PLANTATION FORESTRY AND CONTRACT FARMING FOR PULP FIBER PRODUCTION IN NORTH-EAST THAILAND

Feasibility study

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EXECUTIVE SUMMARY

Pulp demand rising, fiber supply limited

1. Projected demand for pulp and paper in Thailand in the coming 25 years is high, which renders rapid strengthening of country's own pulp milling capacity nationally well justified. Remarkable increment in pulp supply can be met only with planted trees, through plantations and contract farming. Exploitation of natural tropical forests has been banned in Thailand.

2. The proposed pulp mill of the Forest Industry Organization (FIO) has an output capacity of 100,000 ADT/a, with annual demand of 470,000 green tons (or 264,400 m^3/a) of Eucalyptus or other short fiber wood. The FIO's plantation land resource in North-East Thailand is 20,161 ha (126,006 rai), out of which 9,728 ha (60,803 rai) has already been planted with Eucalyptus camaldulensis. The additional area to be reforested is 10,432 ha (65,203 rai).

3. Steady wood supply for the pulp mill is secured if an average growth of 13.1 m^3/ha/a (3.7 tn/rai/a) is achieved. Currently the growth potential of the existing plantations (9728 ha) is at 11.4 m3/ha/a (3.2 tn/rai/a).

4. The planted and plantable area in the North East (20,161 ha) is estimated to sustain an annual timber supply of 410,000 gtn/a. The required management measures for this level are: i) reforest the remaining 10,432 ha with current practices at spacing 3 x 3 m, apply 7 years rotation, ii) enrichment plant the older understocked plantations into spacing of 2 x 4 m, apply 5 years rotation in agroforestry approach (with forest villagers' cassava every 5th year).

5. The remaining wood demand, 60,000 gtn/a, is to be procured from contract farming, open markets, or from the FIO's remote plantations. The concept of contract farming has already been established in Thailand, a working example is applied with Phoenix Pulp & Paper Co., Ltd. in Khon Kaen. Wood markets of plantation Eucalyptus have opened up in the North-East; the wood prices are in steady rise after the logging ban.

Improved tree stock and production optimization raises yields

6. With advanced tree and stand improvement, combined with production and management optimization, a rise in the plantation productivity to the level of 14.1 m^3/ha/a (sufficient supply from the FIO's own plantations) is within reach. This is justified by the following findings:

- Ecological conditions in the North-East Thailand favor Eucalyptus plantation forestry. Rainfall is over 1100 mm/a, soils in general are good enough for eucalypts; they are soft, only few rocky sites have been planted or reserved. Saline soils are rare in the plantation sites of the North-East.

- Thai foresters have developed advanced plantation establishment techniques. Complete ploughing and mechanical weeding are nowadays commonly practiced. Consequently, high survival rate and rapid early growth results. This is especially the case in the youngest FIO plantations.

- Majority of the older plantations are understocked (2 x 8 m spacing). Doubling the density will double the yield at currently practiced short rotation (5 years).

- 5 years' rotation does apparently not maximize pulp fiber yield. In Brazil the rotation of 7 years is practiced in comparable conditions but with much higher yield level. In Ethiopian highlands the biomass yield is maximized at 10-12 years rotation. Future raising of rotation time from 5 to about 10-12 years is likely to increase annual timber supply with 30-50 %.

- Miscellaneous, apparently poor Eucalyptus seed stock is used to raise seedlings. A shift from unimproved seed stock to improved **clonal** stock, has a potential multiplier effect of **2 (two)** on the annual biomass yields. Working examples are found in Aracruz Florestal pulpwood plantations in Brazil, and in South African Eucalyptus forestry. The Thai foresters are capable to adopt these techniques; clonal forestry applications are already under way in the Kasetsart University and in the Royal Forestry Department.

Ecological, social and economic impacts positive

7. The environmental impact of plantation forestry and contract farming in North-East Thailand is positive. It must not be expected that Eucalyptus plantings substitute for tropical rainforests. Eucalyptus must rather be regarded an alternative tree crop in agricultural and agroforestry systems suitable for impoverished soils and degraded lands.

8. The Thai forest research has shown locally that positive ecological effects of eucalypts overweigh the negative ones. In the positive side are the reclamation of open wastelands for tree cover and binding soil from wind and water erosion. Negative ecological effects occur when reforesting fragile upper zones of watershed areas. This problem is known in Thailand and is avoided with careful land management. Agroforestry application of eucalypts combined with cassava or other crops, are better studied in Thailand than anywhere else in the tropics.

9. Reforesting open lands with any tree crop increases the woody biomass density and counterbalances the effect of natural forest destruction on climate. Plantation forests and contract tree farming are a national Thai attack on the global greenhouse effect.

10. The alternative to Eucalyptus planting is the nitrogen-fixing tree Acacia mangium. It grows moderately well in areas where the rainfall exceeds 1400 mm/a. Working examples for ecologically sustained, humid tropics Acacia mangium forestry, are found in Indonesia. In drier areas A. mangium is expected to produce only half of the E. camaldulensis yields.

11. Logging ban from natural forests on one hand, and the already existing Eucalyptus plantations and woodlots on the other hand, have created an operating wood market in the countryside of North-East Thailand. Currently Eucalyptus timber is bought and sold as poles or to be processed for exported wood chips (mainly for Japan). Phoenix pulp mill is steadily increasing the plantation wood demand in the Khon Kaen area. The Eucalyptus wood markets are becoming an essential part of the agricultural and forestry sector in the rural areas. This has a positive effect on the economy of North-East Thailand in general, and on the

farmers livelihood especially. By adding a new crop into selection of profitable alternatives for cropping in impoverished soils, the welfare in the rural areas is expected to increase. Higher wood demand will mean higher security to the wood producing farmers and also steadily rising prices.

11. The forest village concept of the FIO is a model example of successful social forestry. The current experience already shows that shifting cultivators can be settled in the forest areas by providing land for housing, home gardens and permanent cropping, and by providing permanent additional income from plantation forest work. The continued satisfaction of forest villagers is a guarantee for a more positive attitude towards forest plantations.

12. The economic impact of the plantation forestry is positive. Provided improved stock is in use and management optimization is applied, an internal rate of return (IRR) of over 10 per can be expected from the plantations. Lower IRR from older, forest village combined plantations is also acceptable, as the social and agroforestry advantages justify shorter rotations and lower wood yield levels.

13. To guarantee steady pulp fiber supply as early as possible for the proposed pulp mill, it is recommended that possibilities for international soft loans are sought for, to ensure funding for rapid tree improvement and reforestation activities well in advance.

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SUMMARY ON CONCLUSIONS AND RECOMMENDATIONS

Conclusions

1. High economic growth rate in Thailand renders rapidly increasing demand of pulp, paper and paperboard inevitable.

2. The logging ban of 1989 from natural forests has geared the Thai forestry sector towards plantation forestry.

3. Thailand has an 85 years tradition in plantation forest establishment. Average success has, however, remained modest. During 1980s the annual reforestation achievements have sunk down.

4. The FIO is the leader of forest plantations. With its 30,000 ha of *Eucalyptus* plantations countrywide, the FIO has an advantage for immediate initiation of pulpwood production project.

5. The FIO has 20,161 ha of evenly scattered *Eucalyptus* plantation areas in the North-East region. They are moderately suitably located around the pulp mill sites, but the management of such scattered plantations is heavy.

6. The average road distances, 352 km to Buri Ram and 473 km to Ubon Ratchathani, and consequent wood transport costs are rather high from the plantations to the proposed pulp mill sites. From this point of view Buri Ram is more recommendable site.

7. The soils in the FIO plantation blocks are suitable for plantation forestry, especially with *Eucalyptus camaldulensis*. Proportion of stony, rocky, saline and soils with hard pan, is low.

8. In a long-standing series of species trials *Eucalyptus camaldulensis* has proved to be the most productive species for the waste lands and poor soils of the North-East Thailand. The finding is supported by plantation forestry at practical scale.

9. *Acacia mangium* has shown promising growth in Thailand, in areas with sufficient rainfall (at least 1400 mm/a). Better growth results over *Eucalyptus camaldulensis* have not been shown. In drier parts of the North-East *E. camaldulensis* yields about twice as well as *A. mangium*. Large scale plantation forestry with *Acacia mangium* can not

yet be promoted.

10. The provenance research with the most important plantation trees, e.g. with Eucalyptus has not advanced to practical level. The breeding gain is still awaiting the realization of improvement in growth rate of the practical plantations. Faster tree improvement gain can be expected from adopting the clonal Eucalyptus forestry.

11. The FIO is currently applying complete soil cultivation prior to planting and mechanical weeding several times after the planting. The results are excellent, well comparable to the best Eucalyptus projects in the world.

12. In the light of the measured, provisional yield tables, the currently practiced optimum rotation times for Eucalyptus camaldulensis are too short. Raising of rotation from 5 years to 10-12 years is likely to increase the mean annual increment by 30-50 per cent.

13. Counting on the established example of Aracruz Florestal, Brazil, there are reasons to expect doubling of the current yields from Eucalyptus camaldulensis by adopting the approach of clonal forestry. This would ensure sufficient raw material for the presently planned pulp mill, and would open space for enlargening the pulp mill industry in the near future.

14. Forest management system in the FIO plantations is insufficient for making the optimum management decisions. Preliminary steps in plantation inventory and mapping have already been initiated but they do not yet allow optimum plantation management.

15. R & D department under the pulp milling and plantation forestry project will facilitate rapid increase in annual pulp fiber harvests. The most important topics of applied research is the annual screening for better, superior species and clones.

16. At present pulp mill gate prices Eucalyptus camaldulensis plantation forestry is economically feasible in North-East Thailand. Provided improved stock is in use and management optimization is applied, an internal rate of return (IRR) of over 10 per can be expected from the plantations. Transport distance has a strong effect on the internal rate of return; the distance should not exceed 530

km.

17. The FIO Forest Village program has been successful in combining the needs of the people, reforestation and an initial supply of pulp wood from the established Eucalyptus plantations.

18. Contract farming for Eucalyptus pulp wood has already been initiated in North-East Thailand. The slightly rising trend in the pulp wood price also enhances farmers tree planting. There is an established Eucalyptus wood market in the rural areas of North-East Thailand.

19. Plantation forestry and contract farming do have both beneficial and harmful social impacts in the rural countryside. Confrontations with plantation forestry are becoming less frequent as the social problems connected with forestry, are shifting over to the forest reserves program. On the other hand, established wood markets from tree farming after the logging ban, have improved social relations between tree planting and the people.

20. Plantation forestry and tree farming are part of the Thai national attack against the global greenhouse effect. Combined impact of the forest reserve program, reforestation program and tree farming may be expected to counterbalance the tropical deforestation of Thailand, in the future.

21. There is no scientific evidence for significant harmful ecological effects of Eucalyptus in Thailand. Local forest research has shown that Eucalyptus camaldulensis uses less nutrients for its growth than Acacia auriculiformis.

22. The overall feasibility for the plantation forestry and contract farming for pulp fiber production and contract farming in North-East Thailand is good. Timely startup of the planting activities before the pulp mill construction is essential for the future wood supply.

Recommendations:

1. In order to avoid excessive fiber import, establishment of national raw material base from planted forests is highly recommended.

2. To back up the logging ban, and to facilitate Thai forestry industry to adapt new raw material base, an enhanced forest plantation program in demarcated and commonly agreed areas, is recommended.

3. Using the accumulated experience in reforestation technologies, the tree planting program should now be enhanced. Lessons from successful rubberwood plantations are also worth of transferring into pulpwood plantations.

4. The leading plantation establishment experience, of over 25 years, of the FIO should be fully utilized in the future reforestation programs of Thailand. The existing FIO Eucalyptus plantations should be further developed into nucleus and model of Thai pulpwood plantation establishment.

5. Small plantation blocks should be combined together, target area for management block should be 1,000 ha at minimum.

6. In order to avoid excessive transport costs it will be beneficial to concentrate plantation management efforts to the nearest plantations from the selected pulp mill site.

7. Plantation forestry with pulp wood crops, especially with Eucalyptus camaldulensis should be practiced on soils which may be impoverished in their top layers, but which are soft and deep enough. Soils, still good for agricultural crops should not be planted for block plantations, only for agroforestry applications.

8. Research and development in the species selection should continue to monitor long term productivity of Eucalyptus camaldulensis and to screen still more productive species, provenances and clones.

9. Field trials with Acacia mangium should go on in the North-East, to look for better provenances and to establish the environmental suitability, especially how the species

matches with the rainfall in various parts of the North-east Thailand.

10. For rapid gains from tree improvement in Eucalyptus forestry, it is recommendable shift the R & D from provenance research to clonal forestry. Field scale models are to be sought from the Aracruz Florestal in Brazil and from South African Eucalyptus forestry.

11. It is recommended that the developed Eucalyptus plantation establishment techniques, including complete ploughing prior to planting and mechanical weed control after the planting, will be used throughout the future reforestation activities.

12. Regarding the limited land resource, continuous study into optimum plant stocking and rotation time should go on. For pulp production optimization the quantity of high quality fiber should be maximized, not the quantity of the woody biomass only. This calls for justified efforts in R & D.

13. Clonal forestry with Eucalyptus camaldulensis should be initiated in the FIO plantations. Cloned seedlings should in the beginning be produced in a central nursery with an initial capacity of 5 million seedlings per year. Somdet plantation in the Kalasin province is a suitable site for both original plus tree selection, production of coppices (cuttings) and for establishing a central nursery.

14. The FIO plantation forests need an advanced forest management system. Working models for plantation forestry are found both in the temperate zone and in the tropics (Ethiopia and Indonesia).

15. Using the Aracruz Florestal as an example, R & D department should be established under the FIO to enhance rapid gain from species and clones improvement program. R & D department should be adequately staffed and equipped. The field trials should be concentrated in Somdet.

16. To lower the wood transport cost and to raise the internal rate of return, additional plantation areas should be sought near to the pulp mill site.

17. In each of the FIO Forest Village an assessment should be made based on number of families, total area under

Eucalyptus plantations, and the annual area need for taungya-husbandry. It is recommendable to gradually raise the rotation time from the present 5 years to 7 years, whenever the social conditions allow.

18. Contract farming with local farmers in the North-East should be initiated using the system developed by the Phoenix Pulp & Paper Co., Ltd. as a model.

19. Active measures - like steady or slightly rising Eucalyptus wood pricing and additional employment with the forest harvesting work - to improve social relations between the plantation forestry, tree farms and the rural community, should continuously be sought for.

20. Plantation and farm forestry should be promoted for increasing the overall woody biomass density in the Thailand countryside. The impact of tree farming should be especially determined.

21. Eucalyptus should preferably be planted on waste lands, on impoverished soils, not on agricultural soils.

22. In order to ensure steady and sufficient wood supply for the pulp mill, international soft loan funding should be sought for the reforestation program.

Preface

This study, especially by its field investigation part, has been assisted in many ways by the Forest Industry Organization (FIO) staff in Thailand. Mr. Chittiwat Silapat introduced the key persons in Bangkok, the background information and the central project ideas in the field. Mr. Montee Phothitai selected the FIO plantations sites, both fertile and less fertile, both highly and less successfully established, both *Eucalyptus camaldulensis* and *Acacia mangium* plantations as well as nursery sites and harvesting areas to be reviewed. Mr. Veera Songboonkaow assisted in many ways the measuring of the sample plots. Mr. Kanit Muangnil introduced the growth models and economic calculations made for the prefeasibility study and arranged the important post-field-trip meetings with the University of Kasetsart, Faculty of Forestry, and the Royal Forest Department (RFD) staff. He also made soil suitability rating for the FIO plantation blocks.

To all the FIO staff mentioned, as well as to all the plantation site staff unmentioned here, I would like to express my gratitude for the warm welcome, for the thoroughful caretaking in the country, and especially for the inspiring field visit in North-East Thailand.

In Joensuu, 24 January 1992

Veli Pohjonen

Abbreviations, acronyms, conversion rates

AFTA Asean Free Trade Area
AMA Acacia mangium
CAI Current Annual Increment
ECA Eucalyptus camaldulensis
dtn dry tonnes
FIO Forest Industry Organization
GDP Gross Domestic Product
gtn green tonnes (at harvesting moisture of 55 %)
IRR Internal Rate of Return
MAI Mean Annual Increment
NIC Newly Industrialized Country
R & D Research and Development
RFD Royal Forest Department
RTG Royal Thai Government

1 USD = 25.3 Baht

1 rai = 0.16 ha
1 ha = 6.25 rai

Basic density for E. camaldulensis 800 kg/m^3
Moisture content at harvesting 55 %
One green tn = 0.45 dry tonnes = 0.5625 m^3
One m^3 = 0.800 dry tn = 1.778 green tonnes

N.B. Eucalyptus camaldulensis is one of the heavy eucalypts. Eucalypts ... (1981) gives range of density at 12 % moisture of 810 - 1010 kg/m^3 for African plantations, i.e. 713 - 889 kg/m^3 at 0 % moisture. Average basic density of 800 kg/m^3 has been assumed throughout the study.

1. INTRODUCTION

1.1 Background

In December 1991 the Forest Industry Organization, a state enterprise arm of the Ministry of Agriculture and Cooperatives in the Kingdom of Thailand, launched a plan to establish a new short-fiber pulp mill in North-East Thailand. This plan is a direct response to recent changes in the Thai forestry sector and in the National Forest Policy. After the logging ban from the natural forests, of January 1989, there is a clear trend to gear the country's forest industry towards a new raw material base, especially towards wood from established plantations and from farm forestry. Consequently, the planned new pulp mill is to be furnished with wood grown in plantation forests and on farms. Eucalyptus camaldulensis, complemented with other short rotation species such as Acacia auriculiformis and Acacia mangium, would be the main raw material for the pulp mill.

The pulp mill has a planned output capacity of 100,000 air dry tons (ADT) per annum. The corresponding investment need is approximately 160 mill. USD (4 billion Baht). The input need of E. camaldulensis wood has been estimated at 470,000 green tons (gtn) per annum, or at

211,500 dry tons (dtn), or at 264,400 m^3 per annum. The two originally proposed sites for the pulp mill are located in Buri Ram and Ubon Ratchathani (Map 1), in the surroundings of which the FIO already has established E. camaldulensis plantations.

Map 1

For the pulp mill, a new company would be established, in which the FIO would hold a 32 % share of the capital. The company would procure the raw material mainly from the FIO plantations. In addition, to ensure a steady supply of raw material, the pulp mill would try to persuade farmers who plant eucalypts, to sign contracts with the company (Forestry ... 1991).

The pulp mill project will be subject to a series of feasibility studies. In the first step, a prefeasibility study of the pulp mill project was prepared by the FIO. It was submitted to the Government of Thailand in December 1991 (Prefeasibility ... 1991).

According to the prefeasibility study there are prospects for an economically sound industrial exercise. The internal rate of return (IRR) from the enterprise, is estimated at 11.08 % when a pulp mill gate price of 700 Baht/gtn (27.7 US$/gtn) for E. camaldulensis wood and a selling price of 14,800 Baht/tn (585 US$/tn) for the air dry pulp, are applied. - The pulp mill gate price for E. camaldulensis seems somewhat high (27.7 US$/gtn, or 61.6 US$/dtn or 49.2 US$/$m^3$) if it is compared with international reference price of Eucalyptus grandis wood in Brazil: 20 US$/$m^3$ (37.2 US$/dtn or 16.8 US$/gtn, counting 537 kg/m^3 and

55 % harvesting moisture for E. grandis wood). However, the anticipated pulp mill gate price of 700 Baht/gtn for E. camaldulensis logs is currently rather realistic in the Thai countryside. Khon Kaen pulp mill (Phoenix Pulp & Paper Co. Ltd.), for instance, paid 675 Baht/gtn at pulp mill gate in January 1992 (Pithak Thanamongkolin 1992). In the past year, the price had risen with 12.5 %, from 600 Baht/gtn in early 1991 (Laitalainen 1992).

As to the raw material supply, the prefeasibility study made estimates for the Eucalyptus plantation areas which already are, or would in the coming years be, under the authority of the FIO. They were estimated altogether at 30,490 ha (190,564 rai). However, only 20,596 ha (128,731 rai) of the total area are situated in the East and North-East regions, which would be the main wood supplying area for the pulp mill. The remaining 9,894 ha (61,833 rai) are located in the North and South regions, far away from the proposed pulp mill sites.

The prefeasibility study estimated the availability and sufficiency of the raw material supply, based on an inventory of the currently growing stock and on a wood production model. In the modelling it was assumed, that those plantation areas which are not fully stocked, will be reforested in the first step of the project.

Counting on the available, already planted areas, and on reforesting the understocked blocks with the current FIO plantation establishment practices, it was concluded that 300,000 gtn/a of Eucalyptus wood can be supplied from the East and North-East regions. This amount, however, is not sufficient for running the pulp mill at full capacity. The missing part of raw wood is 170,000 gtn/a. This was assumed to be transported from the remote FIO plantations in the North and South regions. The other alternatives are, either to procure Eucalyptus wood from contract farmers, or to procure it from open rural wood market in Thailand.

The second step in the feasibility studies is divided in 2 parts. One is a comprehensive feasibility study on the industrial aspects of the pulp milling. It addresses the technical, economic and environmental issues of the factory itself. The industrial feasibility study is scheduled to start in early 1992.

The other study is a comprehensive feasibility study on the raw material production aspects. It addresses the biological, technical, economic, environmental and social aspects of the plantation forestry and the contract farming.

For the feasibility study into the raw material production, a field mission was carried out in Thailand between 2 - 17 January 1992. It consisted of collection of background information, meetings with various forestry officials in Bangkok, and a 5-day field visit to the FIO *Eucalyptus* plantation sites in the North-East region. This feasibility study report is the outcome of the mission. For a complete itinerary of the mission, see Annex 1. For a list of people met, see Annex 2.

1.2 Scope

The scope and the problem context of the feasibility study is developed from the following chart:

Demand for Eucalyptus wood by the pulp mill?

Existing supply of Eucal. from FIO plantations?

How much the supply is insufficient?

Where and how to find additional raw material?

Improve productivity	Contract farming
How, and how much can we improve?	How to solve social problems?
At what cost?	At what cost?
Is it feasible?	Is it feasible?

In studying the problem context, the feasibility study addresses the following questions:

* Is there a continuous demand for Eucalyptus logs for pulp milling? Is the demand steady or possibly rising, taking into account that 1991 pulp mill gate price of wood is already rather high if compared to international price level?

* What is the biological, silvicultural and forest management status of the current FIO Eucalyptus plantations? Is their production comparable with other Eucalyptus plantations in the tropical world? Are there alternative pulp tree crops to eucalypts? Which measures should be taken to raise the productivity? Are these measures feasible in Thailand?

* Is the required reforestation program for the understocked forests realistic? Does the FIO have nursery, plantation establishment and tending as well as management capacity to run the reforestation program, say in three years? Which measures are needed to enhance the reforestation?

* Which is the potential of contract farming of Eucalyptus in the North-East, in the light of recent land conflicts in rural Thailand? Is it realistic to expect considerable amounts of pulp wood to be bought from the farmers? Which measures are needed to promote Eucalyptus farm forestry in the proximity of the pulp mill.

* Which are the environmental impacts in North-East Thailand connected with plantation and farm forestry of Eucalyptus and of other possible short-fiber and short rotation tree species?

* Which are the social impacts in North-East Thailand of the plantation forestry on one hand and of the farm forestry on the other hand?

* Is the Eucalyptus plantation forestry economically

feasible to the FIO? What is the sensitivity of the economics (Internal rate of Return, IRR) to the most important varying factors, like wood price in the future or wood transport distance to pulp mill?

Provided the demand supply analysis, plantation and farm forestry concepts, the raw material base and the environmental, social and economic settings of the project idea prove feasible, the study addresses the ways how to develop the concept further into reforestation, plantation forestry and contract farming project for North-East Thailand.

2. PLANTATION FORESTRY AND PULP FIBRE DEMAND IN THAILAND

2.1 High economic growth leading to rapidly increasing demand for pulp and paper

In the last decade the Thai economy has been one of the fastest growing in the world. The Gross Domestic Product (GDP) grew on average by 7.8 % per annum, with spectacular 3 years of 1988-1990, when the growth exceeded 10 % (World ... 1991). The Thai growth of GDP has been by far the fastest if compared to some other Asian countries (with remarkable forestry potential) (Table 1).

Table 1. Real growth of GDP (% per annum) in some Asian countries in 1988-1990 (World ... 1991).

	1988	1989	1990
China	10.8	3.6	5.0
India	9.7	5.0	4.3
Indonesia	5.8	7.4	7.1
South Korea	4.5	6.2	9.0
Philippines	6.4	5.6	2.5
Thailand	13.2	12.0	10.0

The high growth of GDP has direct consequences in the forest industries sector. Maybe the most important of them is the rapidly increasing demand for pulp and paper. If compared to international reference figures, the paper consumption in Thailand is still rather low: 20.1 kg/cap/a in 1990 (there was a 17.5 % rise from 17.1 kg/cap/a in 1989). The average for the world in 1990 was about 45 kg/cap/a, for Taiwan 163 kg/cap/a and for South Korea 102 kg/cap/a. Provided the economic growth in Thailand continues favorably, the rise of average paper consumption, at least to world average level, and apparently towards levels of Asian Newly Industrialized Countries (NIC-countries), is most inevitable. This background sets ambitious targets for the domestic fiber supply in Thailand.

The demand for the fiber supply is governed by the production and consumption of paper and paperboard (Fig. 1). Not all the consumed paper is manufactured in Thailand; the own paper production has covered only about 70 %. The rest has been imported.

There is no adequate and steady virgin pulp supply for the paper and paperboard industry in Thailand. The main raw material is waste paper which for instance in 1990 covered 71 % of the raw material need. Also waste paper is partly imported.

Fig. 1. Production and consumption of paper and paper-board in Thailand between 1970-1990, with prediction for 1991-1995. Average consumption in 1990 per capita was 20.4 kg.

The total domestic short fiber pulp production has been at level 150,000 ADT/a (Fig. 2). So far only non-wood virgin pulp has been manufactured in Thailand. Currently almost the entire domestic virgin pulp capacity is based on bagasse, bamboo, kenaf and rise straw (Table 2). The *Eucalyptus* pulp capacity so far is less than one per cent of total, estimated at 5000 ADT/a.

Fig. 2. Production and consumption of short fiber pulp in Thailand between 1985-1990, and prognosis for 1991-2002 (Prefeasibility ... 1991).

Table 2. Domestic pulp mills in Thailand in 1990 and their raw material base.

Pulp mill	Capacity ADT/a	Raw material
Phoenix Pulp and Paper Co. Ltd.	90,000-100,000	bamboo, kenaf, Eucalyptus
Siam Pulp and Paper Co. Ltd.	43,000	bagasse
Pang-pa-in Pulp and Paper Co. Ltd.	9,000-10,000	rice straw

There is a wide gap between the domestic short fiber production (0.15 mill. ADT/a) and the total paper consumption (1.15 mill. tn/a) in the country. Currently the gap is filled with imported short and long fiber pulp, domestic and imported waste paper and also with imported end product, then paper and paperboard.

The gap can even be forecasted to widen in the future. This due to the following 3 reasons:

* Paper and paperboard consumption are related to the rigorous education program in the country. Consequently, the paper consumption may grow faster than the GDP.

* The industry leaders in Thai forest industries have the ambitious aim to become the leading printing center in South-East Asia. Market share from Hong Kong is expected to shift to Thailand. Development of export oriented printing industry is already promoted by the Government.

* There are plans to form ASEAN Free Trade Area (AFTA) within the next 10-15 years. Consequently favorable paper export markets for Thailand may open up in the neighboring South-East Asian countries, for which Thailand has the transport advantage.

Within AFTA, the Thai forest industries may have a chance to export both pulp and paper. Inside a closed AFTA market this may even be the case although the current and planned pulp industry settings (somewhat high raw material cost, small pulp mill size) do not favor successful export endeavors. At current settings the Thai pulp industry is more likely to prosper at domestic market only, which by no means is too limited for the industry.

It must however be remembered that the Thai pulp industry must develop into international cost and price level by the time the AFTA trade opens up. Otherwise the neighboring countries, perhaps Indonesia, will fill the Thai pulp market with cheaper AFTA pulp, provided their pulp industries including the plantation programs for adequate and cheap raw material supply have developed favorably.

The two important aspects for the Thai Pulp industry in this respect are

i) the pulp mill size in one unit (should be 400,000 ADT/a), and

ii) the raw wood price at mill gate (should be 20 US$/$m^3$, or 16.8 US$/gtn for <u>E. camaldulensis</u> wood at 1992 price level).

Research and development into these issues should be carried out already before the AFTA-agreements will be signed and the common ASEAN markets open up.

As the demand for paper products in Thailand has been and will be increasing rapidly, the shortage of pulp is worsening year by year. Investors have become interested in pulp industry. The Royal Thai Government (RTG) also wants to support the establishment of pulp mills because of the favorable foreign exchange impacts. Also employment and income-generating impacts in the rural areas, to provide the raw material to the mills, are expected to increase.

Consequently new pulp mill projects have been announced (Table 3.). Several groups (Siam Pulp and Paper, Sahavighaya Group, Shell group and a Japanese Consortium) have expressed interest in plantation establishment).

Table 3. Planned new pulp mills for Thailand.

Pulp mill	First	Capacity	Raw material

	year	ADT/a	
Suan Kitti Co. Ltd.	1994	330,000	Eucalyptus
Phoenix Pulp & Paper Co. Ltd.	1993	100,000	Eucalyptus
SCL Co. Ltd.	1992	50,000	Eucalyptus, bamboo
Panjapol Paper Co. Ltd.		70,000	
FIO and partners	1995	100,000	Eucalyptus
Total		650,000	

Development of the Thai pulp and paper industries is now essentially dependent on the availability of domestic planted wood. The current plantation areas are far away from meeting the demand. The plantation area - with reasonable well established stocking - of eucalypts and other short fiber tree crops in Thailand, is of the order maximum 100,000 ha (cf. Bhumibhamon 1989).

If the country would aim at self-sufficiency in fiber production within 25 years, around 20 mill. m^3/a of raw wood would be needed. If this amount of wood were to be annually procured from Eucalyptus plantations, growing at current rate, about 10 $m^3/ha/a$, the required plantation area is 200-fold, i.e. 2 million hectares.

To cope with the economic growth and with the current forest policies, massive reforestation in Thailand is unavoidable. Is a plantation program of 2 million hect-ares too ambitious, unrealistic, even in a big country like Thailand? Perhaps not, since it is well comparable to the rubber tree (parawood, Hevea brasiliensis) husbandry in the country, the plantations of which now cover 1.72 mill. ha. The potential of farm forestry must also be counted for the area of 2 mill. ha. All the planted trees need no more grow in large blocks.

Conclusion: High economic growth rate in Thailand renders rapidly increasing demand of pulp, paper and paperboard inevitable. (..1)

Recommendation: In order to avoid excessive fibre import, establishment of national raw material base from planted forests is highly recommended. (..1)

2.2 Effects of logging ban in Thai forestry sector

In January 1989 the Royal Thai Government introduced a complete logging ban from her natural forests. This was a radical response to the ongoing deforestation and forest degradation, which had become both nationally and internationally recognized. The ban has a deep impact on the structure of Thai forest industries. In early 1989, for instance, operations of over 300 concessions were suspended. Tens of sawmills had to close down because of scarcity of wood.

Before the logging ban Thailand had been rapidly losing her forest resources mainly as a result of increasing population, followed by the conversion of forest into agricultural use, and of exploitative commercial cutting. In 1961, forests covered 27.4 mill. ha, or 53 % of the land area. In 1989 the remaining forest area was estimated at 14.4 mill. ha, or 28 % (Forestry statistics 1990). In 28 years 13 mill. ha of tropical forests were lost, on average 0.5 mill. ha/a. In recent years, unto the logging ban, the forest decimation has still been increasing. The last estimate by Hurst (1990) is 0.8 mill. ha/a.

The logging ban is a national attempt to reverse the decimation of natural forests in Thailand. If the change in the Thai forest industries does not take rapid steps in shifting the raw material base from indigenous natural forests to planted trees, there is a danger that the effect of logging ban is eliminated by illegally harvested and smuggled timber. The reforestation, plantation establishment and farm forestry programs connected with the new development in the forest industry, support therefore the national logging ban.

Conclusion: The logging ban of 1989 from natural forests has geared the Thai forestry sector towards plantation forestry. (..2)

Recommendation: To back up the logging ban, and to facilitate Thai forestry industry to adapt new raw material base, an enhanced forest plantation program in demarcated and commonly agreed areas, is recommended. (..2)

2.3 Rise of plantation forestry in Thailand

Thailand has a long experience in plantation forestry, one of the longest in the tropical zone. In the South-East Asian context Thailand can be credited the leading role in the reforestation technologies.

The roots of plantation forestry can be dated back to the establishment of the Royal Forest Department in 1896.

After that time a company that had a right to log teak trees, had to plant 4 teak seedlings for every teak tree harvested (Bhumibhamon 1989). In practice, the rule was not followed.

The first forest plantation program in Thailand began in 1906 with teak (Tectona grandis). In 1943 the forest planting program became one of the main activities of the Royal Forest Department. First two large scale teak plantations were established in Phrae and Lampang provinces (National ... 1988).

Since 1961, when the First National Economic and Social Development Plan was implemented, forest planting program has become one of the most important elements of the national policy on forest resource management. In this plan the RFD was recommended to plant both teak (800 ha/a) and non-teak species (1280 ha/a).

By the Second Plan (1967-1971) the scale of deforestation problem in the country started to become into public awareness. Consequently, the planting program was raised into 14,400 ha/a for teak and 8000 ha/a for the non-teak species. RFD started to grow trees in watershed areas. The state enterprises started to establish plantations with the aim of providing logs for their own uses.

In the Third Plan (1971-1976), reforestation was directed to deforested areas with planting targets of 24,000 ha/a for industrial plantations and 14,800 ha/a for watershed management forestry. In the Fourth Plan (1977-1982) the planting target was raised to 80,000 ha/a for all species. In this plan, also nursery technology was emphasized, as well as - for the first time - encouragement of private sector for plantation forestry.

Problems in the land availability were encountered while implementing the Fourth Plan. Consequently, the planting target for the Fifth Plan (1982-1987) had to be lowered to 48,000 ha/a. To counterbalance the reduced plantation establishment by the state enterprises, plantation establishment through tree farming and farm forestry were further emphasized.

At the end of the Fifth Plan (October 1987) the Council of Ministers approved the National Forest Policy. The main topics related to tree planting are:

* 25 % of the country shall be designated as production forests to produce timber and other forest products. The total forest coverage (including protected and conservation forests) shall be 40 %.

* The state shall promote reforestation by the public and private sectors for domestic industrial consumption. Export of wood and wood products shall be encouraged. Community forestry such as reforestation on public land and by the private sector, tree planting on agricultural marginal land, and the establishment of forest woodlots for household consumption, shall also be promoted.

* Wood energy as a substitute for fossil energy shall be promoted through energy plantations.

* Incentive system shall be established to promote reforestation by the private sector.

The policy indicates the importance of tree planting in Thailand. As the current total forest coverage in Thailand is around 20 per cent, or 10 mill. ha (Hurst 1990), reforestation has a massive task ahead. The figures should be doubled: the share of forest coverage to 40 %, and the forest area to 21 mill. ha. All available silvicultural means are needed to meet with that target. Reforestation via plantations is one of those means.

The Sixth Plan (1987-1991), based on the 1987 Forest Policy covered three main areas: i) planting of fast-growing trees, ii) planting of economic trees, and iii) establishment of community forests.

In summary 528,000 ha of forest plantations have been established by 1985, according to the RFD statistics (Table 4).

Table 4. Tree planting in Thailand, in industrial plantations, environmental plantations, in degraded reserved forests and in concessionaire's reforestation, situation in 1985 (Bhumibhamon 1989).

Year	Indust. plant	Envir. plant.	Refor. degrad.	Concess. reforest.	Total ha
-1978	99,100	33,300	30,000	31,000	193,400
1979	22,500	11,900	14,400	13,400	62,200
1980	38,800	12,900	15,800	13,900	81,400
1981	15,200	11,900	14,500	11,200	52,800
1982	9,000	5,600	4,900	12,900	32,400
1983	9,000	5,600	4,800	12,900	32,300
1984	9,000	9,000	5,200	10,800	34,000
1985	10,700	10,100	7,700	11,000	39,500
Total	213,300	100,300	97,300	117,100	528,000

Thai Forestry Master Plan (Master ... 1989) is currently updating the plantation establishment achievements.

Compared to the neighboring countries, Thailand has initiated more replanting programs than the others in the region. The majority of the replanting is geared towards the industrial sector. So far, the farm forestry projects cover a much smaller area than do the larger block plantations. The drop of the 1980s in the planting efforts, is explained with financial restraints.

Replanting has, however, so far had only little effect on the overall forest cover. Between 1979 and 1984, for instance, on average 80,000 ha/a were planted. Replanting covered less than 8 per cent of the annual decimation which simultaneously took place in the natural forest.

The Thai reforestation program has had a varying success, in general poorer than expected. There is no official record as to the survival rate in the plantations. World Bank estimates an average survival of 33 %. The plantation area registered by FAO in 1989 is 380,000 ha, i.e. 57 % of the total planting program (Tree ... 1990). Especially the concessionaire's plantation establishment has faced difficulties. Assessment of the true established plantation forests is part of the Thai Forestry Master Plan activities (Master ... 1989).

Bhumibhamon (1989) has estimated the established plantation areas by species (Fig. 3.). About 160,000 ha grows under 10 most important species. This indicates average survival rate of 30 % of the plantations. This figure compares well with the World Bank estimate. The low survival rates are realistic, and even expectable in the beginning of such a massive program; they are poor, but they are well comparable with many other reforestation programs in the tropics.

Fig. 3. The most common plantation species in Thailand (Bhumibhamon 1989).

The plantation establishment record of Fig. 3 does not include the rubberwood plantations, which by their areas are at totally different levels (totaling 1,720,000 ha), and with which the survival rate does not pose difficulties.

Conclusion: Thailand has an 85 years tradition in plantation forest establishment. Average success has, however, remained modest. During 1980s the annual reforestation achievements have sunk down. (..3).

Recommendation: Using the accumulated experience in reforestation technologies, the tree planting program should now be enhanced. Lessons from successful rubberwood plantations are also worth of transferring into pulpwood plantations. (..3)

2.4 Reforestation program of the FIO

The Forest Industry Organization has been involved in reforestation activities since 1967. The FIO's reforestation approach is a modification of the old Burmese **taungya-husbandry**, in which trees and cash crops are grown as an agri-silvicultural system. The concept of Forest Village has been created and implemented in this context. The success of this approach has generally been rated as good, and the concept is now famous both in Thailand and abroad.

Since the launching of the reforestation plan, the FIO has occupied an area of 66,000 ha planted with valuable timber species such as teak (*Tectona grandis*), eucalypts (*Eucalyptus* sp.), rubber tree (*Hevea brasiliensis*), acacias (*Acacia* sp.) and a few others. Moreover, according to the policy of the Ministry of Agriculture and Cooperatives, the FIO is entitled to engage in the reforestation of some 68,000 ha owned by provincial forest companies. Thus the FIO has in 1992 a total area of about 134,000 ha of forest plantations in occupations.

The estimated area under FIO *Eucalyptus* plantations is about 30,500 ha (Table 5).

Table 5. Estimated area under *Eucalyptus camaldulensis* plantations of FIO in 1990 (Prefeasibility ... 1991)

Plantation type	Area ha
Forest Village approach	19,138
Transferred concessions	11,352

Total	30,490

Of the three major government bodies involved in reforestation (RFD 394,000 ha, FIO 50,000 ha, Thai Plywood Company 2,700 ha by 1982, see Hurst 1990) the FIO has the most prominent role. As being an industrial enterprise, the FIO has its own funds for the reforestation activities. Own funding renders the seasonally fixed reforestation activities smoother to operate. This gives the FIO an advantage over standard government budget related body like the RFD. The reforestation of the FIO has been for 25 years at practical level, the long experience of which gives it an advantage over the Thai Plywood Company. Currently the FIO is the leader of forest plantations (Forest ...).

Conclusion: The FIO is the leader of forest plantations. With its 30,000 ha of Eucalyptus plantations countrywide, the FIO has an advantage for immediate initiation of pulpwood production project. (..4)

Recommendation: The leading plantation establishment experience, of over 25 years, of the FIO should be fully utilized in the future reforestation programs of Thailand.

The existing FIO Eucalyptus plantations should be further developed into nucleus and model of Thai pulpwood plantation establishment. (..4)

3. STATUS AND POTENTIAL OF PLANTATION FORESTS IN FIO

3.1 Land areas

3.1.1 Already planted

The proposed pulp mill of the FIO and partners will be situated in the North-East region of Thailand. In that region the FIO has both plantations belonging to the Forest Village concept and to the transfers from concessionaire's blocks. By rejecting a few unsuitable blocks for plantations and by combining some smaller, altogether 39 blocks, scattered over the region, are available for the plantation forestry project (Map 2).

Map 2.

14 blocks of the plantation forests belong to the Forest Village approach. Their area, already planted with <u>Eucalyptus camaldulensis</u>, is 9,728 ha (on average 695 ha/block) (Table 6).

Table 6. FIO land areas for plantation forestry in North-East Thailand. Plantation types: VIL - village forest approach, CON - concession reforestation.

Block code	Site	type	Plant. area,ha	Total euca,ha	Under
1	Somdet	VIL	1486	1486	
4	Namson	VIL	57	57	
5	Sopisai	VIL	182	182	
7	Manjakiri	VIL	1582	1582	
8	Khonsarn	VIL	669	669	
9	Kasetsomboon	VIL	558	558	
11	Namsouyhavypladu	VIL	80	80	
12	Pibulmungsaharn	VIL	1352	1352	
13	Khunkarn	VIL	746	746	
14	Sangha	VIL	186	186	
15	Dankhuntod	VIL	953	953	
16	Tepsathit	VIL	1028	1028	
17	Sakaew	VIL	655	655	
18	Watanakorn	VIL	194	194	
20	Thakum	CON	775		
21	Pongnamron	CON	740		
22	Kaenghangmaew	CON	237		
23	Bangchang	CON	5		
24	Borthong	CON	6		
25	Klongtakoa	CON	899		
26	Thatakaeb	CON	69		
27	Bungchareon	CON	475		
28	Karbcherng	CON	1356		
29	Phunoksaew	CON	1070		
31	Plarnkoi	CON	524		
32	Namyun	CON	96		
33	Kantharom	CON	428		
34	Khongcheam	CON	152		
35	Naduang	CON	463		
36	Phurouk	CON	192		

37	Dansai	CON	616	
38	Phusawn	CON	1043	
39	Bungkharn	CON	748	
40	Mookdaharn	CON	246	
41	Kudbark	CON	58	
42	Kaosuangkaung	CON	101	
43	Namphong	CON	11	
44	Kaowong	CON	42	
45	Phochai	CON	83	
Total			20161	9728

The area of transferred concession blocks is 10,432 ha. They are situated in 25 blocks, which gives an average of 417 ha for one block. The concession blocks are mostly older, once reforested areas, which grow scattered, unsuccessfully established plantations. It has been concluded by the FIO that practically all of those sites need replanting. So, the total area of the FIO land resource available for plantation forestry in the North-East is 20,161 ha (Table 7).

Table 7. Plantation area resource of the FIO in North-East Thailand.

Plantation type	Area ha
Forest Village approach	9,728
Transferred concessions	10,432
Total	20,161

The fact that the plantation blocks are situated as scattered over the whole North-East region has both advantages and disadvantages. Generally, for environment's sake, it is more recommendable to have especially the *Eucalyptus* plantations as scattered than as large, continuous block plantations (recommendation by FAO). In the Thai case the scattered location of the plantations is better buffered against abnormal weather conditions (too dry or too wet) and possible outbreaks of biological calamities (pathogens and pests). In other words: the crop certainty from several scattered plantations is higher than from one large block plantation. - The disadvantage of the scattered plantations is the heavy management as well as long distances to pulp milling site.

The average size of the plantation block in the Village Forest approach (695 ha) is modest. For management efficiency the block size could, however, be higher. An average plantation block size of 1,000 ha, for one site manager, has been applied for instance in the Ethiopian block fuelwood plantations (Pohjonen 1989a).

In concession plantations the average block size is still smaller, 417 ha. There are 8 plantation blocks under 100 ha (2 with the Village Forest plantations), which renders the management inefficient. Therefore, ways should be sought for to combine small blocks together, and to possibly get additional plantation blocks. A target of 1,000 ha minimum (6,250 rai) should be set for one management block.

Conclusion: The FIO has 20,161 ha of evenly scattered *Eucalyptus* plantation areas in the North-East region. They are moderately suitably located around the pulp mill sites, but the management of such scattered plantations is heavy. (..5)

Recommendation: Small plantation blocks should be combined together, target area for management block should be 1,000 ha at minimum (..5)

3.1.3 Road distances

The greatest disadvantage from the scattered plantation blocks is due to the excessive road distances from the plantation blocks to the pulp mill gate. Of the proposed pulp mill sites, Buri Ram is centrally located, whereas Ubon Ratchathani is remote, it is situated on the eastern edge of the North-East region. The road network as such in the North-East region is good: dense enough, with first-class paved roads.

The average road distance from the plantations to Buri Ram is 352 km and to Ubon Ratchathani 473 km (Table 8). If the transport distances are weighted with the available plantation areas on each site, the average distances are 332 km to Buri Ram and 467 km to Ubon Ratchathani, respectively. The average road transport distances are relatively high if compared to international references.

Conclusion: The average road distances, 352 km to Buri Ram and 473 km to Ubon Ratchathani, and consequent wood transport costs are rather high from the plantations to the proposed pulp mill sites. From this point of view Buri Ram is more recommendable site. (..6)

Recommendation: In order to avoid excessive transport costs it will be beneficial to concentrate plantation management efforts to the nearest plantations from the selected pulp mill site. (..6)

Table 8. Transport distances (km) from the plantation blocks to the proposed pulp mill sites of Buri Ram and Ubon Ratchathani. Plantation types: VIL - village forest approach, CON - concession reforestation.

Block code	Site	type	Km to Buri	Km to Ubon
1	Somdet	VIL	320	350
4	Namson	VIL	530	490
5	Sopisai	VIL	620	630
7	Manjakiri	VIL	320	420
8	Khonsarn	VIL	420	520
9	Kasetsomboon	VIL	260	540
11	Namsouyhavypladu	VIL	430	30
12	Pibulmungsaharn	VIL	430	0
13	Khunkarn	VIL	250	250
14	Sangha	VIL	180	280
15	Dankhuntod	VIL	230	540
16	Tepsathit	VIL	280	620
17	Sakaew	VIL	190	650
18	Watanakorn	VIL	180	640
20	Thakum	CON	310	770
21	Pongnamron	CON	250	710
22	Kaenghangmaew	CON	310	770
23	Bangchang	CON	310	770
24	Borthong	CON	310	770
25	Klongtakoa	CON	250	710
26	Thatakaeb	CON	250	710
27	Bungchareon	CON	0	410
28	Karbcherng	CON	80	320
29	Phunoksaew	CON	300	490
31	Plarnkoi	CON	430	0
32	Namyun	CON	330	330
33	Kantharom	CON	300	150
34	Khongcheam	CON	430	30
35	Naduang	CON	550	590
36	Phurouk	CON	570	580
37	Dansai	CON	550	700

38	Phusawn	CON	550	700
39	Bungkharn	CON	650	660
40	Mookdaharn	CON	550	410
41	Kudbark	CON	420	450
42	Kaosuangkaung	CON	420	450
43	Namphong	CON	330	400
44	Kaowong	CON	330	340
45	Phochai	CON	310	280
Average			352	473
Average, as weighted with available hectares			332	467

3.2 Suitability of soils for tree plantations

The areas in Thailand which become available for Eucalyptus plantation forestry, are generally very poor. In a typical case of North-East Thailand the soil had originally been formed under Dipterocarpus forest. After logging, the shifting cultivation took over. Finally, cassava was grown in a monoculture, year after year, until the soil became impoverished. The yields of cassava fell below the economic level which the farmer had expectations. The abandoned cassava areas are soon classified as waste lands (Yoda and Sahunalu 1991).

The impoverished soils of the waste lands are typically red in color (laterite), medium textured with low clay content. The soils are acidic, Ph varying from 4.0 - 5.5, with very low nutrient availability. Available phosphorus, especially, and the cation exchange capacity are both very low.

In summary: in typical case the soils of such waste lands are according to all standards poor. They are regarded as unsuitable for arable crops.

In plantation forestry the mere top soil analysis, however, does not tell the whole truth. The soil impoverishment has taken place only in the top layers which the cassava roots have occupied. If the bottom soil, say under 2-3 meters level, has a moderate nutrient availability, the trees can still grow despite crop failures with cassava.

It is a general rule for the arid zone trees that, provided the soil is soft, the roots will grow towards bottom soil at a root growth rate which is comparable to the height growth rate of the stem. In a soft soil *Eucalyptus* and *Acacia* trees have approximately as deep roots as the stem has height. A fast-growing tree is also fast in reaching the bottom soil nutrients. This is one of the explanations why *Eucalyptus* trees have adapted well in the poorest soil conditions, where the other trees do no more thrive. Especially this has happened in the dryland Africa. This is also the case in the dry zone of North-East Thailand, in the impoverished soils. In addition, *Eucalyptus* functions in deep soils as a nutrient pump, raises the bottom soil nutrients to the upper level, and circulates them between the leaves and humus.

Most of the impoverished soils in the North-East Thailand belong to the soil category of poor, but soft and deep soils. As such they are still well suitable for plantation forestry.

But there are also truly poor forest soils in the

North-East. They are poor because they are stony and shallow. Such soils occur in the hill sites and on mountain slopes. An example of such FIO plantation site is Dankh-untod, in the chain of hills, about 100 km west of Nakhon Ratchasima.

Other truly poor soils for plantation forests are saline soils and the soils which have a hard pan under the topsoil. Such soils, however, have not so far been selected for the FIO plantation sites.

The FIO plantation blocks in the North-East were classified based on their average soil suitability. The classification was done at scale 1 - 5, in which 1 denotes the poorest soils (very stony, saline, or soil with hard pan), 3 moderate soil (still in the category of waste lands, but soil is soft enough) and 5 the best available soils for plantation forestry (Table 9).

Table 9. Classification of soil suitability for plantation forestry in the FIO plantation blocks, 1 for the poorest soil, 5 for the best soil. Plantation types: VIL - village forest approach, CON - concession reforestation.

Block code	Site	type	Soil class
1	Somdet	VIL	4
4	Namson	VIL	4
5	Sopisai	VIL	4
7	Manjakiri	VIL	3
8	Khonsarn	VIL	4
9	Kasetsomboon	VIL	4
11	Namsouyhavypladu	VIL	3
12	Pibulmungsaharn	VIL	5
13	Khunkarn	VIL	5
14	Sangha	VIL	3
15	Dankhuntod	VIL	2
16	Tepsathit	VIL	3
17	Sakaew	VIL	5
18	Watanakorn	VIL	4
20	Thakum	CON	4
21	Pongnamron	CON	5
22	Kaenghangmaew	CON	4
23	Bangchang	CON	5
24	Borthong	CON	5
25	Klongtakoa	CON	5
26	Thatakaeb	CON	5
27	Bungchareon	CON	4
28	Karbcherng	CON	3
29	Phunoksaew	CON	3
31	Plarnkoi	CON	4
32	Namyun	CON	3
33	Kantharom	CON	4
34	Khongcheam	CON	3
35	Naduang	CON	4
36	Phurouk	CON	4
37	Dansai	CON	4
38	Phusawn	CON	4
39	Bungkharn	CON	3
40	Mookdaharn	CON	5
41	Kudbark	CON	2

42	Kaosuangkaung	CON	3
43	Namphong	CON	3
44	Kaowong	CON	3
45	Phochai	CON	4

On average the soils in the FIO plantation blocks are rather suitable for Eucalyptus forestry. Truly poor soils (soil class 1) have not been selected for plantation sites. The soil class 2 occurs only in 2 sites (Dankhuntod and Kudbark).

The best analyzer for the soil suitability is the tree itself. The dominant height of planted stands at a certain age is a biological indicator for the soil fertility. The analysis of the dominant height / age relationship for the examined plantation sites is presented in Chapter 3.5. Measurement of the sample plots revealed that Eucalyptus camaldulensis forests thrive successfully in the visited plantation blocks, even if their soil characteristics must be rated from rather poor to very poor, according to conventional soil analysis standards.

Conclusion: The soils in the FIO plantation blocks are suitable for plantation forestry, especially with Eucalyptus camaldulensis. Proportion of stony, rocky, saline and soils with hard pan, is low. (..7)

Recommendation: Plantation forestry with pulp wood crops, especially with Eucalyptus camaldulensis should be practiced on soils which may be impoverished in their top layers, but which are soft and deep enough. Soils, still good for agricultural crops should not be planted for block plantations, only for agroforestry applications. (..7)

3.3 Biological status

3.3.1 Selection of species

According to Bhumibhamon (1989) _Eucalyptus camaldulensis_ has been the most successful of all the tree species planted in Thailand. This cannot be a coincidence. The species selection trials have been carried out since 1960s when the RFD initiated the plantation establishment. The core for the industrial plantation program included such species as _Tectona grandis_, _Pinus kesiya_, _Pinus merkusii_, _Pinus caribaea_, _Acacia auriculiformis_, _Acacia mangium_, _Casuarina_ sp. _Rhizophora apiculata_ and _Eucalyptus camaldulensis_. Later, when the community forestry approach was emphasized, species such as _Azadirachta indica_, _Cassia siamea_, _Tamarindus indica_, _Anacardium occidentale_, _Mangifera_ sp., _Leucaena leucocephala_ and _Bambusa_ sp. were promoted (National ... 1988).

Of all the species tried and promoted _Eucalyptus_ camaldulensis has thrived best and produced most. This finding has lately been verified in a new, well replicated species trial (Poland and Pinyopusarerk 1987).

Of the plantation Eucalyptus species worldwide, E. camaldulensis is by no means the most productive. In the Aracruz Florestal project, Brazil, where the climate resembles North-East Thailand (especially by the rainfall: 1200-1400 mm per annum), Eucalyptus grandis and Eucalyptus deglupta clearly overyield Eucalyptus camaldulensis (The new ... 1984).

Other Eucalyptus species than E. camaldulensis have been tested also in Thailand. The accumulated information, however, does indicate that any species would overyield E. camaldulensis in the North-East. This may be a soil quality issue: the more demanding Eucalyptus species such as E. grandis, E. saligna and E. deglupta do not thrive that well on impoverished Thai dryland soils. The species trial program should however go on, and potentially better yielding Eucalyptus than E. camaldulensis should still be sought for. After all, the experience of Eucalyptus husbandry in Thailand is still rather young, from the beginning of 1940s (Thaiutsa and Taweesuk 1987).

Conclusion: In a long-standing series of species trials

Eucalyptus camaldulensis has proved to be the most productive species for the waste lands and poor soils of the North-East Thailand. The finding is supported by plantation forestry at practical scale. (..8)

Recommendation: Research and development in the species selection should continue to monitor long term productivity of *Eucalyptus camaldulensis* and to screen still more productive species, provenances and clones. (..8)

3.3.2 *Eucalyptus camaldulensis* viz. *Acacia mangium*

Acacia mangium is one of the most promising, less common, nitrogen fixing plantation trees for the humid tropics. It has been only recently introduced as a plantation species in the South-East Asian countries. *Acacia mangium* is extensively planted in Indonesia, as well as in Malaysia. It is also known in Thailand, although the plantation area is still modest, only 400 ha (Bhumibhamon 1989).

The success of *Acacia mangium* is primarily due to its rapid growth rate, robustness and wide range of uses (Mangium ... 1983). When planted as an exotic, it has often shown an unexpectedly good performance ;it has now been widely planted throughout tropical Asia, the Pacific Islands, West Africa, and the Americas. Being a relatively new plantation species, it has not yet been thoroughly studied, and the information and experience on its potential in different conditions are still rather limited (Turnbull 1986, Atipanumpai 1989).

Acacia mangium is a possible candidate for large scale reforestation for pulp milling of the FIO. The species does have potential, and it is well accepted as a raw material for pulp milling. How can the value and the potential of Acacia mangium for plantation forestry in the North-East, be assessed?

Maybe the most carefully studied early growth field trial in Thailand, comparing E. camaldulensis and Acacia mangium grows in the Somdet block, in the heart of the FIO plantation program. Growth of both species were followed from seed sowing and transplanting to age of 4.9 years (Kanzaki et al. 1991). All the stand characteristics were carefully studied. The curves for average height and stem biomass are shown in Fig. 4.

Fig. 4. Height and stem biomass growth of Eucalyptus camaldulensis and Acacia mangium in the FIO plantation site, Somdet, North-East Thailand. Spacing 2 x 2 meters, no fertilization. Data from Kanzaki et al. 1991.

In this trial Eucalyptus camaldulensis clearly overyields Acacia mangium. This is seen both in the height growth, and especially in the stem biomass (volume) growth. The experiment has been followed into the age of 4.9 years only. It is therefore not certain, how the stands develop thereafter. There are, however, no indications that the yield relations between E. camaldulensis and A. mangium would change later. Rather, they might become even bigger. It must also be remembered that the currently recommended rotation age for pulp wood production in the North-East is 5 years, at which age the results of the Somdet experiment are clear. - Based on the experience in Somdet, it would be difficult to recommend Acacia mangium for large scale pulp fiber production, instead of E. camaldulensis.

Growth of Acacia mangium was also measured during the field trip in North-East Thailand in January 1992. Results of 4 sample plot measurement are shown in Table 10.

Table 10. Results of Acacia mangium sample plot measurement in North-East Thailand. Hdom in meters, Ave D in cm, mean annual increment (MAI) in $m^3/ha/a$.

The *Acacia mangium* plot grew well in Pibulmungsahan, near to Ubon Ratchathani. At age of 6.0 years (from seed sowing) the MAI was almost 20 m^3/ha/a. This plot, however, grew next to the plantation site nursery, and it has most probably got better than average tending. The growth results are likely to be biased upwards.

The Buri Ram plots grew also rather well, the younger (6.0 years) 15.5 m^3/ha/a and the older (6.5 years) 9.1 m^3/ha/a, by MAI. The Buri Ram plots grew comparably to *Eucalyptus camaldulensis*, and in any case the results are more positive to *Acacia mangium* in Buri Ram than in Somdet.

Typical to both Buri Ram and Ubon Ratchathani is the higher rainfall, i.e. they are more humid sites than Somdet. It is the hypothesis, based on field experience, of the Thai field foresters that the survival and growth *Acacia mangium* is strongly dependent on rainfall. It may be questionable to grow *Acacia mangium* at large scale, in the drier areas of the North-East region. In Thailand it means that the *Acacia mangium* areas are to be sought from the East, South-East and South. Here, a tentative rainfall isohyet of 1,400 mm/a has been postulated, above which the field trials of *Acacia mangium* should be further strengthened (see Map 3). Below the 1400 mm/a isohyet *A. mangium* and also *A. auriculiformis* should be tested in the regular species trials.

Map 3.

Another reason for the rather modest performance of Acacia mangium in Thailand (especially if compared with E. camaldulensis) is the lack of alang-alang (Imperata cylindrica, aggressive South-East Asian weed grass). This again, is a matter of rainfall. Alang-alang is more common in rainfall areas of near and over 2,000 mm/a. Below 1,400 mm/a level in North-East Thailand, alang-alang is not common.

Conclusion: Acacia mangium has shown promising growth in Thailand, in areas with sufficient rainfall (at least 1400 mm/a). Better growth results over Eucalyptus camaldulensis have not been shown. In drier parts of the North-East E. camaldulensis yields about twice as well as A. mangium. Large scale plantation forestry with Acacia mangium can not yet be promoted. (..9)

Recommendation: Field trials with Acacia mangium should go on in the North-East, to look for better provenances and to establish the environmental suitability, especially how the species matches with the rainfall in various parts of the North-east Thailand. (..9)

3.3.3 Provenances

Thai foresters have carried out a rather long-standing tree improvement program, first with teak (starting in the 1960s) then with other species. Consequently, gene conservation areas, seed orchards, seed production areas and clone banks have been established in various parts of the country. This activity has been extended to the highest academic research, to mention only one example: dissertation of Ladawan Atipanumpai on Acacia mangium genetic in the University of Helsinki 1989 (Atipanumpai 1989).

The tree improvement program has not, however, fully penetrated the gap between the research and practical plantations. For instance the FIO plantations are still sown with unimproved seed, often from own collections from the production forests.

There is no general agreement among the Thai foresters, which is the best provenance of Eucalyptus camaldulensis for the North-East region. Some say it is Petford, the others say it is Surin or Srisaket. Unquestionable, scientifically sound provenance trials are difficult to find, or reports on them. All this has resulted that the tree improvement program is still on its way into practical applications; improved germplasm is not yet in use - unimproved seed is sown for practical plantations.

At this point it is worth of considering whether the provenance-based, conventional tree improvement program will bring the anticipated breeding gain (10-15 % for Eucalyptus) in the FIO and other Thai practical plantations, if it has not done so far. A number of provenance trials have been established in the country. By analyzing the existing information it would apparently possible to identify immediately three superior provenances (say Petford, Surin and Srisaket).

The next step is to have seed production stands established in isolated locations. To avoid unwanted pollen, each stand should be 1-2 km away from the next stand of the same species. In the FIO plantation forests, at least, such seed production stands do not exist so far. The isolation requirement for the selected plus trees (for seed collection) is not met. The father of the seed collected from unisolated stands, is always unknown.

After establishment of the stands of superior provenances, the seed collection from the stand can start at about 5 years of age after the stand establishment, depending on the flowering. It is a matter of about 10 years to get improved seed, from superior provenances, from properly established seed production stands in the reforestation project. For requirements of and procedures connected with improved seed production stands, see Pohjonen 1989a.

Such seed production stands should in reality be under the auspices of the FIO, to guarantee sufficient amounts of improved seed for the nursery and large scale seedling production. Looking at the example of Aracruz Florestal, Brazil, it would be possible to gain a 10-15 % increase in the stand productivity within 10 years by adopting the provenance selection as a part of the R & D activities of the project. By shifting from local *Eucalyptus* provenances into improved South African and Zimbabwean provenances, it was possible to raise the mean annual increment in a decade from 30 to 33 m^3/ha/a (The new ... 1984). - But the next step, shifting from the improved provenance to clonal stock, selected from superior plus trees, yielded a gain of 112 % in another decade, from 33 to 70 m^3/ha/a (all figures refer to MAI at optimum rotation).

By learning about the business idea of Aracruz Florestal, there is only faint justification to go into further Eucalyptus provenance research. The infrastructural capacity of the Thai reforestation organizations, of the FIO among others, is strong enough for establishing Aracruz type clonal forestry in Thailand. The basic forestry training level of the Thai foresters is well comparable to the Brazilian case. The Thai forestry in general, and the FIO reforestation section especially, is capable to adopt the Brazilian approach.

Conclusion: The provenance research with the most important plantation trees, e.g. with Eucalyptus has not advanced to practical level. The breeding gain is still awaiting the realization of improvement in growth rate of the practical plantations. Faster tree improvement gain can be expected from adopting the clonal Eucalyptus forestry. (..10)

Recommendation: For rapid gains from tree improvement in Eucalyptus forestry, it is recommendable shift the R & D from provenance research to clonal forestry. Field scale models are to be sought from the Aracruz Florestal in Brazil and from South African Eucalyptus forestry. (..10)

3.4 Silvicultural status: plantation establishment and tending

Currently, the common practice in the FIO plantations is to use complete ploughing before the planting, and mechanized weeding after the planting. Normal farm tractor is used, equipped with disc ploughs. The spacing arrangement of 2 x 4 meters allows mechanical soil cultivation between the rows. This is also possible with the other currently used spacing, 3 x 3 meters, provided the marking of the seedlings has been carefully done.

The older FIO plantations have been established at spacing of 2 x 8 meters, and with apparent poorer soil cultivation. Consequently, their growth is not as good as it is with the younger plantations.

The importance of thoroughful soil preparation and full weeding has been demonstrated in many projects over the tropical zone. Convincing examples of this techniques can be found in Brazil, Ethiopia and South Africa.

The plantation establishment techniques of the FIO, which has been used for the youngest plantations, is of first class quality. No substantial yield improvement can be waited for from further development of the soil cultivation. The established techniques should be used throughout in the new reforestation sites.

Conclusion: In the Eucalyptus plantation forestry the FIO is currently applying complete soil cultivation prior to planting and mechanical weeding several times after the planting. The results are excellent, well comparable to the best Eucalyptus projects in the world. (..11)

Recommendation: It is recommended that the developed Eucalyptus plantation establishment techniques, including complete ploughing prior to planting and mechanical weed control after the planting, will be used throughout the future reforestation activities. (..11)

3.5 Forest management status: growth and yield

The analysis of the growth and yield of the FIO Eucalyptus plantations below, is based on studying the existing Thai forestry literature on the *Eucalyptus camaldulensis* growth, on forest inventories carried out by the FIO, and on the measurement of 16 additional sample plots during the field trip in the North-East.

The Thai forest research does not routine wise record the dominant height (average height of the 100 largest trees per hectare in a particular forest). According to the modern growth and yield theory of the plantation forests the dominant height is the best indicator of the site and soil quality. Additional measurements sample plots measurements were therefore regarded necessary to monitor the relationship of the age and the dominant height in various E. camaldulensis stands in the North-East. This relationship can be compared to the corresponding data elsewhere in the tropics. The stand data for the measured sample plots are shown in Table 11.

Table 11. Results of Eucalyptus camaldulensis sample plot measurement in North-East Thailand. Dominant height (Hdom) in meters, average breast height diameter (Ave D) in cm, mean annual increment (MAI) in m^3/ha/a, G is the basal area, V is the stand volume.

The dominant height / age relationship follows a certain pattern in one site, or soil class. And vice versa: based on this pattern, conclusions about the site productivity can be derived. The average dominant height / age curve for the measured North-East _E. camaldulensis_ plantations is shown in Fig. 5.

Fig. 5. Dominant height / age relationship in Eucalyptus camaldulensis plantations in North-East Thailand.

If the dominant height of Thai E. camaldulensis is compared to corresponding stands in the Ethiopian highlands (Pukkala and Pohjonen 1989), there is a clear difference. The Thai stands grow faster in the beginning, but loose sooner their growth vigor. This renders the optimum rotation shorter than is the case in the Ethiopian highlands.

For calculation of the optimum rotation time, 2 provisional yield tables were prepared. The stand development models of Pukkala and Pohjonen (1989) were used otherwise, but the Thai pattern for dominant height (Fig. 5) was applied. For further theory of the preparation of yield tables, see for instance Pukkala and Pohjonen (1988a).

The first yield table (Table 12) is for the case when the stand is fully stocked. It can be applied when the stand has been established at spacing of 2 x 2 meters. It is also applicable for coppice stands when they have been singled to stocking of about 2000 stems/ha. In the fully stocked stands there is natural self-thinning along the course of time.

The second yield table (Table 13) is for the current FIO practice, in which the stands are not planted at full stocking. The stands will be established into spacing of 3 x 3 meters, or 2 x 4 meters. By counting on some normal mortality in the planting, the stocking remains at assumed constant density of 990 stems/ha. In the understocked stands there is no density-dependent self-thinning in the early phases of the growth (in this case within about 15 first years).

Table 12. Provisional yield table for the FIO *Eucalyptus camaldulensis* plantations in North-East Thailand. The stand established at full-stocking spacing, about 2000 trees/ha, or the coppice stand has been thinned to the same stocking. Density dependent self-thinning assumed.

Table 13. Provisional yield table for the FIO *Eucalyptus camaldulensis* plantations in North-East Thailand. The stand has been established at spacing of 3 x 3 or 2 x 4 meters. No density dependent self thinning is assumed.

The optimum rotation for *Eucalyptus* pulp plantations is determined as a maximum of the mean annual increment (MAI) curve. They are presented in Fig. 6 (full stocking case) and Fig. 7 (understocked case). The optimum rotations are 10 and 12 years, respectively.

Fig. 6. Provisional current annual increment (CAI) and mean annual increment (MAI) curves for fully stocked Eucalyptus camaldulensis stands growing in FIO plantations, North-East Thailand.

Fig. 7. Provisional current annual increment (CAI) and mean annual increment (MAI) curves for stands planted at 3 x 3 or 2 x 4 meters spacing (some planting mortality has been assumed), Eucalyptus camaldulensis stands growing in FIO plantations, North-East Thailand.

The yield tables presented are provisional by nature because they are based on rather few measurements in the field and on applying the growth information of _Eucalyptus_ from elsewhere (from East Africa, Ethiopia). When investigating the FIO plantations an obvious finding is that the youngest stands have been established in most thoroughful preparations, whereas the older plantations have not received similar care in the establishment. This biases the growth results in such a way that the younger stands grow better than average whereas the older stands grow worse than average. This has a reflection in the dominant height. The earlier retardation in dominant height growth, when compared with Ethiopian _Eucalyptus_ plantations, maybe due to differences in silvicultural treatments, not due to the genetics of the species or the typical pattern of growth in North-East Thailand. Should this be case, the present younger plantations may grow relatively better in their old days than do the presently old stands. The optimum rotation time is likely to increase with a couple years if such a phenomenon is revealed.

The **provisional** yield tables, however, give raise for considerable practical conclusions:

* The rotation time of 5 years often recommended in

Thailand is obviously too short for maximum biomass production. In the current spacing of about 1000 trees/ha the mean annual increment can be raised from 9 to 13.5 m^3/ha/a, by raising the rotation time from 5 to 12 years. The productivity increase would be 50 %.

* In coppice stands the optimum rotation time for biomass production is 10 years. Again, by raising the rotation from 5 years to 10 years, the mean annual growth is raised, from 11.5 to 15.5 m^3/ha/a (35 % increase).

* The denser the stand, the shorter the rotation. The difference in the optimum rotation time between 2 x 2 spacing and 3 x 3 (or 2 x 4) spacing is about 2 years in favor of the denser planting.

* The denser the stand, the higher the biomass yield. The difference in maximum MAI is about 2 m^3/ha/a, in favor of the denser planting.

* Coppice stands in general are more productive than seedling stands. The currently planted 3 x 3 and 2 x 4 spacing stands will grow on average 2 m^3/ha/a better as coppices than what they grew as seedling stands (in the

first rotation).

* In the FIO Forest Villages 5 years rotation is practiced with agroforestry application. in 2 x 4 meter spacing a rise of one year in the rotation (from 5 to 6) would rise the wood productivity by 1.4 m^3/ha/a, by 15 %.

Even if these results are provisional and should be verified in the field, in practical applications of the FIO plantations, they are consistent with Eucalyptus forestry elsewhere in the world. In Ethiopia the optimum rotation for maximum biomass production is about 14 years for seedling stands and about 10 years for coppice stands (Pukkala and Pohjonen 1989). In Aracruz Florestal, Brazil, the optimum rotation is 7 years. In Aracruz, however, the stands grow 5 times faster than in Thailand and the results are not directly applicable. On the other hand, the Aracruz optimum rotation, 7 years, may be optimum also in Thailand in the future clonal forestry applications.

On the other hand, the optimum rotation is affected by the pulp fibre quality. There are indications that the younger trees will yield better pulp. Based on laboratory results in Thailand, Rativanich et al. (1987)

concluded that if considering the pulp quality only, rotation times of 3-6 years are more preferable than 10-15 years. This finding should now be related to the yield level. How much can we afford in dropping the yield for the raised pulp quality?

The matter of fiber quality is a function of tree size rather than of tree age. If the pulp fiber quality can be related to tree size, oversized logs are culled out from the fiber market. This, however, will not necessarily shorten the optimum rotation time, as there are other uses for the large _Eucalyptus_ logs, for instance use of poles, need for lumber and future demand of saw milling industry.

Conclusion: In the light of the measured, provisional yield tables, the currently practiced optimum rotation times for _Eucalyptus camaldulensis_ are too short. Raising of rotation from 5 years to 10-12 years is likely to increase the mean annual increment by 30-50 per cent. (..12)

Recommendation: Regarding the limited land resource, continuous study into optimum plant stocking and rotation time should go on. For pulp production optimization the quantity of high quality fiber should be maximized, not the quantity of the woody biomass only. This calls for justified efforts in R & D. (..12)

4. POTENTIAL FOR IMPROVED YIELDS

4.1 Need for improved yields - pulp milling requirements for raw material

By calculating in cubic meter terms, the new pulp mill of the FIO and partners will require 264,600 m^3 *Eucalyptus camaldulensis* wood per annum. With present plantation technology (2 x 4, or 3 x 3 meters spacing, advanced silviculture), using partly Forest Village approach (5 years rotation), and using partly optimized production in concessionaire’s plantations (12 years), the calculated potential fiber flow to the pulp mill can be satisfied by 87 % (Table 14). The average annual wood production would be 11.4 m^3/ha/a. The 100 % satisfaction can be achieved if this is raised into 13.1 m^3/ha/a, i.e. by 15 per cent. Again, considering the lessons from the Aracruz Florestal, this is well within reach.

Table 14. Potential wood supply from current FIO plantations and reforestation areas using agroforestry approach in Forest Villages (VIL) and optimized production in concession plantations (CON).

Type	Area ha	Rotat. years	MAI m3/ha/a	Annual harvest m3 tot.	% cent of need
VIL	9,728	5	9.2	89,498	34
CON	10,432	12	13.5	140,838	53
Total	20,161		11.4	230,336	87

The pulp fiber production chain from the seed or clone through established plantation to harvested end product, the wood chips ready for pulp milling, is a long chain of management activities. In the chain every link is important and needed. Improvement is some of the links will, however, bring the quickest gains in the economics. Identifying such links is especially important in a country like Thailand where the land resource for plantation forests is limited, where the overall production cannot be raised by just reforesting new open areas to meet the raw material demand. The most important of such links in the FIO plantations are identified as i) tree improvement (shift to clonal *Eucalyptus* forestry) and, ii) optimized management.

4.2 Towards clonal forestry

In the light of the rapidly increasing demand for *Eucalyptus* fiber in Thailand in general, and with FIO and the new pulp mill company especially, there may be no time to wait for selected seeds and improved yield gains through conventional provenance research. The plantation technology using seed - the sexual route - can not meet all the pulp fiber requirements which are now ahead in Thailand.

The asexual approach employing rooted *Eucalyptus* cuttings has not yet being widely used in Thailand. Pilot studies have, however, been already initiated. The first cutting-based *Eucalyptus camaldulensis* seedlings were prepared by the Seed Center of the RFD. The basic technology of this approach is already known in Thailand. Part of the cloned seedlings were planted in Manjakiri plantation of the FIO. The seedlings showed promising growth: the dominant height was already 9.5 meters at age of 1.8 years (Table 11).

Large scale vegetative propagation of *Eucalyptus* camaldulensis would be the best approach to achieve the goals of rapidly growing Thai pulp milling industry. In combining technical, operational and economic requirements, it will be the most feasible way to achieve rapid increases in the average wood growth in the FIO plantations. Models for that approach are to be sought from Aracruz Florestal Brazil, CSIRO Australia, CTFT Congo and South Africa. The technical concept of this approach, as well as the industrial success connected, has been described in The new ... (1984).

The FIO has an advantage over the other pulp mill companies because it has own plantations, with established Eucalyptus camaldulensis plantations from a period of 15 years. The plus tree selection has partly been initiated already, and could be enhanced straight away. For instance in the Somdet plantation, the super trees are left standing in the current harvests - not necessarily for conserving their genes but for later use as saw timber. Selecting from these trees, the best ones could be immediately selected for clonal propagation. The other source of superior genotypes is the 12-year old provenance trial in Somdet. It could be measured, super trees selected and harvested. Cuttings can be made from the selected trees for clonal propagation. The provenance trial as such could continue as coppice trial.

The average growth potential of the FIO *Eucalyptus camaldulensis* plantations is currently rather low, at 15.7 m^3/ha/a (by applying optimum stocking and optimum rotation), especially if compared to international standards. The expectations to raise the yield level in the FIO plantations by 100 per cent are good. Potential average growth level of 30 m^3/ha/a is within reach within 15 years. This would guarantee steady and adequate wood supply for the pulp mill from the FIO own plantations.

Conclusion: Counting on the established example of Aracruz Florestal, Brazil, there are reasons to expect doubling of the current yields from *Eucalyptus camaldulensis* by adopting the approach of clonal forestry. This would ensure sufficient raw material for the presently planned pulp mill, and would open space for enlargening the pulp mill industry in the near future. (..13)

Recommendation: Clonal forestry with *Eucalyptus camaldulensis* should be initiated in the FIO plantations. Cloned seedlings should in the beginning be produced in a central nursery with an initial capacity of 5 million seedlings per year. Somdet plantation in the Kalasin province is a suitable site for both original plus tree selection, production of coppices (cuttings) and for establishing a central nursery. (..13)

4.3 Optimized management

The example of optimum rotations and optimum planting density (Figs. 6 and 7) shows the power of the optimized management. By making appropriate decisions, the yield levels can be raised without remarkable inputs. This is the topics of Forest management planning.

The plantation forest management should use the existing resource, the land, the forest and the manpower in such a way, that the production targets and other objectives set for the plantation forest are achieved in the most efficient manner. The task of plantation forest management planning is to show how this can be achieved. Answers are sought for questions like "What is the amount of pulpwood in the plantation today, or after 3 years?", In which order should the compartment be harvested?", or "What is the maximum, sustained amount of pulpwood that the plantation can yield annually?"

A complete plantation forest management planning system starts by making an inventory over the plantation forest resource. The inventory part has three components:

i) measurement system is a set of methods to acquire necessary basic information on the resource,

ii) the calculation system is needed to convert the basic measurements into cubic meters, green tonnes, into growth and yield figures which the pulp mill is interested in,

iii) the mapping system transfers part of the results into operational forest management maps.

The results from the plantation inventory are used in the planning system to analyze the different production alternative and synthesize the results. The management planning system produces growth predictions, stand treatment proposals and information on how the stands develop along different treatment alternatives. In particular, the planning system should be able to answer the following questions: "What happens to the plantation is this management option is selected? or "What are the consequences of this decision?" To be able to answer these questions, it is essential that the planning system has means to predict the future growth and development of the forest.

The planning system presents a synthesis of the computations to a decision maker, usually in a form of forest management plan. Based on this synthesis the decision maker, the manager of the pulp milling project or the plantation manager selects the optimum way, from his point of view, of utilizing the existing plantation forest resource.

Forest management planning is a well-developed discipline in the main forest industry countries. Working examples are known from Scandinavia, from Finland among other countries. Advanced forest management planning systems have also been developed for Eucalyptus plantations, for instance in Ethiopia (Pukkala and Pohjonen 1988b). It was applied in practical scale (over a few thousand hectares), with rigorous targets to find the production frontiers and optimum set of plantation treatments (Pukkala and Pohjonen 1988c, Pohjonen and Pukkala 1989).

Elements for advanced forest management planning system already exist in the FIO Eucalyptus plantations. Forest inventory, using 5 % sampling ratio, is currently done annually, block by block, compartment by compartment.

For instance in 1990 the growing stock was estimated at 186,365 m^3 over 9,881 ha, or at 18.86 m^3/ha (mainly plantations with Forest Village approach).

There exists also forest management maps for every plantation block. There is, however, no accurate yield prediction system in the FIO, nor a way how to define the optimum treatments, for instance the optimum rotation.

Before the pulp fiber production from Eucalyptus starts at large scale the FIO needs a forest management system, to execute optimum management. This consists of computerized forest management mapping system (preferably based on Arc Info), the calculation system and optimization system. Such systems are currently under development for other tropical countries as well, with plantation forests in large scale, for instance in the timber estates program in Indonesia.

Conclusion: Forest management system in the FIO plantations is insufficient for making the optimum management decisions. Preliminary steps in plantation inventory and mapping have already been initiated but they do not yet allow optimum plantation management. (..14)

Recommendation: The FIO plantation forests need an advanced forest management system. Working models for plantation forestry are found both in the temperate zone and in the tropics (Ethiopia and Indonesia). (..14)

4.4 Research and development

4.4.1 Need for R & D

Research and development (R & D) in the species, and especially clone selection for superior planting material is a topic of applied research. It is an essential part of a successful pulp milling and plantation forestry exercise. Again, if using the Aracruz Florestal as a working example, the phenomenal achievements were possible only because the enterprise itself established a R & D body directly under the pulp milling company leadership.

Another approach, the most common in the plantation forestry worldwide, is to centralize all species, provenance and clone research under one governmental research institute. Also this is a working example. But it is slower to disseminate the research results for a fast tempo, day-to-day management.

An example of the slow pace of the centrally implemented Research and Development comes from the FIO plantations, from the provenance trial in Somdet. The trial has not been measured at least for two years. The previous measurements and their conclusions (which is the best and recommendable provenance of _Eucalyptus_ _camaldulensis_ in Somdet), were not known to the plantation manager. Consequently, due to missing information, the plantation manager did apparently not have the best possible provenance for the Somdet nursery and plantation.

This bottleneck was avoided in the Aracruz Florestal by ordering the R & D under the enterprise command. It should be noted that routine wise species and clone selection is no more academic research. It is a piece of quick pace applied research, supplying at least annually new information for management decisions.

4.4.2 Principles for species and clonal selection

The most important task of the R & D body in the _Eucalyptus_ plantation project would be to arrange an efficient species and clones selection procedure. Often, new species, provenance or clones enter into plantation forestry in a casual, unplanned manner. This is especially the case with exotic species, like eucalypts or acacias. New species, provenance and clones have been introduced based on information from neighboring countries or based on general ecological similarities between the site of origin and the new proposed site of cultivation. The introduction of new exotic trees by such methods is not particularly systematic or efficient but rather innovative and explorative.

However, if the testing of new introductions is not systematic, the species selection works at random and inefficiently. A great deal of information is lost from such an attempt. Finally, unnecessary repetition with similarly unsuitable species occurs.

Systematic screening of new introductions is based on field trials in which new candidates are screened against the best existing, already cultivated species. There should be a component for species and clones selection in every serious plantation forestry project. Even if the species has been defined beforehand in the project plans, this component is needed for continuous screening of new, better clones of the selected species.

The screening and selection of new species has different scales. On the scale of the country as a whole, there is a network of species elimination trials usually carried out by the national forest research organization. This network gives the basic list of already tested, potentially suitable species for local plantations. Such a basic list can contain 2 to 3 species that can be planted immediately on a large scale, and 5 to 10 species that must first be locally tested on a smaller scale.

Since every new plantation site is a climatic and ecological entity in itself, the wider range of national recommendations has to be verified under local conditions. And, in addition to the already 5 to 10 recommended potential candidates from the national testing, new species can be incorporated in the local test scale.

For the species, provenances and clones elimination level the best candidates are selected from observation plots. The observation plot is a preliminary stage which need not be replicated. In the observation plot the candidates are always screened against the reference species which is the currently recommended standard species, provenance or clone for large-scale planting. The elimination level is designed to achieve immediate results in a situation in which the number of seedlings is limited. The growth and other performance are measured on a per-tree basis. The species, provenance or clone elimination trial is replicated to ensure statistically sound conclusions. A sufficient number of replications is 4. A suitable layout for a species elimination trial is a row experiment.

The best candidates from the elimination level go to the species, provenance and clone testing level. At this testing level the growth and performance of the species, provenance or clone is screened at stand scale. To ensure statistically sound conclusions, the testing level should also be designed to be replicated. The planting density should be standard (preferably 3 x 3 m). The suitable number of seedlings per plot is 100 (10 x 10 rows) and per test 300, 400 or 500 (3, 4 or 5 replications x 100). A suitable layout for such an experiment is Latin square. In the following some examples of Latin square design are given.

A	B	C
B	C	A
C	A	B

A	B	C	A
B	C	D	A
C	D	A	B
D	A	B	C

A	B	C	D	E
B	C	D	E	A
C	D	E	A	B
D	E	A	B	C
E	A	B	C	D

A model experiment could be the one with 3 replications in such a way the

A = Regularly planted, unimproved *E. camaldulensis*

B = Improved clone of *E. camaldulensis*

C = *Acacia mangium*

The design with 4 or 5 replications are more suitable to test new clones as the need of replications is higher.

The last phase in the introduction is the species, provenance and clone proving level. At this level the selected candidate - new superior species, provenance or clone - is grown at compartment scale: hectares or tens of hectares. The stands at proving level are already production plantations, and this level needs no replications. Screening is carried out against other species planted in neighboring compartments. Measurements on stand growth are carried out as standard forest compartment inventory.

The performance of trees and stands at different test levels and trials should be monitored continuously and measured at least once a year by the field staff. The basic rule for selection is to do it at one-third the age of the rotation time; in short-rotation pulp wood plantations at the age of 3 years (The new ... 1984). - For more details about the selection procedure, see for instance Pohjonen (1989a).

Conclusion: R & D department under the pulp milling and plantation forestry project will facilitate rapid increase in annual pulp fiber harvests. The most important topics of applied research is the annual screening for better, superior species and clones. (..15)

Recommendation: Using the Aracruz Florestal as an example, R & D department should be established under the FIO to enhance rapid gain from species and clones improvement program. R & D department should be adequately staffed and equipped. The field trials should be concentrated in Somdet. (..15)

5. ECONOMIC ASSESSMENT IN PLANTATION FORESTRY

5.1 Cost factors in plantation establishment

Cost factors in *Eucalyptus* plantation establishment have been studied rather extensively in Thailand, in the FIO itself, as well as in a number of studies related to the Kasetsart university (e.g. Jeeranantasin 1987). The FIO has followed plantation establishment costs in its plantations over many years. Those data will be used here (Table 15).

Table 15. Summary on plantation establishment and tending costs in the FIO _Eucalyptus_ plantations, over the first 15 years. Three rotations, 5 years each.

Year/rot.	Baht/rai	US$/ha
1 / 1	2020	499
2 / 1	533	132
3 / 1	355	88
4 / 1	205	51
5 / 1	205	51
Total 1-5	3318	820
6 / 2	793	196
7 / 2	303	75
8 / 2	265	65
9 / 2	165	41
10 / 2	165	41
Total 6-10	1690	414
Total 1-10	5008	1237

11 / 3	365	90
12 / 3	265	65
13 / 3	265	65
14 / 3	165	41
15 / 3	165	41
Total 11-15	1225	303
Total 1 -15	6223	1540

The costs in Table 15 include only the running (recurrent) costs. If counting an additional 20 % for the fixed costs and administration, the total plantation establishment cost over the first rotation will be 3982 Baht/rai, or 984 US$/ha, which is well comparable to the international reference value for the gross cost in plantation forest establishment: 1,000 US$/ha.

Another way to study the gross plantation establishment cost is to divide, block by block, the overall reforestation costs by the plantation areas. This way of calculation includes both fixed and running costs in a lump sum (Table 16). In addition to the lump sum, there are some headquarter-based administration overheads (maybe 5-15 % on top) which in the final calculations should be taken into consideration.

Table 16. Overall plantation establishment cost in the FIO

Village Forest plantation blocks. Both the fixed and running costs over the period of running years have been included.

Block code	Site	Costs over years of	Cost/rai Baht
1	Somdet	18	4156
4	Namson	17	24219
5	Sopisai	15	3381
7	Manjakiri	14	3040
8	Khonsarn	15	4586
9	Kasetsomboon	14	4264
11	Namsouyhavypladu	8	19205
12	Pibulmungsaharn	15	3417
13	Khunkarn	17	5352
14	Sangha	12	11275
15	Dankhuntod	13	3404
16	Tepsathit	14	2910
17	Sakaew	18	6578
18	Watanakorn	15	10630
Average			4450

The overall cost (there has been no harvesting) is very modest, 4,450 Baht/rai (1,099 US$ per ha) because it has been calculated over 10 years.

5.2 Harvesting and transport

In Thailand the pulp mill wood is bought as per pulp mill gate price. The wood grower and seller must bear the harvesting and transport costs. Often there is a middleman who buys the wood at stump, in auction, takes care of the harvesting and transport, and sells the wood to the pulp mill. Currently, a considerable amount of Eucalyptus wood is bought and traded in the North-East. The harvesting and transport cost figures are rather well known.

The harvesting cost is between 80 - 120 Baht/gtn. In the FIO Village Forest plantations, the harvesting payment of 120 Baht/gtn is applied for the villagers, and 80 Baht/gtn for the outsiders. In the calculations below the harvesting cost of 120 Baht/gtn is used throughout.

There is a so called one-to-one-to-one rule for the wood transport in Thailand, that is: the normal wood transport cost is 1 Baht/km/gtn. In long distances (over 200 km) cost of 0.9 Baht/km/gtn may be used.

5.3 Cost-benefit analysis

For the cost-benefit analysis a basic case was first designed. It is based on the following assumptions (and explanations):

i) Mean annual increment is 11.4 m^3/ha/a, corresponding to the current potential wood supply, see Table 14.

ii) Wood price at pulp mill gate is 700 Baht/gtn, as anticipated by Prefeasibility ... (1991).

iii) Fixed costs over the running costs are 20 per cent. They include both capital and administration costs in the plantation site and the headquarters overheads.

iv) Average transport distance is 332 km, corresponding to the proposed pulp mill site of Buri Ram

v) Harvesting cost is 120 Baht/tn, as paid to forest villagers currently.

vi) Transport cost of 0.9 Baht/gtn/km has been assumed, due to longer transport distance than average.

vii) Eucalyptus camaldulensis is grown at 7 years rotation; a seedling crop and 5 coppice crops have been assumed, the whole calculation period is 42 years.

viii) Plantation establishment and tending costs are based on the FIO own sources, cf. Table 15.

ix) Harvesting at year 7 is 7 times the mean growth (11.4 m^3/ha/a) converted to green tonnes per rai; harvesting at years 14, 21 and 28 yields 15 per cent more than the first harvest due to coppicing; harvestings at year 35 and 42 is 5 per cent less than the previous harvest due to stump mortality.

x) Total costs include establishment, capital, administration, harvesting and transport costs, total revenue is the harvested amount multiplied by the pulp mill gate price, net return is their difference.

xi) The costs and benefits are summed, and discounted to the present time. Net Present Value (NPV) (Baht/rai) of the exercise, is calculated at interest rates 0, 3, 6, 9, 12, 15, 18 and 21 %. Internal Rate of Return is calculated based on these per cent points (at IRR per cent the NPV equals zero).

The basic case is shown in Table 17.

Table 17. Cost benefit analysis for Eucalyptus camaldulensis plantation, the basic case, all calculations as per rai basis. For assumptions and explanations see Chapter 5.3.

5.4 Sensitivity analysis

The internal rate of return (IRR) for the basic case of the Table 17 can be seen in Fig. 8. IRR in this case is about 14.5 %.

Fig. 8. Net present value and determination of the Internal Rate of Return (IRR) from the basic case (cf. Table 17).

Any of the inputs in Table 17 can be taken as a variable for the sensitivity analysis. First, comparison between Buri Ram and Ubon Ratchathani was made (Fig. 9). The comparison shows the importance of finding suitable plantation areas near to the pulp mill - or establishing the pulp mill near to existing plantations. The internal rate of return for Ubon Ratchathani is less than half (6.5 %) compared to that of Buri Ram (14.5 %).

Fig. 9. NPV and IRR for the basic case but with transport to Ubon Ratchathani (cf. Table 17).

In Fig. 10 the mean annual increment from the FIO plantations had been raised to the level of 13.1 m^3/ha/a. This corresponds to the case where the pulp mill can be supplied at 100 per cent level from the FIO's own _Eucalyptus camaldulensis_ plantations. The corresponding IRR is 16.7 % (Fig. 10).

Fig. 10. NPV and IRR for the case of successful tree and stand improvement; MAI has been raised to level 13.1 $m^3/ha/a$.

In the basic case the pulp mill gate price for the *Eucalyptus* wood is high, as has been earlier discussed, i.e. 700 Baht/gtn (49.2 US$/$m^3$). Two critical factors contribute to that high price:

i) excessive transport distances, and

ii) low growth level in the plantations.

In Fig. 11 it has been assumed that the mean annual increment has been raised with successful tree improvement program into 20 m^3/ha/a, and suitable areas have been found within 50 km radius around the pulp mill. In such a case, *Eucalyptus* wood can be produced at international competitive price of 20 USD/m^3, and however, 9.5 % IRR can be achieved from the exercise (Fig. 11).

Fig. 11. NPV and IRR in an ideal case for *Eucalyptus camaldulensis* plantation.

Finally, sensitivity of the internal rate of return of the basic case (Table 17) was studied for the two most important factors, wood price at pulp mill gate, and transport distance from the plantation to the pulp mill gate. When the wood price varied between 525 - 750 Baht/gtn, IRR - values varied between 2-17 per cent (Fig. 12.).

Fig. 12. Effect of *Eucalyptus camaldulensis* wood price on the internal rate of return in the basic case.

The transport distance from the plantation to the pulp mill gate cannot be more than 530 km for a positive internal rate of return. When the transport distance is about 200 km, IRR of 20 % results (Fig. 13.).

Fig. 13. Effect of transport distance from the plantation to the pulp mill gate, on the internal rate of return in the basic case.

Conclusion: At present pulp mill gate prices _Eucalyptus camaldulensis_ plantation forestry is economically feasible in North-East Thailand. Provided improved stock is in use and management optimization is applied, an internal rate of return (IRR) of over 10 per can be expected from the plantations. Transport distance has a strong effect on the internal rate of return; the distance should not exceed 530 km. (..16)

Recommendation: To lower the wood transport cost and to raise the internal rate of return, additional plantation areas should be sought near to the pulp mill site. (..16)

6. SOCIAL FORESTRY, FARM FORESTRY AND CONTRACT FARMING

6.1 Developments of social forestry

Social forestry or community forestry, as defined by FAO, is a set of forestry activities in which the members of a given community are involved in the decision making process and the benefits accrue to the community. It is in contrast to commercial forestry in which the decisions are made by and benefits accrue to private enterprise. While conventional forestry is usually practiced on state-owned and managed forest under a concession, granted by the state forest service to a private company subject to specified terms and conditions, community forestry is usually found in communal property with or without the government's awareness and consent.

Social forestry is often viewed as a means to reduce forest encroachment, to promote afforestation through tree planting by rural communities or individuals, to reduce rural poverty with forestry, agroforestry, or other tree-related development, and to contribute to sustainable agricultural and forestry production through more environmentally sound land use.

The forests will not necessarily be replanted in their original form, but trees will increase in the landscape, mixed among the fields and villages. The forests may have gone with the social forestry, but the trees are still there. The **woody biomass** density with the social forestry can be remarkable in a particular area, although the area may be recorded as deforested. This is often the case in North-East Thailand.

By producing their own tree products, people should no longer exploit the remaining forests. Through successful social forestry, protection and sustained management of natural forests is believed to be easier.

Commercial or industrial forestry, one of the traditional forms of forestry, is rarely considered to be any form of social forestry, even though it involves employment, profits for companies or the state, taxes, and usually national or corporate ownership of the resources - all of which benefit certain groups or segments of the society. Ideally, if the government benefits through profits and taxes, the entire society, including the population living near the resource, should benefit the services provided by the government (Mehl 1990). The FIO village forest program has this principle in miniature scale.

The principles and objectives of community forestry have been well known in the tropical countries starting from the 1970s. The achievements of community forestry, however, have been rather poor, worldwide. The tropical forest encroachment, forest decimation and environmental degradation have continued even at an increased rate in many of the countries where rigorous community forestry programs have been launched. A typical example is Ethiopia in East Africa, where the forest cover has already dropped to 2.7 %. The largest (the most expensive) soil and water conservation-oriented community forestry program in the world, funded through the World Food Program of the FAO, has been implemented there, but with meager results.

During the recent years more emphasis in the international development has been directed to **farm forestry**, instead of community forestry. This is based on a conclusion that a private farm, with a secured land tenure, is the largest unit in social forestry where sustained results in tree planting can be expected. Farm forestry-oriented forestry extension projects have shown this for instance in Kenya. This is apparently the case also in Thailand.

6.2 The FIO Forest Village program

Social forestry has been practiced in Thailand for a long period, and with a success that is far above the tropical average. An early, successful form of social forestry was the Burmese **taungya**-husbandry, which was introduced by the RFD already in 1906. In 1967 the FIO expanded the taungya-system within the creation of Forest Villages in its teak plantations (60 years rotation). Later the program was extended to shorter rotation plantations like for Pterocarpus macrocarpus (rosewood, rotation of 20-30 years), and for Eucalyptus plantations (rotation of 5 years at minimum).

The FIO Forest Village program has the following general principles:

* 100 families of shifting cultivators are collected and settled in a certain place in order to prevent further forest clearing through shortened shifting cycles.

* The previous shifting cultivators will be employed for reforestation of the logged over sites.

* The settlers are provided with medical care, and the children with primary education for 6 years.

* The settlers are encouraged to grow agricultural crops for subsistence and cash, by providing enough land for agriculture.

* Gradually new community is set up, with rising standard of living, attractive to people reside in the rural area instead of moving to urban centers.

The area is allocated to agroforestry along with the following principles:

* The total area of the plantation block should be enough for the whole rotation of the selected species, for the villagers agricultural needs, and for the annual agroforestry-based plantation establishment program.

* Annual plantation establishment target is 1,000 rai (160 ha), so that each family is allotted 10 rai (1.6) per annum for taungya-based agroforestry.

* After the plantation establishment is over, the annual harvesting would be the same 1,000 rai, in order to allow growing of new agricultural crops in the reforested area, or within coppice rows of Eucalyptus stand.

* In addition, each family has 1 rai (0.16 ha) for residence and 5 rai (0.8 ha) for home garden.

In a typical case, *Eucalyptus camaldulensis* plantations are grown at 5 years rotation. Cassava occupies the area every 5th year. There are 100 families in the Forest Village, they grow cassava under 20 % of the plantation area (Somdet ... 1992). From the forest growth point of view, it would be more beneficial to increase the rotation time. This would result a reduction in the farming area. A way to avoid this is to increase the plantation area, if possible (Tables 18 and 19).

Table 18. Area requirements in an average Forest Village of total 5600 rai (896 ha), if *Eucalyptus camaldulensis* is grown at 5-7 years rotation.

	5 yrs	6 yrs	7 yrs
Annually planted or harvested, rai	1000	833	714
Taungya/family, rai	10.0	8.33	7.14
Older forest, rai	4000	4167	4286
Residential + home garden area	600	600	600
Total block area, rai	5600	5600	5600

Table 19. Area requirements in a larger Forest Village of total 7600 rai (1216 ha), if *Eucalyptus camaldulensis* is grown at 5-7 years rotation.

	5 yrs	6 yrs	7 yrs
Annually planted or harvested, rai	1400	1167	7000
Taungya/family, rai	14.0	11.7	10.0
Older forest, rai	5600	5833	6000
Residential + home garden area	600	600	600
Total block area, rai	7600	7600	7600

Of the FIO forest villages for the pulp mill project, 5 are bigger than the typical case (over 800 ha under plantation forests), 3 are bigger than the larger case (over 1120 ha under plantation forests). especially in the biggest blocks it would be possible to continue the rotation time.

The FIO Forest Village is regarded as a successful project because it takes account of the needs of the local population (Hurst 1990). By the early 1980s most families were earning approximately 700 US$ per year from cash crops and bonuses, a considerably higher figure than the average Thai rural income.

The FIO Forest Village program has now entered a new phase as much of the originally designated area has already been reforested. In order to allocate the annual taungya-area to the people, Eucalyptus harvesting has already been started in many plantation blocks. There is a plan in the FIO, to go on with harvesting at 5 years rotation, even if this does not allow the highest possible wood production. The five years rotation, however, is well justified to provide employment land areas for forest villagers. In the plantation blocks where the allows for longer rotation, a shift to 6 years or 7 years rotation should in the future be considered.

Conclusion: The FIO Forest Village program has been successful in combining the needs of the people, reforestation and an initial supply of pulp wood from the established Eucalyptus plantations. (..17)

Recommendation: In each of the FIO Forest Village an assessment should be made based on number of families, total area under Eucalyptus plantations, and the annual area need for taungya-husbandry. It is recommendable to gradually raise the rotation time from the present 5 years to 7 years, whenever the social conditions allow. (..17)

6.3 Farm forestry and contract farming

Farm forestry is the most advanced form of social forestry in the countries where the land tenure questions have been settled. Partly this is the case in Thailand. Compared to many other countries in the tropical zone, the farm forestry in Thailand is much more advanced. The most convincing sign about that is the operating Eucalyptus wood market in the Thai countryside. Domestic and foreign customers buy the wood for poles and pulp wood. There is also a continuous flow for export of Eucalyptus chips from Thailand to Japan and Taiwan. Often the source of the raw wood is in private farms.

The land tenure development in Thailand favors the development of tree farming. It may be anticipated that the same effect will happen in tree farming as has happened with agricultural crops: land titling, if secure and transferable, increases the productivity between 10 - 30 percent (Tongpan et al. 1990).

The woodlots in the private farms are normally planted at spacing of 2 x 2 meters (2500 trees per hectare). This density is likely to yield 2 m^3/ha/a more in the first rotation, compared to 3 x 3 meters spacing in the industrial plantations. The soil cultivation and weed control in the village woodlots is often poorer than in the industrial plantations. If this is improved, the village woodlots can compete successfully with industrial plantations, both in growth and by wood price.

The farm forestry does not need to be restricted in woodlots. Scattered trees can be grown as in the boundaries of farms, some in the boundaries of rice paddies. Windbreak can also be a timber belt, which supplies continuously wood for cash.

The bottleneck for tree farming and steady supply of pulp wood from the farms is insecurity of having the harvest sold when matured, and sold at a reasonable price. The wood markets in the Thailand for pulp wood have started to establish after the logging ban, and the wood price has been in slight but steady rise. The pulp mill gate price for Eucalyptus wood, for example in Phoenix Pulp & Paper Co., Ltd. have risen from 600 to 675 Baht/gtn during 1991.

Even if a steady market and slightly rising wood prices are the best guarantee for successful pulp wood tree farming, contract farming is nowadays looked for with the farmers to secure the flow of raw material to the pulp mill. Phoenix Pulp & Paper Co., Ltd. in Khon Kaen shows direction in this issue.

Phoenix is signing contracts both for Eucalyptus and for bamboo. The Eucalyptus farming is subsidized with free seedlings and some occasional extension material. After 5 years, Phoenix guarantees to buy the product from the farmer at the market price which is applicable then. For bamboo contract farming, Phoenix gives also loan, without interest, which is deducted from later bamboo sales. By January 1992 Phoenix had signed about 4,000 contracts with farmers, out of which 600 were Eucalyptus contracts.

Conclusion: Contract farming for Eucalyptus pulp wood has already been initiated in North-East Thailand. The slightly rising trend in the pulp wood price also enhances farmers tree planting. There is an established Eucalyptus wood market in the rural areas of North-East Thailand. (..18)

Recommendation: Contract farming with local farmers in the North-East should be initiated using the system developed by the Phoenix Pulp & Paper Co., Ltd. as a model. (..18).

6.4 Social impacts

North-East Thailand has been the venue for controversies around plantation forestry in the past years. These issues have been dealt with for instance in Tongpan et al. (1990). Earlier the controversy was with plantation forestry, nowadays more with the forest reserve program.

The controversies have been also around Eucalyptus as a tree species, but lately it has been found out the problems were not that much connected with the species, but rather with the frontiers between villagers rights and governments rights to use certain land resources.

Of the social and community forestry programs, the FIO Forest Village program is one of the most successful. Similar, already long-term successes, cannot be found for instance in Africa.

Thailand's experience of forest village program has undoubtedly been of great value. The other programs are either more specialized - for example woodlots - or have taken a less integrated and sustained approach, such as People's Voluntary Tree Planting Program. The next step from Forest Villages is farm forestry, which also is well on the way in Thailand.

The villages are a further illustration that, despite the local farmers have largely contributed to the problem, they can also contribute substantially to its solution. The social impacts of the FIO Forest Villages are now in general positive when the villagers have realized the source of income and welfare of the villages. The FIO has also actively sought for improved social relations, for instance by paying higher rate for harvesting work to villagers (120 Baht/gtn) than to outsiders (80 Baht/gtn). Also agreement about five years rotation to allow enough land for cash crops, is a decision justified by social impacts.

In the North-East region where the wood market has been established, the plantation forestry and contract farming with tree crops do have beneficial social impacts by providing additional source of income. It should, however, be noticed that the smallest farmers have not received all the subsidized support for tree farming for which the industrial plantations and other large-scale woodlots have been entitled for (Tongpan 1990).

Conclusion: Plantation forestry and contract farming do have both beneficial and harmful social impacts in the rural countryside. Confrontations with plantation forestry are becoming less frequent as the social problems connected with forestry, are shifting over to the forest reserves program. On the other hand, established wood markets from tree farming after the logging ban, have improved social relations between tree planting and the people. (..19)

Recommendation: Active measures - like steady or slightly rising Eucalyptus wood pricing and additional employment with the forest harvesting work - to improve social relations between the plantation forestry, tree farms and the rural community, should continuously be sought for. (..19).

7. ENVIRONMENTAL IMPACT

7.1 Global impact: counterbalancing the greenhouse effect

Despite ambitious tree planting programs in Thailand, the deforestation has continuously exceeded the reforestation efforts. Between 1979 and 1984, during the peak of Thai reforestation for example, replanting covered less than 8 per cent of the deforestation.

Deforestation is - next to burning of fossil fuels - the second reason for the so called global greenhouse effect. Carbon emissions into the atmosphere result from burning of tropical forest, either in shifting cultivation or in incidental forest fires. Thailand has contributed her share into this process during the past decades. Unfortunately, the process is still going on at alarming rate. The annual acreage of tropical forests estimated to have been destroyed in the beginning of the 1960s was 640,000 ha. It emitted 95 mill. tons of carbon into the atmosphere. Thailand was number 5 in the world statistics (Fig. 14). In 1990 the rate of deforestation is believed to have still increased, to 800,000 ha/a (Hurst 1990).

Fig. 14. Net release of carbon to atmosphere from tropical deforestation in 1980 (Pohjonen 1989b).

The harmful climatic effects of the tropical deforestation can be turned by planting new forests to replace the burned ones. Reforestation in Thailand is a national attack on the global greenhouse effect. Massive reforestation, which Thailand is now facing and which the government is already aware of, has therefore besides national, also global impact.

It should also be noticed that the farm forestry in its all means has the same, although small but however positive climatic effect. The scattered trees, windbreaks and woodlots all belong to the category of the woody biomass. The higher the woody biomass density in the rural countryside, the bigger is the counterbalancing impact of the trees. In a big country like Thailand, the importance of farm trees should not be neglected. The magnitude of this effect, however, has not been determined in Thailand.

Conclusion: Plantation forestry and tree farming are part of the Thai national attack against the global greenhouse effect. Combined impact of the forest reserve program, reforestation program and tree farming may be expected to counterbalance the tropical deforestation of Thailand, in the future. (..20)

Recommendation: Plantation and farm forestry should be promoted for increasing the overall woody biomass density in the Thailand countryside. The impact of tree farming should be especially determined. (..20)

7.2 Ecological effects of eucalypts

The question of creating eucalypt plantations raises strong feelings, both for and against. The ecological effects of eucalypts are generally agreed to be negative. They disturb the water and nutrient balance, they are the cause of increased erosion, there is a heavy competition with other species, eucalypts have a toxic effect on other vegetation. But positive accounts are recorded as well (see eg. Pohjonen 1989a).

The displacement of natural, indigenous forests with exotic eucalypt plantations has often been regarded as negative as such. In some cases, part of the criticism can be related to disappointed expectations rather than to ecological facts. Eucalypts have often been heralded as a wonder species that will bring immediate solutions to local wood problems.

When such expectations are followed by plantings that fail due either to unsuitable species, the wrong site selection or the improperly understood needs of management (usually lack of weeding), the blame often falls on eucalypts in general, rather than on the real culprit which is bad forestry practice.

Based on strong arguments concerning the positive and negative effects of eucalypts, the Food and Agriculture Organization (FAO) has made an attempt to carry out an objective investigation of the matter (Poore and Fries 1985). As a result, it was found that there are four key ecological questions involved in the positive or negative effects of eucalypt plantations: i) water, ii) erosion, iii) nutrients, iv) competition.

7.2.1 Water

The main criticism that has been made against eucalypt plantations is that they deplete water supplies and that, on sloping catchments, they do not regulate the flow of water as well as the natural vegetation which they may have replaced when the plantation was established.

The question of depletion of water supplies is somewhat trivial. One of the principal justifications for selecting eucalypts for planting is their rapid growth compared to alternative species. In local species trials, eucalypts have produced more biomass (fuelwood, poles, pulpwood) per year, per ha than the alternatives. This high growth is necessarily associated with an increased need for water.

It is a basic law of plant physiology that production of biomass is closely associated with the transpiration coefficient. Each dry matter kilogram of biomass produced needs a rather constant amount of water, a few hundred liters. Therefore, the higher the demand for fuelwood, the greater the need for water. The increased use of water is the price paid for the higher growth rate of the tree. The question then arises, which is more important in each particular case: to save water or to produce wood?

At the same time, critical evidence is still lacking on the most important question: are eucalypts less or more efficient in their water use compared to other tree species? Compared to alternative species, do eucalypts produce less or more wood per unit of water used?

Sloppy catchments that are under forestation have a lower water table than those under scrub or grassland. This phenomenon is apparently unique to all forest trees, not merely to eucalypts, and it is due to the deeper roots of trees that take water from lower levels. On the other hand, the flow of rainwater into the soil and inside the soil is more consistent under the forest than under the bare ground. Whether eucalypts behave differently than other trees in letting water penetrate into the soil and in regulating the water flows inside the soil, is, as yet, unclear. There is some evidence from the humid tropics that young, rapidly growing eucalypt plantations regulate the flow of water inside the soil less well than a natural forest.

Eucalypts have often been planted in catchment areas where there have been no trees before. Under such circumstances, the soil water is used more by eucalypts than by the previous bushy vegetation, and the water table will be drawn down. The effect is greatest when trees are young and growing rapidly. Later, when the stand closes its canopy, the canopy also catches more water from the rains than the bare land since the overland wash is reduced. The negative and positive effects counterbalance each other. Tree genera other than _Eucalyptus_ would probably produce a comparable effect.

Some eucalypts have very strong surface roots. These roots can compete vigorously for water with the roots of ground vegetation and neighboring crops. If water is in short supply, the strongest competitor survives. Often it is *Eucalyptus*.

7.2.2 Erosion

Eucalypts are not particularly good trees for erosion control. When young, they are susceptible to grass competition; and to obtain good growth, clean weeding is necessary. Bare soil under trees is undesirable on steep or eroding terrain. Even mature eucalypt stands may be ineffective in halting surface runoff and overland wash.

It has long ago been observed that in steep dry areas where *Eucalyptus globulus* has been densely planted, the understored development and litter buildup are insufficient to prevent surface runoff. In closed plantations, all fast-growing eucalypts have a considerable demand for water. Since they also have an extensive and dense root system, eucalypts compete successfully for available soil moisture. This is of little importance in humid areas, but where rainfall is less than 750 mm, the failure to develop an understory leaves the soil exposed to runoff.

Dense eucalypt plantations are not recommended for erosion control in semi-arid climates. Even if their litter production could compensate for a light understory, in many places this litter is collected because of fuelwood shortages. In such cases, the sheet erosion is a serious threat.

7.2.3 Nutrients

In their natural environment, eucalypts appear to control the leaching and runoff of nutrients, perhaps even better than other natural forests. When eucalypts are established as plantations, their effect on the nutrient status depends on the original vegetation. If eucalypts are planted on bare sites there is an accumulation and incorporation of organic matter; the overall effect of eucalypts on the nutrient status is beneficial. But when replacing indigenous, diversified forests, the effect of eucalypts on nutrient status is negative; there is also evidence to show that the litter of eucalypts decomposes less rapidly than the litter of indigenous trees.

The cropping of eucalypts on a short-rotation basis, especially if the entire biomass is harvested, always leads to the depletion of soil nutrients. This is a direct consequence of their rapid growth; it would apply in much the same way to any highly productive crop.

7.2.4 Competition

The tall eucalypt forests typically have a dense undergrowth because their relatively sparse and usually pendulous leaves allow a great deal of light to pass. Thus, the site is not fully utilized by eucalypts alone. When eucalypts are planted in an area of natural or semi-natural vegetation, it has an effect on the flora and fauna of that particular area. This may be due to shading, competition for water and nutrients, or due to the direct chemical influences of eucalypts on other plants. It has been found out that mosses and epiphytes, common in natural forests, are completely absent under eucalypt forest, and that mushrooms have nearly disappeared. The most specialized plants are replaced by tolerant weeds.

Certain eucalypt species may produce chemicals from their leaves or litter that inhibit the germination or growth of other species. This chemical or biochemical effect is quite different from direct competition for water, minerals or light. Such an effect has been recorded under *Eucalyptus camaldulensis*. It is caused by phytotoxins which is extracted by rain water from either living leaves in the tree or decaying leaves on the soil. The effect, however, is selective. Certain highly valued fodder grasses like *Bromus mollis* and *Lolium multiflorum* have been found to be highly sensitive but other, lower valued grasses are less so.

A claim that eucalypts will poison all the grass vegetation under them is a myth. Instead, the grass species composition changes - usually in the direction of lower grazing and feeding value. In the beginning of the plantation establishment it often happens that the grass growth is strongly boosted.

To summarize the ecological effects of eucalypts, it is both positive and negative. Fast-growing eucalypts are neither ideal multi-purpose nor agroforestry trees. Instead they are efficient producers of biomass, the production of which is possible to arranged at sustained basis. As long as better alternatives cannot be found for short-rotation energy forestry in the Ethiopian highlands, eucalypt plantations cannot be eliminated due to their negative ecological effects.

7.2.5 Thai experience

Because of contradicting views about Eucalyptus ecology, the Thai forest research has studied this question especially in Thailand. A separate issue of Thai Forestry Journal (Vol. 6) was launched in 1987. Summary of the local findings is repeated here:

* Eucalypts, when planted in previously open areas, result a significant drop in the water table, but a similar drop was observed with Acacia auriculiformis.

* Yields of upland crops intercropping with Eucalyptus camaldulensis are not affected by root competition during the first two years; they are affected when the trees are three years old and older.

* Eucalypts have no long-term harmful effects on soil such as soil poisoning, but they deplete the soil nutrients as other tree monoculture practices do.

*   Based on a 4-year rotation period, the net annual uptake of the nutrients N, P, Ca and Mg was lower with Eucalyptus camaldulensis than with Acacia auriculiformis. The nitrogen fixing acacia did not have any plant nutritional advantage over Eucalyptus. There are many studies which indicate that eucalypts consume less nutrients than do cassava.

*   Observations of possible allelophatic effects are still controversial. No negative effect of Eucalyptus on germination rate of mungbean and mungobean was found in one study, while the other study found such negative effect on germination of maize, sorghum, sesame, soybean, mungbean, peanut and leucaena.

The Thai literature concludes that eucalypts should not be planted on good agricultural soils, or in watershed and conservation areas, but rather on impoverished, poor soils.

Conclusion: There is no scientific evidence for significant harmful ecological effects of Eucalyptus in Thailand. Local forest research has shown that Eucalyptus camaldulensis uses less nutrients for its growth than

Acacia auriculiformis. (..21).

Recommendation: Eucalyptus should preferably be planted on waste lands, on impoverished soils, not on agricultural soils. (..21).

8. SUMMARY ON PROJECT FEASIBILITY

The national, local, economic, ecological and social indicators are all in favor of entering into reforestation project for pulp fiber production with Eucalyptus and other short fiber tree crops. In this respect the proposition to establish a pulp mill in North-east Thailand, with raw material base of Eucalyptus camaldulensis and other short fiber tree crops, is considered feasible. The current plantation area is near (87 %) to supply all the required wood from the FIO's own plantations. This would need optimized management of the current plantations and the area resource. With tree improvement program the 100 % fiber supply is well within reach. Contract farming is backing up the raw material supply. Another possibility, even if expensive, is to transport Eucalyptus wood from the FIO's own plantations in the Southern and Northern regions.

Matching the timetable of the reforestation project with the establishment of the pulp mill, and the possibilities for full-scale funding must, however, be considered. The pulp mill should have an adequate supply of Eucalyptus wood from 1995 onwards. To be able to meet the wood demand, the reforestation activities should be started as soon as possible. About 10,000 ha of open or poorly stocked land should be reforested within three years. Counting on a standard cost of 1,000 US$/ha, this will need an investment of 10 mill. US$. Are these funds available before there is revenue from the pulp mill, i.e. beforehand? If the reforestation funding is not secured, there will be delay in the reforestation program and the subsequent pulp wood harvesting. This would ease smooth start of the pulp mill.

Conclusion: The overall feasibility for the plantation forestry and contract farming for pulp fiber production and contract farming in North-East Thailand is good. Timely startup of the planting activities before the pulp mill construction is essential for the future wood supply. (..22)

Recommendation: In order to ensure steady and sufficient wood supply for the pulp mill, international soft loan funding should be sought for the reforestation program. (..22).

9. TOWARDS REFORESTATION AND FOREST MANAGEMENT PROJECT

9.1 Wood harvesting for the FIO plantations prior to 1995

In the following it is assumed that:

* The pulp mill of the FIO and partners is established in the North-East between 1992-1995.

* The pulp mill procures the first part of the Eucalyptus wood, at 50 % level (235,000 gtn or 132,200 m^3) in 1995.

* During the years 1992-1994 Eucalyptus harvesting program is executed in the Forest Village plantations at planned intensity: 5 years rotation (20 % of the area is harvested annually).

* The harvested wood is sold in the open Eucalyptus market at estimated (current) price of 675 Baht/gtn. The

wood is harvested at Forest Village cost, 120 Baht/gtn. The wood is transported on average 200 km from the plantation to the customer (for instance to Khon Kaen).

The current FIO Village forest plantations have been established mostly at spacing of 2 x 8 meters. Consequently, they are understocked as compared to the calculated provisional yield tables. In 5 years rotation the plantation blocks are estimated to produce at mean annual increment (MAI) level of 7.5 m^3/ha/a (corresponds to 13.35 gtn/ha/a, or 2.136 gtn/rai/a); compare also the measured data from a few plantation blocks, Table 11.

Of the already established FIO Forest Village plantations, 9728 ha (see Table 6), 20 per cent is harvested annually, i.e. 1946 ha. The annual net revenue from the wood harvests will thus become at about 46 million Baht, according to the following calculation:

- Harvested area	1946 ha
- Harvest per ha	37.5 m^3
- Total harvest, in volume	72975 m^3
- Total harvest, in gtn	129896 gtn
- Value at mill gate	87.679 mill. Baht
- Deduct transport cost, 200 km at 1 Baht/gtn/km	25.979 mill. Baht
- Deduct harvesting cost,	

120 Baht/gtn 15.588 mill. Baht

- Net value of the harvested wood at stump 46.112 mill. Baht

Comparing to the reforestation cost in the Forest Villages (4450 Baht per rai, cf. Table 16), the 46 mill. Baht is sufficient to reforest about 10,400 rai per annum (1660 ha/a).

A target should, however, be set that the poorly stocked or open areas of concessionaire's blocks (10,432 ha) are reforested before the pulp mill starts to operate, that is during the 3 years of 1993-1995. To fulfill that, the annual plantation establishment area should be 3477 ha. **The harvesting revenue from the existing plantations covers only 48 % of the reforestation costs. The total reforestation cost needed annually would be 96.7 mill. Baht.**

9.2 Reforestation and forest management project proposal

As the feasibility for improved Eucalyptus wood production from the FIO's plantation areas is good, it is suggested that a special reforestation and forest management project will be launched to satisfy the anticipated raw material need for the pulp mill, and to further enhance the pulp fiber production in the North-East. The project should take care of both the FIO's own plantation forests as well as the woodlots and farm forests belonging to the contract farming.

The project should have the following components:

1. Extension for contract farming of pulp fiber tree crops

- Training of the local FIO field personnel for contract farming

- Training of the local farmers for improved plantation establishment and tending

- Distribution of improved seedlings to contract farmers.

2. Research and development

- Inventory and assessment of the existing *Eucalyptus camaldulensis* provenance trials

- Selection of plus trees from the existing *Eucalyptus camaldulensis* and *Acacia mangium* stands and trial areas

- Establishment of additional species trials

- Continuation of the provenance trial programme

- Initial establishment of scion gardens for cutting production (first in Somdet)

- Tree improvement (breeding) for clonal forestry

- Investigations into optimum soil mix for the seedling pots, testing of suitable composting raw materials and methods for the new nurseries

3. Training

- Training of the FIO nursery staff

- Training of the FIO plantation establishment staff

- On-the-job training of the contract farmers for optimized production

- Harvesting training for both the FIO staff, temporary workers and farmers.

Timetable

The initial phase of the project takes 4 years, for example 1.9.1992 - 31.8.1996. The first phase would be partly funded from international soft loans; the first phase would also be partly staffed by international expertise.

* During the first year

- the Somdet central nursery will be established

- Selection of plus trees for improved clones is initiated,

- Establishment of scion gardens (for cuttings) is initiated

- Establishment of species and provenance trials is continued, depending the availability of improved seed

* <u>During the second year</u>

- Establishment of species and provenance trials is continued

- Trials with cutting-based seedlings are initiated, using the plus trees from Somdet and other selected plantations

- Establishment of another central nursery near to the pulp mill site (which have been decided and confirmed by then). The Somdet central nursery will be used as model.

* <u>During the third and fourth year</u>

- Continuation of seedling production in the two central nurseries, using improved seed and cloned stock, by gradually increasing the amount of clonal seedlings as much as the material will allow

- Analysis of the established and otherwise measured tree improvement trials.

- Studies into fast-growing <u>Eucalyptus</u>- and <u>Acacia</u>-hybrids are initiated.

<u>The required expatriate expertise</u>

1) Project team leader / tree improvement specialist, duties:

- To assume the responsibilities of project team leader and coordinator

- To establish, take care of and analyze the species, provenance and clonal trials

- To select the plus trees for cutting production

- To organize the propagation of the clonal stock in the project nurseries

- To further develop the tree improvement for instance through hybridization

- To conduct the training and extension activities of the project.

Duration: 42 months in Thailand

Qualifications: M.Sc. in forestry, plant breeding or biology, with background and experience in the above mentioned duties.

2. Expert in plant propagation

Duties:

- Supervise the establishment of the central nurseries

- Supervise the procurement of improved seed

- Supervise the preparation of the soil mix in the nurseries

- Supervise the establishment of scion gardens for the improved cuttings

- Supervise the raising of the cutting-based seedlings

- Train the nursery staff

Duration: 30 months

Qualifications: Familiar with modern plant propagation methods in the tree seedling nurseries, either M.Sc, B.Sc. or Diploma in Forestry, with experience

3. <u>Mechanics / Adviser</u>

Duties:

- Supervise the installations in the nurseries

- Train the technical nursery staff

Duration: 6 months

Qualifications: Qualified mechanics with experience

4. In addition an extension advisor is needed. It is anticipated that qualified person is available locally in Thailand.

<u>Budget</u>

1. <u>Development of clonal forestry systems</u>

- 2 clonal forestry nurseries
- Share for imported installations and material 1,050,000 US$ per nursery

Subtotal 2,100,000 US$

2. <u>Forest management system</u>

- Satellite images, maps
- Computers and software

- The FIO staff training

Subtotal 270,000 US$

3. <u>Costs for international expertise</u>

- Project team leader, tree improvement specialist, 42 months, 690,000 US$

- Expert in plant propagation, 30 months, 470,000 US$

- Mechanics/Adviser, 6 months 90,000 US$

Subtotal for expertise 1,250,000 US$

GRAND TOTAL FOR PROJECT COSTS 3,620,000 US$

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Annex 1

Itinerary, Thailand January 1992 Veli Pohjonen

Tue 31 Dec Collect Thai forestry background information, Joensuu University

Wed 01 Jan Study background information

Thu 02 Jan Study background information

Field trip preparations

Flight Helsinki-Bangkok

Fri 03 Jan Arrival in Bangkok, meet with Mr. Kenneth Oo, DUCO International Co., Ltd.

Briefing meeting in Forest Industry Organization (FIO) (Messrs. Winai Subrungruang, Chittiwat Silapat, Kanit Muangnil, Montee Phothitai)

Meet with Mr. Supan Jotikabukkana, DUCO International Co., Ltd.

Sat 04 Jan Meet with Mr. Supan Jotikabukkana, DUCO International Co., Ltd.

Study background material, report writing

Sun 05 Jan Study background material, report writing

Mon 06 Jan Meet with Mr. Chittiwat Silapat, FIO, to collect background data

Meet with Mr. Rauno Laitalainen, Thai Forestry Sector Master Plan

Tue 07 Jan Meet with Mr. Chittiwat Silapat and Mr. Montee Phothitai, FIO, to collect background data

Meet with Faculty of Forestry staff, Kasetsart University

Wed 08 Jan Travel Bangkok to Manjakiri plantation, inspect plantation, measure Eucalyptus camaldulensis (ECA) sample plots

Travel Manjakiri - Khon Kaen

Thu 09 Jan Travel Khon Kaen to Phoenix pulp mill, briefing on Phoenix pulp and paper milling activities and on the approach to contract farming of eucalypts and bamboo

Visit Phoenix nursery and demonstration farm, measure ECA and Acacia mangium (AMA) sample plots

Travel Phoenix to Somdet plantation, inspect nursery, provenance trial and plantation, measure ECA sample plots

Travel Somdet - Kalasin

Fri 10 Jan Travel Kalasin - Ummao, inspect and measure sample plot in ECA village woodlot site (Ummao school)

Travel Ummao - Ubon Ratchathani - Pibulmungsahan. Inspect plantation and potential pulp mill site, measure ECA and AMA sample plots.

Travel Pibulmungsahan - Ubon Ratchathani

Sat 11 Jan Travel Ubon Ratchathani - Khunhan. Inspect plantation, measure ECA sample plots

Travel Khunhan - Buri Ram (Nakhonrachasima). Inspect potential pulp mill site and plantation. Measure ECA and AMA sample plots.

Travel Buri Ram - Nakhon Ratchasima

Sun 12 Jan Travel Nakhon Ratchasima - Kham Thale. Inspect private ECA woodlot (280 rai, 45 ha).

Travel Kham Thale - Dankhuntod. Inspect plantation, measure ECA sample plots.

Travel Dankhuntod - Bangkok

Mon 13 Jan Analyze field trip material in FIO

Tue 14 Jan Collect more background material in FIO, report writing

Wed 15 Jan Meet with Mr. Kanit Muangnil, FIO

Meet with Faculty of Forestry staff, Kasetsart University

Meet with Mr. Pisal Wasuwanich, Head of seed center, Royal Forest Department

Meet with Mr. Rauno Laitalainen, Thai Forestry Sector Master Plan

Thu 16 Jan Report writing

Fri 17 Jan Debriefing meeting with Mr. Chittiwat Silapat, FIO

Report writing

Flight Bangkok - Helsinki

Sat 18 Jan Arrival in Helsinki, Report writing

Sun 19 Jan Report writing

Mon 20 Jan Report writing

Tue 21 Jan Report writing

Wed 22 Jan Report writing

Thu 23 Jan Report writing

Fri 24 Jan Debriefing meeting with Mr. Yrjö Schildt, ENSO Forest Development

Sat 25 Jan Report writing

Sun 26 Jan Report writing, Delivery of the feasibility study.

Annex 2

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