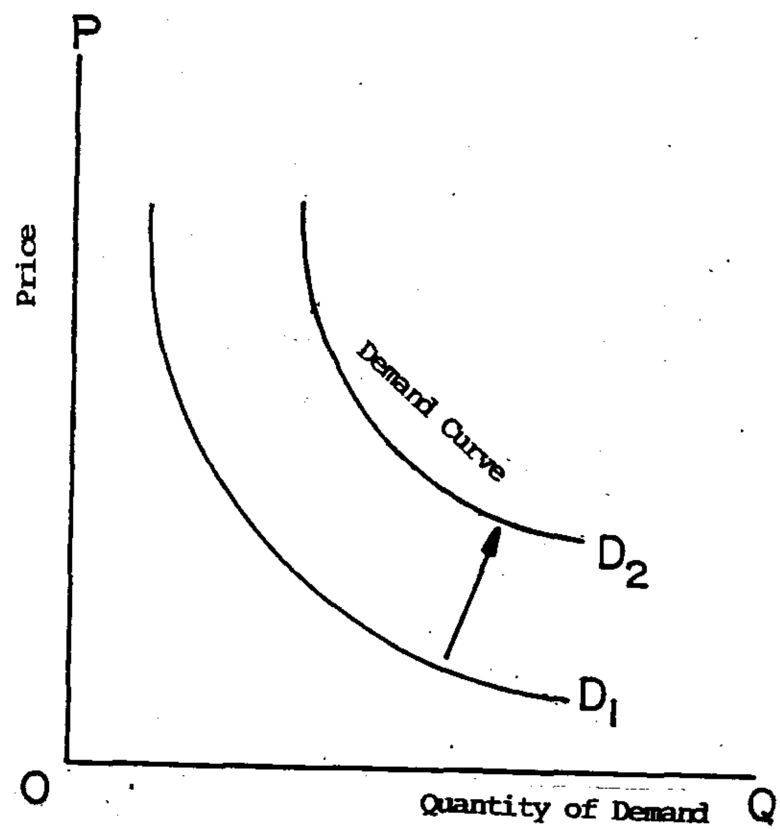


Figure A.4 A Typical Demand Curve for a Product

Appendix II

Nature and Property of Some Fast-Growing Tree Species

ACACIA AURICULIFORMIS

Botanical name	:	*Acacia auriculiformis* A. Cunn. ex Benth.
Common names	:	Northern black wattle (Australia) Papua wattle (Papua New Guinea), Kasia (Indonesia), Kratin Narong (Thailand)
Family	:	Leguminosae (Mimosoideae)

This nitrogen-fixing tree is native to the savannas of Papua New Guinea and northern Australia. Because of its ability to grow well in tropical lowland on variety of soil types including infertile, clayey, saline and seasonally waterlogged soils, *Acacia auriculiformis* has been introduced to various countries in Southeast Asia including Thailand. It mostly is a medium-sized tree with heavily branched and short crooked stem of 40 cm in diameter and 20 m in height. Temperature range throughout Thailand is appropriate to *Acacia auriculiformis*. Although well adapted to drought, the species prefers humid climates with an average annual rainfall of about 1,500 mm. Its altitudinal limit as a plantation crop is below 600m. Soil pH is not a limiting factor for tree growth, because it grows well on acid soil derived from tin mining in the South (pH 3) as well as on papermill sludge (pH 9). *Acacia auriculiformis* has been successfully planted on the spoil heaps left after tin mining at Takuapa district, South Thailand.

Because of its fine-grained, easily finished nature, and its attractiveness, hardness, and durability wood, it is a valuable timber for flooring and furniture making. A 10-year-old plantation-grown *Acacia auriculiformis* has proved to be very promising for the production of high quality sulphate and neutral sulphite semichemical pulp. It is used for making pulp by papermills in West Bengal. The wood is also suitable for fuelwood with specific gravity of 0.60-0.75 and a calorific value of 4,800-4,900 kcal/kg as firewood and 7,650 kcal/kg as charcoal. 98.70 percent of *Acacia auriculiformis* stem can be used as firewood, while such percentage of branch is 35.81. 100 tons of its woody biomass can produce 25.64 tons of charcoal. The bark contains about 13 percent watersoluble tannin. A natural dye used in the batik textile industry is also extracted from the bark. (Bunyavejchewin et al., 1986)

Although direct seeding is possible, container-grown seedlings are recommended for industrial plantation. There are about 30,000-60,000 seeds/kg. In well-prepared ground, seedlings of about 4-6 months old or 15-30 cm tall can be planted successfully. Under optimal conditions, *Acacia auriculiformis* is very prolific and may reach 18 m tall and 20 cm diameter at age 10 to 12 years. An experiment on tin-mined spoils at Takuapa show that 8-year-old *Acacia auriculiformis* planted in spacing of 5 x 5 m yielded 17 cm diameter and 10 m tall with stem biomass and biomass of woody portions of 33 t/ha and 39 t/ha, respectively. Fertile planting sites in combination with intensive site preparation, cultivation, and fertilizer application in the early establishment phase should improve growth rate significantly. Moreover, due to its short-crooked trunk, careful selection and introduction of provenances having tall and straight stem is highly recommended in order to minimize this drawback for future plantations.

Acacia auriculiformis has been planted in Thailand in forest plantation since the last decade. Total areas planted throughout the country are 21,980 rai. Table A2.1 shows the plantation areas by provinces.

Table A2.1 Areas in rai of *Acacia auriculiformis* plantation.

Region	Province	Owner				Total
		RFD	FIO	TPC	Private	
North	Chiang Rai	-	-	-	102	102
	Lampang	100	-	-	-	100
	Nan	-	-	-	773	773
	Phitsanulok	250	-	-	21	271
	Phrae	303	-	-	-	303
	Tak	200	-	-	-	200
Northeast	Buri Ram	-	-	-	5	5
	Khon Kaen	945	-	-	-	945
	Loei	115	-	-	-	115
	Nakhon Phanom	20	-	-	-	20
	Nakhon Rat-chasima	1,050	-	-	-	1,050
	Nong Khai	-	-	-	20	20
	Roi Et	200	-	-	-	200
	Surin	900	270	-	10	1,180
	Ubon Ratcha-thani	3,310	-	-	-	3,310
Central	Chachoengsao	1,200	-	-	-	1,200
	Phetchaburi	225	-	-	-	225
	Prachin Buri	2,331	-	-	-	2,331
	Prachuap Khiri Khan	1,430	-	-	-	1,430
	Ratchaburi	730	-	-	-	730

Table A2.1 (cont.)

Region	Province	Owner				Total
		FRD	FIO	TPC	Private	
South	Chumphon	3,300	44	-	-	3,344
	Krabi	630	531	-	-	1,161
	Nakhon Si Thammarat	500	-	-	-	500
	Phangnga	750	-	-	-	750
	Ranong	1,450	33	-	-	1,483
	Songkhla	13	-	-	-	13
	Surat Thani	-	80	-	-	80
	Trang	-	139	-	-	139
	Total	19,952	1,097	-	931	21,980

ACACIA MANGIUM

Botanical name : *Acacia mangium* Willd.

Common names : Brown salwood, Sabah salwood, mangium, Katin Tepha (Thailand)

Family : Leguminosae (Mimosoideae)

Acacia mangium is a large, nitrogen-fixing tree growing along the boundary of warm and hot climatic tropical zones, either humid or wet. The temperatures of these areas are high throughout the year with 31-34°C for the mean maximum and 15-22°C for the mean minimum. The tree grows very fast and can be planted successfully on abandoned shifting cultivation areas. The amount of rainfall is a critical factor affecting the growth rate. In general, the mean annual rainfall of planting site should be between 1,500-3,000 mm or more. Although it can tolerate acidic soils of low fertility, yields may be reduced on adverse sites.

The wood is pale, yellow-brown colour with specific gravity of 0.56. It is one of outstanding multipurpose trees in the humid tropics. *Acacia mangium* can be used as firewood, having calorific value of 4,800-4,900 kcal/kg. Its fiber length of 1-2 mm makes it possible to become a major raw material for wood pulp industry. The wood is also excellent for producing particle board, especially to be mixed with *Albizia falcataria* wood at the ratio of 30:70. Since the timber can be sawn easily, planed to a smooth surface, it is suitable for furniture and cabinet-making as well as for veneer.

Due to its adaptability to a wide range of acidic soils in the moist tropical lowlands, selection of proper seed sources for a certain planting site is of prime importance. An experiment at Chachoengsao found that the provenances from Papua New Guinea grew faster than those from northern Australia. At 30 months of age, diameter at breast height and total height of the best provenances are of 13.9 cm and 8.7 m, respectively. For a proper provenance on a favourable site, mean annual increment of stem volume may approach 7.3 m^3/rai, but the average is about 5 m^3/rai/year. In Thailand, *Acacia mangium* should be planted in the South where annual rainfall is higher than 2,000 mm. Total areas planted are about 2,642 rai (Table A2.2).

Table A2.2 Areas in rai of *Acacia mangium* plantation.

Region	Province	Owner				Total
		RFD	FIO	TPC	Private	
North	Phetchabun	-	-	610	-	610
Northeast	Nakhon Ratchasima	1,121	-	-	-	1,121
Central	Chachoengsao	-	-	180	-	180
	Kanchanaburi	-	84	-	-	84
	Uthai Thani	-	-	386	-	386
South	Chumphon	-	-	68	-	68
	Krabi	-	193	-	-	193
	Total	1,121	227	1,244	-	2,642

AZADIRACHTA INDICA

Botanical name : *Azadirachta indica* A. Juss

Common names : neem, nim, Sadao (Thailand)

Family : Meliaceae

Azadirachta indica is an outstanding fast-growing tree of tropical arid zone. Since *Azadirachta indica* can grow well on shallow-nutrient-deficient soil, it is commonly found as the roadside plantation along Highway 1 to the North and Highway 2 to the Northeast. This medium-sized tree can survive the maximum temperature of up to 44°C and minimum temperature of 0°C. Although neem tree is a drought tolerant due to its deep-rooted system, a successful establishment requires an average annual rainfall of 450-1,150 mm. The optimum soil pH ranges from 5.5 to 6.2, while the elevation varies from 100 to 1,100 m. Two major limitations of artificial regeneration are soil salinity and seed viability. It does not grow well on saline soils. Seeds should be sown within 3 weeks after harvest.

Azadirachta indica is considered as a multipurpose tree. It has commercially exploitable by-products. Neem bark yields about 10 percent tannin. Neem oil is a useful ingredient in soap, pharmaceuticals, and cosmetics. Seeds and leaves contain the compound azadirachtin which is known as a promising insect and nematode repellent. Neem wood is relatively heavy similar to mahogany with an average specific gravity of 0.68. It is excellent for general construction and furniture making. For fuelwood, its calorific value is 4,700 kcal/kg as firewood and

6,670 kcal/kg as charcoal. 99.03 percent of stem dry matter can be used for firewood, while 28.32 percent is recorded for branch. The ratio of charcoal weight to woody biomass is 26.09 : 100.

Neem seed is rather big compared to that of *Acacia auriculiformis*. There are about 4,000 seeds/kg. Seed harvesting periods in Thailand range from March to May. Seeds do not retain their viability very long and have to be sown within 2 or 3 weeks after harvest. Although direct sowing of fresh seed in the shelter of existing vegetation is possible for artificial regeneration, successful guarantee in growth and survival is expected from transplanting of containerized seedling. Growth rate of young neem tree is fairly rapid. An experiment at Ratchaburi where soil is infertile and only 800-mm annual rainfall revealed that biomass increment of neem stem planted at spacing of 1 x 2 m was 1.34 t/rai/year. It is relatively low compared to the stem-biomass increments of *Eucalyptus camaldulensis* (3.22 t/rai/year) and *Leucaena leucocephala* (2.48 t/rai/year), but this figure is higher than those of *Cassia siamea* (1.15 t/rai/year) and *Acacia auriculiformis* (0.58 t/rai/year).

Plantation area throughout Thailand is relatively low in comparison to that of *Acacia auriculiformis*. The total areas planted are about 13,100 rai, almost 100 percent by the Royal Forest Department (Table A2.3).

Table A2.3 Areas in rai of *Azadirachta indica* plantation.

Region	Province	Owner				Total
		RFD	FIO	TPC	Private	
North	Tak	-	-	-	200	200
Northeast	Khon Kaen	2,200	-	-	-	2,200
	Nakhon Ratchasima	585	-	-	-	585
	Sakon Nakhon	100	-	-	-	100
Central	Kanchanaburi	1,290	-	-	-	1,290
	Phetchaburi	3,187	-	-	-	3,187
	Prachuap Khiri Khan	2,500	-	-	-	2,500
	Ratchaburi	550	-	-	-	550
	Saraburi	1,670	-	-	-	1,670
	Nakhon Sawan	-	-	-	21	21
South	Krabi	300	-	-	-	300
	Phatthalung	-	-	-	5	5
	Surat Thani	360	-	-	-	360
	Trang	-	-	-	100	100
	Total	12,742	-	-	326	13,068

CASUARINA EQUISETIFOLIA

Botanical name : *Casuarina equisetifolia* Forst. & Forst.

Common names : Casuarina, she-oak, she-oak, horsetail oak, ironwood, Son Thalae (Thailand)

Family : Casuarinaceae

The natural distribution of *Casuarina equisetifolia* extends along seacoasts from tropical India to Malaysia and subtropical Australia. This is generally a lowland tree, but it can be planted from sea level up to 1,000-m altitude. The amount of rainfall is not a limiting factor because it has been planted successfully in areas with annual rainfall as little as 200-300 mm or as much as 5,000 mm. The species tolerates calcareous and slightly saline soils, but it grows poorly on heavy soils such as clay. It is a fire sensitive species and does not coppice after burning.

Because of its salt tolerance and ability to grow in sand, *Casuarina equisetifolia* is commonly planted along coastlines and river-banks for windbreak and erosion control. Casuarina wood is dark color, heavy, and very tough. It is used for fishing pole and construction post. The wood is considered as one of the best firewood in the world and is used for both domestic and industrial fuel. It has a specific gravity of 0.8 - 1.2 with calorific values of 4,950 kcal/kg as firewood and 7,180 kcal/kg as charcoal. Due to its heavy knots originated from big branches, casuarina wood chip is not in common.

Artificial regeneration of *Casuarina equisetifolia* is generally made through transplanting of container-grown seedling. When seeds are planted outside the natural range, the soil may need inoculating with crushed nodules from natural stands. On proper sites, tree may grow 2-3 m high a year. At Prachuapkirikhan, the 7-year-old casuarina planted at spacing of 4 x 4 m has 15 cm in diameter and 19 m in height. Areas of *Casuarina equisetifolia* plantation are about 14,000 rai (Table A2.4).

Table A2.4 Areas in rai of *Casuarina equisetifolia* plantation.

Region	Province	Owner				Total
		RFD	FIO	TPC	Private	
North	Phichit	-	-	-	10	10
	Phitsanulok	-	-	-	83	83
Northeast	Nakhon Ratchasima	-	-	-	45	45
Central	Chon Buri	-	-	-	125	125
	Lop Buri	-	-	-	184	184
	Phetchaburi	565	-	-	-	565
	Prachin Buri	-	-	-	220	220
	Prachuap Khiri Khan	7,310	-	-	758	8,068
	Ratchaburi	5	-	-	-	5
	Rayong	-	-	-	118	118
	Suphan Buri	-	-	-	10	10
	Uthai Thani	-	-	28	-	28
South	Chumphon	50	300	9	32	391
	Krabi	-	1,222	-	-	1,222
	Pattani	17	-	-	-	17
	Phuket	1,800	-	-	50	1,850
	Ranong	300	-	-	-	300
	Surat Thani	700	-	-	33	733
	Total	10,747	1,522	37	1,668	13,974

CASUARINA JUNGHUHNIANA

Botanical name : *Casuarina junghuhniana* Mig.

Common name : Jemara (Indonesia), Son Pradipat (Thailand)

Family : Casuarinaceae

This tall and straight stem with symmetric conical crown casuarina was introduced to Thailand around 1900. Its is native to eastern Indonesia. *Casuarina junghuhniana* can grow in a wide range of altitudes from sea level to 1,500 m elevation. Although the tree is moderately drought tolerant, an annual rainfall of over 1,000 mm makes it grow faster. *Casuarina junghuhniana* can grow well in various types of soil, from compact clay with pH of 3.0 to light sandy soil having pH up to 7.

Because of its tall and straight stem in combination with small branches, the tree is commonly used for poles. Another advantage of tiny branches compared to *Casuarina equisetifolia* is its property to be used as wood chip and pulp. *Casuarina junghuhniana* wood both in forms of wood chip and small log is exported to Taiwan. The wood is also suitable for parquet flooring.

A major limitation for artificial regeneration of this species is that trees do not produce seed and must be propagated only by vegetative means. Twig cutting treated with 5 ppm IBA for 18-24 hours is in common. Growth rate of *Casuarina junghuhniana* is rather fast. It may reach 21 m in height and 15 cm in diameter within 5 years. For well-managed plantation on proper site, mean annual increment can be expected at 5-6 m^3/rai. Total areas planted in Thailand are about 40,000 rai (Table A2.5). It is the only species in man-made forest in which the planted areas of private sector are greater than those of the state.

<u>Table A2.5</u> Areas in rai of *Casuarina junghuhniana* plantation.

Region	Province	Owner				Total
		RFD	FIO	TPC	Private	
North	Kamphaeng Phet	-	-	-	407	407
	Phitsanulok	-	-	-	18	18
	Pichit	-	-	-	40	40
Northeast	Buri Ram	-	-	-	734	734
	Chaiyaphum	-	-	-	49	49
	Kalasin	-	-	-	26	26
	Khon Kaen	-	-	-	2,281	2,281
	Maha Sarakham	-	-	-	36	36
	Nakhon Phanom	-	-	-	15	15
	Nakhon Ratchasima	-	-	-	4,084	4,084
	Sakon Nakhon	-	-	-	117	117
	Si Sa Ket	-	-	-	30	30
Central	Ang Thong	-	-	-	84	84
	Chachoengsao	-	-	-	2,708	2,708
	Chai Nat	-	-	-	240	240
	Chanthaburi	-	-	-	1,057	1,057
	Chon Buri	-	-	-	500	500
	Kanchanaburi	-	-	-	3,642	3,642
	Lop Buri	-	-	-	338	338
	Nakhon Nayok	-	-	-	7,283	7,283
	Nakhon Pathom	-	-	-	2,939	2,939
	Nakhon Sawan	-	-	-	184	184
	Phetchaburi	450	-	-	1,905	2,355
	Phra Nakhon Si Ayutthaya	-	-	-	659	659
	Prachin Buri	-	-	-	1,544	1,544

Table A2.5 (Cont.)

Region	Province	Owner				Total
		RFD	FIO	TPC	Private	
	Prachuap Khiri Khan	100	-	-	3,791	3,891
	Prathum Thani	-	-	-	845	845
	Rayong	-	-	-	437	437
	Samut Sakhon	-	-	-	10	10
	Samut Songkhram	-	-	-	717	717
	Saraburi	15	-	-	18	33
	Sing Buri	-	-	-	10	10
	Suphan Buri	-	-	-	1,521	1,521
	Trat	-	-	-	178	178
	Uthai Thani	-	-	-	62	62
South	Chumphon	-	-	-	207	207
	Surat Thani	-	-	-	160	160
	Total	565	-	-	38,876	39,441

EUCALYPTUS CAMALDULENSIS

Botanical name : *Eucalyptus camaldulensis* Dehnh.

Common name : Red river gum, red gum, river gum

Family : Myrtaceae

Although *Eucalyptus camaldulensis* is native to Australia, plantations are mostly found in Africa, Latin America, and around Mediterranean. *Eucalyptus camaldulensis* and *Eucalyptus globulus* are the most widely planted eucalypts in the world. The species can grow in an array of climates from arid and semiarid to tropical and subtropical. It has the ability to grow on relatively poor soils. It is also known as an outstanding salt-tolerant species. The trees withstand both lower and upper critical temperatures. A lower limit of rainfall for commercial plantations is 400 mm/year, although the trees can grow well in drier areas. Also, an upper limit of altitude is about 800 m.

The reddish durable hardwood resistant to termites of red river gum is useful in general construction. As firewood, the timber from *Eucalyptus camaldulensis* has few equals. It is a good charcoal wood, not only for cooking but also for steelmaking. The specific gravity of wood is about 0.65 with a calorific value of 4,760 kcal/kg as firewood and of 6,450 kcal/kg as charcoal. 89.24 percent of stem can be used as firewood, while such percentage of branches is zero due to its small limbs. (Bunyavejchewin et al., 1986). At least 39.46 percent of charcoal can be expected from the woody portions. Although the wood is harder, heavier, and more deeply colored than that from

Eucalyptus globulus, it is commonly used for paper pulp. The screened pulp yields decrease with increasing age of the trees from 3 years old (51.80 percent) to 10 years old (43.62 percent). The optimal rotation for pulp plantation is 5-6 years supplying pulp yield of about 45-46 percent. Bark of *Eucalyptus camaldulensis* accounts for 15 percent by weight and 17 percent by volume of green wood. For wood chip production, percentage of chip gained from green wood is 51 by weight and 215 by volume (Rativanich et al., 1987).

Eucalyptus camaldulensis was introduced to Thailand in 1946, but large-scale plantation was not established until 1978. Due to its ability to grow successfully in a wide range of environment, red river gum has been planted extensively making the total areas of about 10 percent of existing man-made forest (Table A2.6). About one-third of the areas planted belong to the private sector. Again, due to its wide range of environment, it is critically important to get seeds from a climatic zone similar to that of the planting sites. Two outstanding seed sources suitable to Thailand are those from Katherine (Northern Territory) and Petford (Queensland). With a right provenance on a favorable site, *Eucalyptus camaldulensis* grows very fast. Mean annual growth increments of 4.7 m in height and 4.0 cm in diameter were reported from the first 4-year plantation of 4 x 4 spacing planted at Sisaket. This results in the average stem wood of 14 m^3/rai in volume, 15.2 tons/rai in green weight, and 7.8 tons/rai in ovendry weight (Chakrapholwararit, 1985). For intensively managed plantation, stem biomass may reach 25 tons/rai equivalent to the volume of 45 m^3/rai at 6 years of age.

Table A2.6 Areas in rai of *Eucalyptus camaldulensis* plantation.

Region	Province	Owner				Total
		RFD	FIO	TPC	Private	
North	Chiang Mai	9,749	4,918	-	-	14,667
	Chiang Rai	1,611	-	-	-	1,611
	Kamphaeng Phet	564	-	-	2,930	3,494
	Lampang	2,592	3,201	-	602	6,395
	Lamphun	2,296	155	-	460	2,911
	Mae Hong Son	2,653	-	-	-	2,653
	Nan	22	-	-	280	302
	Phayao	2,139	-	-	-	2,139
	Phetchabun	2,253	-	1,767	1,036	5,056
	Phichit	210	-	-	1,386	1,596
	Phitsanulok	55	221	-	102	378
	Phrae	146	376	-	1,080	1,602
	Sukhothai	8	6,066	-	4,977	11,051
	Tak	1,634	90	-	2,624	4,348
	Uttaradit	932	-	-	417	1,349
Northeast	Buri Ram	4,051	-	-	2,974	7,025
	Chaiyaphum	10,007	11,408	-	-	21,415
	Kalasin	1,815	7,381	-	7,166	16,362
	Khon Kaen	4,798	8,178	-	8,486	21,462
	Loei	1,822	500	-	947	3,269
	Maha Sarakham	7,317	-	-	2,296	9,613
	Mukdahan	1,455	-	-	152	1,607
	Nakhon Phanom	3,713	-	-	575	4,288
	Nakhon Ratcha-sima	6,370	4,178	-	11,580	22,128
	Nong Khai	128	1,092	-	-	1,220
	Sakon Nakhon	291	-	-	-	291
	Si Sa Ket	1,213	4,151	-	2,749	8,113
	Surin	9,832	1,251	-	40	11,123
	Roi Et	-	2,805	-	-	2,805
	Ubon Ratcha-thani	13,522	8,352	296	-	22,170
	Udon Thani	4,384	539	-	1,735	6,658
	Yasothon	1,620	-	-	-	1,620

Table A2.6 (Cont.)

Region	Province	Owner				Total
		RFD	FIO	TPC	Private	
Central	Ang Thong	18	-	-	87	105
	Chachoengsao	7,203	-	7,310	23,282	37,795
	Chai Nat	53	-	-	-	53
	Chanthaburi	654	75	-	231	960
	Chon Buri	32	-	-	681	713
	Kanchanaburi	4,475	2,978	-	1,095	8,548
	Krung Thep-Maha Nakhon	-	-	-	105	105
	Lop Buri	1,242	-	-	229	1,471
	Nakhon Pathom	1	-	-	1,820	1,821
	Pathum Thani	-	-	-	64	64
	Phetchaburi	800	-	-	-	800
	Phra Nakhon Si Ayutthaya	205	-	-	3,215	3,420
	Phrachin Buri	89	6,464	-	5,582	12,135
	Prachuap Khiri Khan	1,153	-	-	1,181	2,334
	Ratchaburi	2,046	-	-	1,247	3,293
	Rayong	1,245	-	-	4,192	5,437
	Samut Songkhram	2	-	-	12	14
	Saraburi	527	-	-	600	1,127
	Sing Buri	35	-	-	10	45
	Suphan Buri	1,944	3,474	-	2,740	8,158
	Trat	855	-	-	638	1,493
	Uthai Thani	1,651	-	3,352	2	5,005
	Nakhon Sawan	140	-	-	765	905
South	Chumphon	6,722	10,545	1,184	1,213	19,664
	Krabi	4,609	11,110	-	-	15,719
	Nakhon Si Thammarat	1,650	-	-	127	1,777
	Narathiwat	837	-	-	9	846
	Pattani	-	-	-	15	15
	Phangnga	7,033	-	-	151	7,184
	Phatthalung	-	-	-	41	41
	Ranong	353	2,524	-	-	2,877
	Satun	-	-	-	7	7
	Songkhla	276	-	-	1	277
	Surat Thani	7,503	9,489	-	-	16,992
	Trang	1,474	2,985	-	215	4,674
	Total	154,029	114,506	13,909	104,151	386,595

LEUCAENA LEUCOCEPHALA

Botanical Name : *Leucaena leucocephala* (Lam.) de Wit

Common Names : Leucaena, leadtree, ipil-ipil (Philippines), lamtora (Indonesia), Kratin Yak (Thailand)

Family : Leguminosae (Mimosoideae)

Due to its wide variety, leucaena may vary in height from a round crown of many-branched shrub to a tall slender tree approaching 20 m. This species is native to Central America. It was introduced to the Philippines and other Spanish island possessions over 250 years ago. Leucaena is a species for lowland areas mainly below 500-m altitude. Since it is restricted to the tropics and subtropics, heavy frost in northern highland may kill leucaena. The optimal average rainfall for leucaena ranges from 1,000 to 3,000 mm/yr. However the species survives dry periods lasting 8 months and occasionally even 10 months, although long dry season greatly reduces productivity. Leucaena grows well only in neutral or alkaline soil with pH of 6.0-7.7. Root system will be stunted and growth rate is slow if it is grown on acidic soils, especially where soil pH is below 5.5.

Leucaena is also a multipurpose tree. Besides its role in nitrogen fixation, leucaena grown on well-drained, fertile soils, and regularly clipped, produces large quantities of foliage serving as forage for both ruminant and nonruminant animals.

However, the foliage contains mimosiore which causes weight loss and ill health in nonruminants if consumed in excessive amounts, i.e., above 7.5 percent of the diet. *Leucaena wood is a major* source of raw material for pulp and rayon manufacture. Although fiber length is short in comparison to softwoods, pulp quality is acceptable and is comparable to that of other fast-growing hardwoods. Pulp yield is high, 50-52 percent. The wood can also be converted to fibreboard. It also makes good firewood and charcoal with the calorific value of 4,200-4,600 kcal/kg as firewood and 7,060 kcal/kg as charcoal. 98.53 percent of stem can be used as firewood. Due to its big branches, such percentage is as high as 59.07 for branch. Dry matter of leucaena wood can produce 32.68 percent charcoal.

Similar to *Acacia auriculiformis*, artificial regeneration can be done both by direct seeding and transplanting. There are about 16,000 seeds of high viability per kg. Where soils are suitable and rainfall is well distributed throughout the year, planted tree can reach height of about 18 m in 4-8 years and diameter of 20-35 cm after 8 years of growth making the average annual increments of about 5.0-6.5 m^3/rai. However, growth rate and yield are relatively low if the plantation is not well-managed.

Large-scaled plantation of *Leucaena leucocephala* in Thailand was started about 10 years ago. Total areas planted are about 58,000 rai, mainly by the Royal Forest Department (Table A2.7).

Table A2.7 Areas in rai of *Leucaena leucocephala* plantation.

Region	Province	Owner				Total
		RFD	FIO	TPC	Private	
North	Chiang Mai	1,415	-	-	-	1,415
	Chiang Rai	-	-	-	182	182
	Lampang	800	-	-	-	800
	Nan	12,735	-	-	-	12,735
	Phayao	-	-	-	500	500
	Phetchabun	-	-	-	444	444
	Phitsanulok	250	-	-	-	250
	Phrae	1,406	-	-	100	1,506
	Tak	250	-	-	-	250
	Uttaradit	200	-	-	-	200
Northeast	Chaiyaphum	-	-	-	30	30
	Kalasin	1,100	-	-	-	1,100
	Khon Kaen	1,210	-	-	14	1,224
	Maha Sara-kham	2,300	-	-	-	2,300
	Nakhon Rat-chasima	14,720	-	-	115	14,835
	Nong Khai	-	-	-	8	8
	Roi Et	1,000	-	-	-	1,000
	Udon Thani	930	-	-	-	930
Central	Chachoengsao	60	-	3,105	-	3,165
	Kanchanaburi	-	181	-	-	181
	Lop Buri	-	-	-	4	4
	Phetchaburi	140	-	-	30	170
	Phra Nakhon Si Ayutthaya	-	-	-	125	125
	Prachin Buri	2,580	120	-	20	2,720
	Prachuap Khiri Khan	1,550	-	-	270	1,820
	Ratchaburi	5	-	-	-	5
	Saraburi	4,585	-	-	-	4,585
	Suphan Buri	-	28	-	-	28
	Uthai Thani	-	-	1,819	-	1,819
South	Chumphon	810	1,668	-	-	2,478
	Krabi	-	507	-	-	507
	Surat Thani	-	380	-	-	380
	Trang	-	216	-	-	216
	Total	48,046	3,100	4,924	1,842	57,912

MELIA AZEDARACH

Botanical name	:	*Melia azedarach* L.
Common names	:	Persian lilac, bead tree, umbrella tree, bastard cedar, Lian (Thailand)
Family	:	Meliaceae

Melia azedarach is deciduous, fast-growing, and medium-sized tree, about 20-30 m in height with a diameter up to 80 cm. It is native to Asia, but has long been planted in Africa, South America, and Australia. Although *Melia azedarach* is a lowland species, it is able to grow up to 200 m altitude. The tree grows in tropical and subtropical climates where mean annual temperature is at least 18°C. It is a drought tolerant species and can grow in areas with 600-1,000 mm annual rainfall. Although the tree can grow on a wide range of soils, industrial plantations should be established on well-drained, deep, and sandy loams in order to obtain the maximum growth.

A moderately soft, weak, and brittle wood is light in weight and is susceptible to attack by dry-wood termites. The wood is pale pink-brown with markedly decorative figure, used for cabinet and furniture making. It is planted in reforestation project by Thai Plywood Company Ltd. for veneer. Although it has a specific gravity of about 0.66 with a firewood calorific value of 5,043-5,176 kcal/kg, it is not in common use for fuel because of its softness. Like *Azadirachta indica*, *Melia azedarach* has insecticidal properties based on which its leaves and fruits are used to protect articles against insects.

Melia azedarach is normally propagated from seed by raising 6-month-old seedling. There are about 5,000 seeds/kg with an average germination percentage of about 65. High yields can be expected from plantation grown on deep soils with moderately intensive management. An experiment at Thong Phaphum, Kanchanaburi found that stem biomass of 6-year-old trees planted at spacing of 4 x 4 m were 7.17 tons/rai. Total areas planted are approaching 20,000 rai, over 80 percent by Forest Industry Organization and Thai Plywood Company Ltd. (Table A2.8)

Table A2.8 Areas in rai of *Melia azedarach* plantation.

Region	Province	Owner				Total
		RFD	FIO	TPC	Private	
North	Chiang Mai	50	-	-	-	50
	Chiang Rai	100	-	-	-	100
	Lampang	240	-	-	-	240
	Phetchabun	-	-	444	-	444
	Phitsanulok	100	-	-	-	100
	Phrae	820	-	-	-	820
Northeast	Chaiyaphum	-	100	-	-	100
	Kalasin	-	2,165	-	-	2,165
	Khon Kaen	100	100	-	-	200
	Loei	50	-	-	-	50
	Nakhon Rat-chasima	742	20	-	-	762
	Ubon Ratcha-thani	80	250	-	-	330
Central	Chachoengsao	-	-	4,456	-	4,456
	Kanchanaburi	-	1,428	-	-	1,428
	Prachuap Khiri Khan	29	-	-	-	29
	Prachin Buri	147	125	-	-	272
	Saraburi	500	-	-	-	500
	Suphan Buri	-	2,410	-	-	2,410
	Uthai Thani	240	-	2,043	-	2,283
South	Chumphon	-	-	577	-	577
	Krabi	-	75	-	-	75
	Ranong	-	58	-	-	58
	Surat Thani	-	93	-	-	93
	Trang	-	50	-	-	50
	Total	3,198	6,874	7,520	-	17,592

PINUS SPECIES

Botanical names	:	1. *Pinus caribaea* var. *hondurensis* Morelet
		2. *Pinus kesiya* Royle ex Gordon
		3. *Pinus merkusii* Jungh & de Vriese
		4. *Pinus oocarpa* Schiede
Common names	:	Pine, Son Khao (Thailand)
Family name	:	Pinaceae

Pinus kesiya and *Pinus merkusii* have natural ranges in Thailand, while *Pinus caribaea* and *Pinus oocarpa* are native to Latin America. They were introduced to Thailand through the UNDP Project on fast-growing-tree inventory for pulp and paper industry about 20 years ago. *Pinus merkusii* grows at relatively low elevations. All species grow well on tropical highlands of well-drained soils. Also, all species are sensitive to fire and do not coppice after burning.

Pinus caribaea and *Pinus oocarpa* grow little faster than *Pinus kesiya*, while the growth rate of *Pinus merkusii* is found to be slowest, especially in its early stage. Ten-year-old *Pinus kesiya* planted at Hod (Chiangmai) with a spacing of 2 x 3 m has an average height and stem biomass of 10.5 m and 8.5 tons/rai, respectively. Mean annual increment of stem biomass slightly increases with decreasing stand density, i.e., 1.16 tons/rai for 2 x 2 m spacing, 1.36 tons/rai for 2 x 3 m spacing, and 1.37 tons/rai for 2 x 4 m spacing. The wood of these tropical pines is excellent for long fiber pulp. It is also good for furniture making.

There are now almost 600,000 rai of pine plantation in Thailand (Table A2.9), mainly *Pinus kesiya*.

Table A2.9 Areas in rai of *Pinus* species plantation.

Region	Province	Owner				Total
		RFD	FIO	TPC	Private	
North	Chiang Mai	452,712	-	-	-	452,712
	Chiang Rai	78,241	-	-	-	78,241
	Lampang	5,850	-	-	-	5,850
	Mae Hong Son	22,825	-	-	-	22,825
	Nan	6,825	-	-	-	6,825
	Phayao	300	-	-	-	300
	Tak	6,450	-	-	-	6,450
	Uttaradit	100	-	-	-	100
Northeast	Loei	350	-	-	-	350
	Total	573,653	-	-	-	573,653

RHIZOPHORA APICULATA

Botanical name : *Rhizophora apiculata* L.

Common names : Rhizophora, Kong Kang (Thailand)

Family name : Rhizophoraceae

Rhizophora apiculata is an outstanding mangrove tree growing along the muddy seacoast. The tree is medium in size which may grow up to 35 m tall and 80 cm in diameter. It can survive in highly saline, poorly drained soils and grows well in areas that are flushed by tide.

Due to its heavy wood with a specific gravity of 0.9, 4,300 kcal/kg calorific value, and 2.9 percent ash content, *Rhizophora apiculata* is considered as one of the best firewood in the world. It yields about 43.8 percent charcoal of 0.49 g/cc density. It is also reported that 5 tons of *Rhizophora apiculata* equals the calorific value of 2-3 tons of coal. The wood is also used for poling as well as for paper pulp. Indonesia exported a lot of *Rhizophora* wood chips to Taiwan.

Artificial regeneration of *Rhizophora apiculata* is quite simple. In general, seeds germinate while still attached to the tree, but viability period is rather short after being harvested. Only direct seeding of newly harvested seed is used in reforestation program resulting in about 90 percent survival. Tree grows rather fast, 6-year-old trees planted in spacing of 1 x 1 m have woody biomass of 6.24 tons/rai, stem biomass accounts for 28 percent. At 9 years of age such woody biomass may reach 12.29 tons/rai. There are about 42,000 rai of *Rhizophora* plantation, mainly *Rhizophora apiculata* (Table A2.10).

Table A2.10 Areas in rai of *Rhisophora apiculata* plantation.

Region	Province	Owner				Total
		RFD	FIO	TPC	Private	
Central	Chanthaburi	5,357	-	-	-	5,357
	Samut Songkhram	-	-	-	8,204	8,204
	Trat	-	-	-	330	330
South	Chumphon	1,200	-	-	-	1,200
	Krabi	6,000	-	-	-	6,000
	Nakhon Si Thammarat	16,064	-	-	-	16,064
	Trang	4,539	-	-	-	4,539
	Total	33,160	-	-	8,534	41,694

APPENDIX III

A Domestic Resource Cost of the Thai Pulp Industry

I. Purpose and scope of the study

Pulp and paper is a typical wood-manufacturing industry which creates considerable value-added in the process of converting raw wood from commercial fast-growing tree plantation to intermediate or final goods. Generally, ratios of final products to round wood i.e. a ton of final product in proportion to tons of round wood required for most selected wood commodities in this study (charcoal, fuelwood, woodchip, particle board, cement-based board, fibreboard and parquet) are around 1:2.5. Only wood pulp requires 4.4 tons of round wood to produce one ton of pulp. This implies that the size of plantation required for pulp industry is the largest among all types of wood industries. Since pulp industry is the greatest potential user of raw wood, the industry's expansion would create largest backward linkages to commercial reforestation.

With a rather low rate of present paper consumption per capita of only 15 kilogram (kg.) per-year, compared with other countries such as Taiwan (80 kg.) and Malaysia (30 kg.), Thailand still has plenty of room to expand. However, from a rather strict economic view point, a country is worth producing a commodity if it has comparative advantage, otherwise it will be more advantageous to import that product. The governmental policy to protect the industry of which the country does not possess comparative advantage will definitely lead to inefficient allocation of resources.

This appendix aims at investigating the comparative advantage status of the Thai pulp industry. It will also explore the industry's import substitution potentials. With such potentials, the governmental policy to promote the pulp industry can then be reassured; not only to create an efficient resource allocation but also to strengthen the demand for more fast-growing trees.

To find out the comparative advantage status of the industry, the concept of domestic resource cost (DRC) is applied. A country is said to have comparative advantage in a commodity production if the cost of producing it is lower than the cost of foreign exchange, measured at the shadow exchange rate saved or earned from its production.(1) In measuring comparative advantage of a selected industry, DRC is an appropriate indicator since its definition is a measurement of real opportunity cost of total domestic resources to produce (or save) a net marginal unit of foreign exchange.(2)

Currently, the pulp industry in Thailand comprises two major private producers, with an overall production capacity of nearly 100,000 metric ton per annum. Based on available production cost data,

---

(1) IFCT, Comparative Advantage of electronics and wood - Processing Industries in Thailand, 1981.

(2) Bruno, Michael, "Domestic Resource Costs and Effective Protection : Clarification and Synthesis in Journal of Political Economy, (Jan/Feb/1972)

the study attempts to estimate domestic resource cost of the pulp industry when employing eucalyptus as their fibrous raw material. Results and their interpretations are illustrated in the following sections.

II. Theoritical Framework and Methodology

2.1 Theoritical Framework

As pointed out by Pearson and Meyer[3], the domestic resource cost per unit of foreign exchange earned or saved (DRC) is equivalent to a measure of comparative advantage. Based on the paper, it follows that a country has a comparative advantage in the production of a tradable commodity if the ratio of the opportunity costs of total (direct and indirect) domestic factors used in each unit of production to the net foreign exchange generated or saved per unit of the commodity (i.e. the export or import price less total foreign factors employed per unit of output) is less than the exchange rate.

Adapted from Bruno's article,[4] a simplified expression of DRC per unit of output j^{th} can be illustrated as follows :-

$$DRC_j = \frac{f_{sj}v_s + a_{ij}p_i}{u_j - m_j} \qquad (1)$$

where f_{sj} = domestic primary factors (such as labour, capital and land) used in producing output j^{th}

---

(3) Pearson, Scott and Ronald W. Meyers, "Comparative Advantage among African Coffee Producers" in <u>American Journal of Agricultural Economic</u> vol. 56 (1974)

(4) See Bruno, <u>Opcit</u>

v_s = shadow prices of domestic primary factors (in local currency)

a_{ij} = domestic nontradable commodity input i^{th} (intermediate goods) used in producing one unit of output j^{th}

p_i = shadow price of domestic non-tradable commodity input i^{th} (in local currency)

u_j = total value of output j^{th} measured at the border price, expressed in foreign currency (total foreign exchange earned or saved by producing output j)

m_j = total value of tradable inputs used in producing j, expressed in foreign currency (total foreign exchange cost in producing j)

The first term in the numerator is the direct value added of domestic factors (such as labor, capital and land) evaluated at their opportunity costs. This will include wage as return to labor and interest payment as return to capital owner. The second term of the numerator is an accounting value of the domestic non-tradable commodity inputs (local intermediate goods used in producing the final product j). These domestic non-tradable inputs may also require imported inputs for their own production; in this case, the imported contents in question will be considered as a part of m_j in the denominator. By removing all the imported inputs in the numerator and place it as a part of m_j in the denominator, eventually the numerator will be left with only direct and indirect domestic value-added measured at real opportunity costs.

2.2 Methodology

The DRC concept, in a more practical manner, as being defined by the IFCT and adopted by this study, is just a ratio of total opportunity cost of domestic resources to a net foreign exchange earned or saved in producing a product in questions. Its simplified expression is illustrated as follows[5]:

$$DRC = \frac{\text{total domestic cost (expressed in local currency)}}{\text{net foreign benefits (expressed in foreign currency)}} \quad \text{--(2)}$$

The study has modified the methodology employed by IFCT which is a rather practical approach. From (2), total domestic costs are calculated by adding up all direct and indirect domestic value-added measured at real opportunity costs. Direct domestic value-added items comprise the following :-

- salary and wage
- local interest payment
- depreciation cost of construction and local equipment
- return to local equity-capital

Indirect domestic value-added items consist of : -

- management and administrative costs, substracted by all their imported contents

---

(5) IFCT, Economic Analysis of Projects, August, 1984

- energy and water supply subtracted by all their imported inputs

- local non-tradable raw materials

Net foreign benefits come from total sales based on either c.i.f. or f.o.b. prices minus by the following costs of foreign exchange : -

- imported raw materials
- depreciation cost of imported machineries and equipment
- cost of imported contents in energy and water supply and other intermediate inputs produced locally
- foreign interest payment
- royalty and management fee for foreign technical assistance

In calculating DRC, cost of all inputs have to be evaluated at their real opportunity costs. However, market prices generally fail to correctly reflect the true social values of these inputs and factors of production. This study then follows Little-Mirlees and Squire-Vander Tak approach as adopted by IFCT in using conversion factors (ratio of shadow prices to market prices) to adjust for shadow prices. This approach assumes world prices of commodities as appropriate shadow prices.

General rules for converting market prices of tradable and non-tradable goods into their relevant accounting values are as follows : -

a) Shadow prices of Tradable goods

As mentioned earlier, a shadow price of any tradable goods is defined by its border price which represents foreign exchange forgone for imports and those earned by exports. As such, the c.i.f. (cost, insurance, freight) price stands for the shadow price of importable goods whereas the f.o.b. (free on board) price is particularly for exportable goods.

To convert local market price into its relevant border price, the following adjustment must be made[6] : -

$$P_{mj} = \frac{P_{dj}}{(1 + t_j)\{1 + b_{mj}\ (1 + S_j)\}} \qquad \text{--------(3)}$$

where P_{mj} = Border price of commodity j

P_{dj} = Domestic price of commodity j

b_{mj} = Importer's business and municipal tax rate on commodity j

s_j = Standard Profit rate

t_j = Ad valorem import tax rate, expressed as a percentage of c.i.f. price of commodity j.

In obtaining an f.o.b. price, formula (3) can also be used : but the final result has to be subtracted by transportation cost. (freight)

---

(6) U-Boureaproy, Chalermporn, "Import substitution industries : A Case Study of Audio-visual Industry" a Master Degree Thesis, Faculty of Economic, Thammasat University, May, 1986

b) Shadow prices for non-tradable goods

Typical non-tradable goods in this study includes electricity, water supply, construction, labor cost and administrative cost.

Theoretically, these items can be shadow-priced on the basis of its marginal social cost (MSC), marginal social benefit or a weighted average of the two.[7] Through marginal social cost (MSC) approach, non-tradable inputs will be divided into primary factors and tradable contents. The primary factors (labor and land, for example) are evaluated at their shadow prices while the tradable goods are to be directly converted into shadow-prices in terms of their border prices. MSB can be derived based on consumers' willingness to pay.

In practice, general conversion factors can be applied to these non-tradable values so as to yield their relevant shadow prices which actually are equivalent to their free trade values.

This study adopts the Standard Conversion Factor (SCF) in adjusting for social cost of non-tradable components.

---

(7) Ahmed, Sadiq "Shadow Prices for Economic Appraisal of Projects : An Application to Thailand" World Bank Staff Working Paper Number 609, 1983

SCF translates domestic prices into border prices expressed in units of the domestic currency(8) and can be determined by the following formula(9)

$$SCF = \frac{M + X}{M(1 + t_m) + X(1 - t_x)} \qquad \text{---------(4)}$$

where

M = c.i.f. value of imports

X = f.o.b. value of exports

t_m = average tax on imports

t_x = net average tax on exports

Furthermore, the SCF bears a close relationship to the concept of shadow exchange rate (SER) which has been determined in practice by UNIDO(10) as follows : -

$$SER = OER \left[1 + \left(\frac{M}{M + X}\right)(t_m) + \left(\frac{X}{M + X}\right)(-t_x)\right]$$

As such, the relationship between SCF and SER can also be expressed as follows : -

$$SCF = OER/SER$$

After obtaining DRC, comparative advantage of the product in question can be determined by comparing this estimated DRC to the official exchange rate (OER).

---

(8) Squire, Lin and G. Van der Tak, Economic Analysis of Projects, World Bank, 1975

(9) Ahmed, Sadiq, Ibid

(10) Dasgupta, P.S., A.K. Sen and S.A. Marglin, Guideline for Project Evaluation, UNIDO, 1968

$$\text{If} \quad DRC < OER$$

$$\text{or} \quad \frac{DRC}{OER} < 1$$

the product is worth to be manufactured locally.

III. Empirical result and its implication

This section illustrates an application of the methodology previously discussed in estimating DRC for the Thai pulp industry. Data used in the calculation are based on the modified production cost of two pulp firms with different production capacities and degree of management capability.

Production cost structures of firm A and B (in percentage) as illustrated in table A3.1 and A3.2 respectively, have been modified from the actual production cost of the Thai pulp industry when employing eucalyptus as fibrous raw material. All data used in this study are based on 1986 figures.

3.1 Calculation

Based on a simplified expression of DRC as illustrated in the preceeding section : -

$$DRC = \frac{\text{Total domestic costs (in local currency)}}{\text{net foreign benefits (in foreign currency)}}$$ (11)

---

(11) *This study adopts the US dollar as foreign currency.* Official foreign exchange in 1986 was 26.3 baht/US dollar.

Total domestic costs comprise cost of fibrous raw material (eucalyptus)[12], chemical cost excluding its imported contents, electricity cost, cost of water supply, labor cost, depreciation cost of local construction, administrative cost and local interest payment.[13]

Net foreign benefits consist of total sales of pulp in 1986 which was based on c.i.f. price of short-fibre wood pulp[14] minus the following costs of foreign exchange : -

- all imported content of intermediate inputs[15] (chemical electricity, and construction)
- depreciation cost of imported machines
- foreign interest payment

---

(12) Domestic price of eucalyptus wood is 600 baht per ton (Baht/ton)

(13) Based on the ratio of foreign liabilities to total deposit of the commercial banks, it may be assumed that foreign fund accounts for only 10% of the total private sector borrowing, of which the remaining 90% comes from local source of fund.

(14) Based on the Customs Department, average c.i.f. price of sulphate bleached kraft hard wood pulp in 1986 was 12,060 baht/ton.

(15) Percentage of imported contents in these selected intermediate items have been obtained from the Input-Output Table of 1982.

3.2 Assumptions

Several assumptions are made in adjusting for social costs. These are : -

a) Tradable goods (except for machineries). In this case, these items refer to chemicals and fuel oil. Their relevant social costs can be calculated based on border prices by using equation (3) expressed in the previous section. (Also see annexes 1 and 2).

For imported machineries and equipment which are generally under BOI tax-exempt scheme, their costs are already evaluated at border prices. No adjustment is required.

b) Non-tradable goods Assumptions are varied in great length as follows : -

b.1) Primary factors including labor and local interest payment. The study assumes that both labor and local financial markets work competitively enough so that their market prices almost reflect their real opportunity costs. Therefore no adjustment is made in this case.

b.2) Non-tradable intermediate goods, excluding electricity, are water supply and depreciation cost of construction. Each item accounts for less than 10 percent of the total production costs. The study thus uses standard conversion factor (SCF) to convert market values into their accounting values. (Also see annex 3).

b.3) Social cost of electricity has been estimated by multiplying the firms'electricity consumption with a shadow price of electricity.(16) (See also annex 4).

c) No adjustment has been made for administrative cost.

d) Opportunity cost of registered capital is an additional social cost which has been calculated based on the Minimum Loan Rate (MLR) of 12 percent per annum or the government bond rate of 8% per annum.(17)

e) Pollution cost has to be taken into consideration. In this study, firm A is assumed to adopt closed-cycle water treatment technology in abating pollution. Its cost of water supply can be replaced by pollution treatment cost. (See annex 5 for the calculation of social cost of pollution abatement).

f) All foreign costs are calculated based on percentage of imported content of each intermediate items in the 1982 Input-Output Table. However, they have to be adjusted to reflect real foreign exchange forgone by divided with SCF. ($SER = \frac{OER}{SCF}$)

Table A3.3 summarizes all the factors used in converting market values into accounting values.

---

(16) Shadow price of electricity is represented by shadow Long-Run Marginal Social Cost (LMSC) of EGAT as being estimated by NIDA in Thailand Power Tariff Structure Study, September 1986. The value was 1.29 baht/kWh in 1984. By adjusting the 1984 value with GDP inflator for electricity, the shadow LMSC in 1986 was equivalent to 1.54 baht/kWh.

(17) Bank of Thailand.

3.3 Results and its implications

First, data listed in Table A3.1 and A3.2 which have been expressed in terms of market prices have to be adjusted for their relevant social values. After the adjustment, these newly adjusted data then will be used for calculating DRC based on the simplified expression illustrated in the previous section.

Results of DRC estimation for the Thai pulp industry when employing eucalyptus as fibrous raw materials have been summarized in table A3.4 with sensitivity analysis of 4 different conditions indicated in the table.

Dividing DRC values in table A3.4 with the official exchange rate gives the ratios under 4 different categories as illustrated in table A3.5.

According to the DRC ratio criterion, if the ratio is less than unity, it implies that the social cost of producing the product is less than the cost of importing that same product from the world market. Under such circumstance, the country does possess comparative advantage in manufacturing the product in focus; for it is cheaper to produce it locally than to import.

The study's result indicates that firm A which represents a rather efficient producer has comparative advantage in producing pulp under all four circumstances; and the government should try to encourage its expansion. This is not the case for firm B particularly under case IIa in which a DRC ratio is slightly over one. However, for other three cases firm B still demonstrates its comparative advantage status with the DRC ratios less than one.

For the weighted average DRC ratio of these two firms, the result turn out to be less than one for all except case IIa. As a result, it may be concluded at this stage that Thailand does posses a certain degree of comparative advantage in pulp production provided that firms are operating efficiently. However, it should be noted that DRC results tend to be sensitive to interest rates (opportunity cost of capital) used in the calculation.

In addition, the so-called comparative advantage status which has been determined by the DRC ratio criterion (of being less than unity) also depends significantly on the level of its import c.i.f. price. When the DRC ratio of the product is less than one it does not always imply that its local cost of production is lower than the cost of production of the very same product in the world market. Instead, it indicates that the local production cost of this product is less than its imported c.i.f. price which can be driven up and down by supply-demand situation in the world market. One clear example is a drastic increase in the current price of pulp. After the wood-pulp market started to rise after four years of recession in the last quarter of 1985, the c.i.f. price of sulphate bleached kraft hard wood pulp rose from 11,335 to 14,432 baht per ton in 1987. This sharp rise in pulp price is a direct result of demand in the industrialized economies of Europe, US and Japan.

Regarding the result of the DRC ratio as illustrated in table A3.5, its low value can be better explained by this high price effect rather than its comparatively low cost of production.

Since DRC ratio varies with change in c.i.f. price, it is interesting to identify the price at the point which exactly turn DRC ratio to one. Table A3.6 summarizes all these prices under four different conditions.

From the table, it is quite obvious that if the c.i.f. price is more than 12,817 baht/ton, DRC ratio in all cases will be less than one and vice versa, if the c.i.f. price is lower than 10,587 baht/ton.

With a continuing upward trend of c.i.f. prices (14,432 baht/ton in 1987) in respond to sharp increase in world demand for pulp, Thailand's comparative advantage status for pulp industry as determined by the DRC concept will certainly remain strong. However this situation can be maintained up to the point when too many firms start to produce excess supply of pulp which will eventually drive down the price again.

Table A3.1 : Structure of production cost of Firm A
(full production capacities = 50,000 ton/year)

I Variable cost (per ton of pulp)	percent
1 Fibrous raw materials (eucalyptus)	27.1
2 Chemicals	13.4
3 Fuel oil	1.6
4 Electricity	9.2
5 Water supply	1
6 Labor	0.7
7 Other costs	6.2
TOTAL VARIABLE COSTS	59.2
II Fixed cost (per ton of pulp)	percent
1 Depreciation cost	
- Machineries	21.8
- Construction	3.9
TOTAL FIXED COSTS	25.7
III Administrative cost	1.6
IV Financial cost	13.5
TOTAL COST	100

note: Cost of fibrous raw material is calculated based on market price of eucalyptus of 600B/ton.

Table A3.2 : Structure of production cost of Firm B
(full production capacities = 70,000 ton/year)

I Variable cost (per ton of pulp)	percent
1 Fibrous raw materials (eucalyptus)	21.4
2 Chemicals	15.6
3 Fuel oil	14
4 Electricity	2.5
5 Water supply	1.5
6 Labor	5.5
TOTAL VARIABLE COSTS	60.5
II Fixed cost (per ton of pulp)	percent
1 Depreciation cost	
- Machineries	9
- Construction	0.6
TOTAL FIXED COSTS	9.6
III Administrative cost	10
IV Financial cost	19.9
TOTAL COST	100

note: Cost of fibrous raw material is calculated based on market price of eucalyptus of 600B/ton.

Table A3.3 : Conversion factors used in social cost adjustment

Item	Conversion factor	See Annex
1. Chemical conversion factor (CCF)	CCF = 0.75	1
2. Fuel oil conversion factor (FOC)	FOC = 0.67 or average cif price of fuel oil in 1986 = 2.25 Baht/litre	2
3. Standard conversion factor (SCF)	SCF = 0.94	3
4. Electricity	shadow price of electricity = 1.54 Baht/KWh	4
5. Pollution treatment	social cost of pollution treatment = 190 Baht/ton of pulp	5
6. Eucalyptus cost	case a : estimated shadow price of eucalyptus = 800 Baht/ton case b : estimated shadow price of eucalyptus = 692 Baht/ton	6
7. Opportunity cost of capital	case a : Minimum Loan Rate (MLR) = 12 % per annum case b : Government Bond rate = 8 % per annum	- -

Table A3.4 : Domestic Resource Cost (DRC)

	Case Ia	Case Ib	Case IIa	Case IIb
Firm A	22.93	21.94	25.66	23.2
Firm B	25.78	24.9	28.55	26.17
Weighted average between firm A and B	24.66	23.74	27.41	25

Notes : 1. Case Ia represents DRC when the calculation is based on the eucalyptus market price of 600 B/ton and the capital opportunity cost of 12% per annum.

2. Case Ib represents DRC when the calculation is based on the eucalyptus market price of 600 B/ton and the capital opportunity cost of 8% per annum.

3. Case IIa represents DRC when the calculation is based on the eucalyptus shadow price of 800 B/ton and the capital opportunity cost of 12% per annum.

4. Case IIb represents DRC when the calculation is based on the eucalyptus shadow price of 692 B/ton and the capital opportunity cost of 8% per annum.

Table A3.5 : Domestic Resource Cost Ratio (DRC/OER)

	Case Ia	Case Ib	Case IIa	Case IIb
Firm A	0.87	0.83	0.98	0.88
Firm B	0.98	0.95	1.08	0.995
Weighted average between firm A and B	0.94	0.90	1.04	0.95

Note : See notes in Table A3.4

Table A3.6 : Various imported c.i.f. prices of pulp which yield DRC Ratio = 1 (Baht/ton)

	Case Ia	Case Ib	Case IIa	Case IIb
Firm A	10922	10587	11847	11013
Firm B	11892	11595	12817	12021
Weighted average between firm A and B	11515	11203	12439	11628

Note : See notes in Table A3.4

Annex 1

Estimation of Chemical Conversion Factor (CCF)

From (3) in section II

$$CCF = \frac{P_{mc}}{P_{dc}} = \frac{1}{(1 + t_c)\ [1 + b_{mc}\ [1 + s_c)]}$$

where
P_{mc} = border price of basic chemical products

P_{dc} = domestic price of basic chemical products

b_{mc} = import business and municipal tax rate on commodity j

s_c = standard profit rate

t_c = advalorem import tax rate, expressed as a percentage of c.i.f. price of basic chemical products

Based on data from the Customs Department[1] for chemical industry.

b_{mc} = 1.5%

s_c = 8.5%

t_c = 30%

$$CCF = \frac{1}{(1 + 0.30)\ \{1 + 0.015\ [1 + 0.085]\}}$$

CCF = 0.75

(1) Wisuthachinca, Dhavit Customs Tariff of Thailand, 1986.

Annex 2

Estimation of Fuel Oil Conversion Factor (FOC)

Average retail price of fuel oil as announced by the Ministry of Commerce in 1986 was approximately 3.35 baht/litre.

Average c.i.f. price of fuel oil obtained from the Customs Department in 1986 was approximately 2.25 baht/litre.

$$FOC = \frac{\text{c.i.f. price}}{\text{retail price}} = \frac{2.25}{3.35} = 0.67$$

(1) Customs Department, *Foreign Trade Statistics of Thailand, December 1986*, 1987.

Annex 3

Calculation of Standard Conversion Factor (SCF)

$$SCF = \frac{M + X}{M(1 + t_m) + (1 - t_x)}$$

where M = c.i.f. value of imports

X = f.o.b. value of exports

t_m = average tax on imports

t_x = net average tax on exports

Based on data in 1986 from the Bank of Thailand[1]

M = 245.7 million baht

X = 231.5 million baht

Based on TDRI study[2] on features of the tax system in Thailand

t_m = 12.89 % in 1986

t_x = 0.35 % in 1986

SCF = 0.94

---

(1) Bank of Thailand, Bank of Thailand Monthly Bulletin, December 1987.

(2) Sahasakul, Chaipat Features of Tax System in Thailand, Thailand Development Research Institute (TDRI), December 1987.

Annex 4

Estimation of Shadow Price of Electricity

Based on the National Institute of Development Administration[1] (NIDA)

- The shadow long run marginal capacity cost for EGAT is 171.043097 baht/kW demand/month in 1984 price.
- The shadow long run marginal energy cost for EGAT is 0.9393 baht/kWh in 1984 price.

Shadow price of electricity = shadow long run marginal capacity cost (expressed in baht/kWh) + shadow long run marginal energy cost (baht/kWh)

$$= \left(\frac{171.043097}{\frac{\#hr/_{day} \times \#day/_{month}}{LF}}\right) + 0.9393$$

$$= \frac{171.043097}{\frac{24 \times 365/12}{0.67}} + 0.9393$$

= 1.29 baht/kWh in 1984 price

(where LF = load factor = 0.67 kWh/$_{\text{kW.\#hr./month}}$)

Converting the shadow price of 1.29 Baht/kWh in 1984 into 1986 price can be done by inflating this 1984 figure with a ratio

---

(1) Lorchirachoonkul, Vichit and Thirapong Vikitset, Thailand Power Tariff Structure Study, National Institute of Development Administration (NIDA), September, 1986

of 1986 price over 1984 price($\frac{P_{1986}}{P_{1984}}$) which has been illustrated as follows : -

Based on GDP of electricity from the national account[(2)]

GDP of electricity in 1984 at current price (GDP_{1984}) = 16990 million Baht

GDP of electricity in 1984 at 1972 price ($GDP_{84,72}$) = 7397 " "

GDP of electricity in 1986 at current price (GDP_{1986}) = 24362 " "

GDP of electricity in 1986 at 1972 price ($GDP_{86,72}$) = 8892 " "

$$GDP_{1984} = P_{1984} \times Q_{1984}$$

$$GDP_{84,72} = P_{1972} \times Q_{1984}$$

$$\frac{P_{1984}}{P_{1972}} = \frac{GDP_{1984}}{GDP_{84,72}} = \frac{16990}{7397} = 2.297$$

$$GDP_{1986} = P_{1986} \times Q_{1986}$$

$$GDP_{86,72} = P_{1972} \times Q_{1986}$$

$$\frac{P_{1986}}{P_{1972}} = \frac{GDP_{1986}}{GDP_{86,72}} = \frac{24362}{8892} = 2.740$$

$$\text{inflator} = \frac{P_{1986}}{P_{1984}} = \frac{2.740}{2.297} = 1.193$$

The shadow price of electricity in 1986 price = 1.29 x 1.193 = 1.54 baht/kWh

---

(2) Office of The National Economic and Social Development Board (NESDB), National Income of Thailand, 1986 edition

Annex 5

Social Cost of Pollution Abatement
(baht/year)

(closed-cycle water treatment technology)

	Private Cost[1]	Conversion	Social Cost
I. Variable Cost			
1. labor	150,000	-	150,000
2. maintenance	500,000	SFC = 0.94	470,000
3. power consumption (170 kWh /hr)	2,450,000	shadow price of electricity = 1.54 baht/kWh	2,293,368
4. chemicals	2,920,000	CCF = 0.75	2,190,000
5. contingencies (30%)	1,806,000	SCF = 0.94	1,697,640
total variable cost	7,826,000		6,801,008
II. Fixed Cost			
1. depreciation (10 years)			
- machinery	900,000	-	900,000
- construction	760,000	SCF = 0.94	714,400
2. contingencies (10%)	166,000	SCF = 0.94	156,040
total fixed cost	1,826,000		1,770,440
Total Cost	9,652,000		8,571,448

Total social cost of pollution abatement per ton of pulp[2] = 190 baht/ton.

---

(1) Thailand Development Research Institute (TDRI), Clean Technologies for the Pulp and Paper Industry, The Textile Industry and Metal Coating and Finishing in Thailand, Feb., 1986.

(2) Assuming that the firm operates at 90% of its full production capacity.

Annex 6

Estimation on Shadow Price of Eucalyptus

An estimation of shadow price of eucalyptus (as fibrous raw material to pulp industry) has been done in two steps as follows:

1. obtaining social cost of eucalyptus plantation
2. adjusting for social cost of transportation

Plantation costs of eucalyptus (baht/rai) faced by private sector in Chachoeng Sao Province are illustrated in the following table :-

Table 1 (Baht)

Item	Year1	Year2	Year3	Year4	Year5	Year6	Total
1.Direct Cost							
-Site preparation	507.01	-	-	-	-	-	507.01
-Planting	92.85	-	-	-	-	-	92.85
-Tending	224.67	202.36	9.24	-	-	-	436.27
-Agriculture supplies	534.52	-	-	-	-	-	534.52
-Machine expenditure	63.52	31.55	31.55	26.94	26.94	26.94	207.76
-Land tenure	180.00	180.00	180.00	180.00	180.00	180.00	900.00
2.Indirect Cost							
-interest payment	5.02	5.02	5.02	5.02	5.02	5.02	25.10
Total Cost	1,607.91	418.93	255.81	211.96	211.96	211.96	2,888.53

Source : Faculty of Forestry, Kasetsart University.

1. To obtain social cost of eucalyptus plantation

Land value needs to be adjusted to reflect its real opportunity cost. This study assumes that net return from an alternative crop, in this case cassava, represents a proxy for social cost of land.

Based on Agricultural Statistics of Thailand Crop(1), cassava price and its cost of production in 1986 are 0.78 and 0.42 baht/kg., respectively.

With the yield of 2297 kg./rai in Chachoeng Sao Province, the net return from cassava production in 1986 is estimated to be around 827 baht/rai.

Consequently, by replacing the net return from cassava for cost of land tenure in the previous table, newly adjusted cost of eucalyptus plantation in each year is illustrated below :

	Year1	Year2	Year3	Year4	Year5	Year6	Total 6 years
Total cost per rai	2254.6	1065.9	872.8	859.0	859.0	859.0	6770.3
Total cost per ton (given yield of 15 ton/rai)	150.31	71.06	58.19	57.27	57.27	57.27	451.35

(1) Office of Agricultural Economics, Agricultural Statistics of Thailand Crop 1986/87, Ministry of Agriculture & Co-operatives, 1987.

However, these still not correctly reflect the social cost of eucalyptus plantation. Additional opportunity cost of money invested during the period of 6 years without any return has to be taken into consideration as well. The results will vary with different rates of interest used in the calculation.

Case a : Assuming an interest rate used is equal to Minimum Loan Rate (MLR) of 12%

Additional opportunity cost of invested money during the 6-year period (based on the cost structure in table 1) is equal to 4075.7 baht/rai or 271.71 baht/ton of eucalyptus (given the yield of 15 ton per rai).

Case b : Assuming an interest rate used equal to the government bond rate of 8%

Additional opportunity cost of invested money during the 6-year period (based on the cost structure in table 1) is equal to 2504.4 baht/rai or 167.0 baht/ton of eucalyptus (given the yield of 15 ton/rai).

As a result, the social cost of eucalyptus plantation can be summarized as follows :

Case a : Social cost of eucalyptus plantation = 723 baht/ton

Case b : Social cost of eucalyptus plantation = 618 baht/ton

2. Social cost of transportation

Generally, transporting round wood from plantation to factory costs approximately 1 baht/ton/kilometer. Cost of diesel oil is assumed to be the sole transportation expense. In order to adjust for social cost of transportation, retail price of diesel oil has to be converted into its border price.

Average retail(2) and c.i.f(3) price of diesel oils in 1986 are 6.45 and 3.16 baht/litre, respectively. This yields the conversion factor of 0.49 for converting the value of diesel oil based on retail price into the value at border price.

This study assumes that an average distance between a plantation and a factory is 150 kilometers. (Maximum distance that still allow profitable investment is 200 kilometers). As a result, private cost of transportation is 150 baht/ton and 73.5 baht/ton of social cost.

Taking into account both plantation and transportation costs, shadow prices of eucalyptus as fibrous raw material are estimated as follows :

---

(2) National Energy Agency News, Dec. 1986

(3) Customs Department

Shadow Price of Fibrous Raw Materials (Eucalyptus)

	baht/ton of raw wood	baht/ton of pulp (4.92 ton of raw wood = 1 ton pulp)
Case a (interest rate = 12%)	800	3936
Case b (interest rate = 8%)	692	3405