Can Forest Plantations Alleviate Pressure on Natural Forests?: An Efficiency Analysis in Indonesia

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May, 2002

ACKNOWLEDGMENTS

The author gratefully acknowledges the research grant provided by EEPSEA and appreciates the constructive comments and valuable advice from Dr. David Glover, Dr. Herminia Francisco, Dr. William Hyde, and Dr. Nancy Olewiler regarding an earlier version of this paper. I am also grateful to Dr. Tim Coelli of the University of New England for the provision of the computer software FRONTIER 4.1. Last but not least, I would like to thank Bambang Mulyo Sukowiyono, Nono Suwadji, Supriyono, Sudirno, and Aris Suwandi for their tremendously valuable assistance in data collection.

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EEPSEA is supported by the International Development Research Centre (IDRC); the Danish Ministry of Foreign Affairs (DANIDA); the Swedish International Development Cooperation Agency (Sida); the Ministry of Foreign Affairs, the Netherlands; the Canadian International Development Agency (CIDA); the MacArthur Foundation; and the Norwegian Agency for Development Cooperation (NORAD).

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CAN FOREST PLANTATIONS ALLEVIATE PRESSURE ON NATURAL FORESTS?: AN EFFICIENCY ANALYSIS IN INDONESIA

Bambang Tri Hartono

EXECUTIVE SUMMARY

This study examines the efficiency of the industrial timber and pulp plantation program in Indonesia using panel data from 1994 to 1998. Thirty-two companies from four provinces were included in this study. Firm-specific technical efficiencies were computed from the estimation of a stochastic frontier production function. The efficiency of a firm is measured by the shortfall of realized planting against what fully efficient firms could have produced using the same amount of inputs.

The estimated technical efficiencies of the plantation firms varied widely, ranging from 0.12 to 0.93, and 0.13 to 0.93, with a mean value of about 0.60 for both analyses. This mean value of 0.60 indicates that during the period of study, the firms were, on average, 40% inefficient. This means that the firms could have performed almost twice as much as what they actually achieved during the period 1994 to 1998, with the given level of inputs. Considerable technical inefficiencies were found in the industrial timber and pulp plantation companies included in the study.

Sub-optimal efficiency levels appeared to be a hindrance in alleviating the pressure on the natural rainforests. The results showed that plantation size, choice of scheme, and the involvement of local people were significant determinants affecting variations in the level of inefficiency. Self-financed schemes and the involvement of local people had serious adverse effects on efficiency. The involvement of local people was measured by local people employment in the plantation firms. The study found that the less efficient firms were generally those with a high proportion of local employees.

Medium and large-scale plantations and pulp schemes were found to contribute to higher efficiency. This evidence contradicts the Government's policy of limiting landholding size and suggests that a governmental reform of transmigration and self-financed schemes is called for. The findings also advocate that the Government should proceed with the privatization of efficient medium and large-scale plantation companies.

1.0 INTRODUCTION

1.1 Background

The current forest-based industries in Indonesia, with a total installed capacity of 63.48 million cubic meters of logs per year (Table 1), are expected to continue to be dependent upon tropical rainforests over the next several years. The capacity of forest resources to provide raw material support for forest-based industries is, however, becoming very limited. Official data from the Ministry of Forestry (Directorate General of Forest Production Utilization 1999) indicate that the existing commercial volume of standing stock could sustainably yield logs of 20 to 25 million cubic meters per year which is close to official log production figures. This means that sustainable yields can supply only about a third of the volume needed to keep existing forest-based industries operating at full capacity.

Based on the current rate of harvesting, the timber supply situation in Indonesia presages a bleak future. Unless adequate remedial action is taken, the country's forest reserves will soon be depleted. It has, in fact, been predicted by the Ministry of Forestry that before the turn of the century, the annual log shortage of 44.45 million cubic meters is likely to be a serious problem faced by Indonesia (Directorate General of Forest Production Utilization 1999).

On average, annual harvesting has been at the level of 800,000 hectares over the last ten years using the poly-cyclic selective cutting system with minimum diameter and enrichment planting. The former specifies that every logging concession firm should rehabilitate the blocks in which logging has been carried out by applying timber stand improvements or enrichment planting methods in keeping with sustainable forest management requirements. Enrichment planting to augment the regeneration of valuable (tree) species has been carried out with generally limited success. It has frequently been found that seedlings fail to grow or grow poorly, or are killed by climbers and weeds. Reforestation bonds were too low to finance timber stand improvement. (Reforestation bonds were monetary guarantees to replant or to effect enrichment planting in logged areas. The Government would repay the value of the bonds to a company which has fulfilled this obligation. The bonds were later replaced by/renamed as reforestation funds). In situations where poor survival rates and slow growth prevail, it is unlikely that enrichment planting is a cost-effective investment (Ota 1984; Asabere 1987; Kio and Ekwebelam 1987, cited in Panayatou and Ashton 1992; Potter 1996).

Considering this unfavorable situation, Indonesia must respond with the establishment of a sustainable forest production system incorporating an effective protection policy for its tropical rainforests. More than six million hectares of new forest plantations need to be established for the next 25 years to meet this shortfall (Haeruman 1994). However, Morrel (1997) reported criticisms and allegations of inefficiency and negative environmental effects (like degraded areas, and monocultures with narrow genetic bases that replace the ecosystem's precious genetic base and make the forests more susceptible to disease and pests) in timber plantation development schemes. The growth rate and density for economically viable industrial use has been only 50%.

Table 1. Estimation of Raw Material Requirement for Wood-based Industries

No	*Industry*	*Number of Companies (units)*	*Annual Raw Material Requirement (m^3)*
1	Plywood	107	18,866,190
2	Sawmill	1,618	22,096,166
3	Pulp and Paper	6	17,910,000
4	Others	150	4,610,097
	Total	1,881	63,482,453

Source: Directorate General of Forest Production Utilization (1999)

One aspect of plantation development in Indonesia that needs closer attention is the role of local communities which is believed to significantly affect the efficiency levels of plantation firms. Over the past decade, the idea of local participation has gained tremendous acceptance in forestry development. In line with participatory management principles, the timber and pulp plantation program in Indonesia, like most typical plantation programs in developing countries, must meet a broad range of economic, environmental and social expectations. Nasendi (1996) indicated that in many cases, the local people's interests are merely interpreted by logging and plantation firms as a need for employment. The development of commercial forest plantations in some localities in the tropics does not involve local people. In reality, the issue of involving local labor forces in forest activities, the simplest form of local participation in sustainable forest development, is not a trivial matter. Plantation companies should recognize that local people who have lived in the forests all their lives have been deriving their livelihoods from natural forest products (rattan, herbs, mushrooms, etc.). The wages these companies offer must, therefore, be sufficient to replace this lost livelihood and sustain the local people’s well-being. Also the companies should respect the fact that the locals live according to customary laws.

1.2 Focus of the Study

From a policy perspective, the elasticities of the stochastic frontier production model as well as the coefficients of the inefficiency models address a number of relevant issues. For instance, the skilled labor variable in the stochastic frontier production model is related to training and education policies in the plantation sector; the equipment variable is closely related to site preparation policies; and the government financial support variable is related to subsidy policies. In other words, policy implications can be derived from the interpretation of the elasticities of the coefficients of the model used in the study. This research will focus on the estimation of the efficiency levels of plantation firms and identifying what the determinants of efficiency levels are.

First, how have successful plantation firms achieved technical efficiency levels in the first rotation and how can the percentage of plantations that have failed as a result of inefficiency be reduced? Second, what input factors are the most relevant in explaining the planting performance level? (Planting performance is defined as hectares of realized planting adjusted by the survival rate.) Third, what are the crucial determinants of efficiency? The research findings gave rise to further examination of other important issues, such as the effect of government policy on the development of the various plantation schemes and on the sizes of the firms. In Indonesia, the rights to logging concessions and plantations held by conglomerates has long been criticized. There is a growing demand for more involvement by small and medium-sized firms. Human resources, technical expertise, and other input factors are, however, often insufficient in these firms. There is also a clamor for increased local people involvement in plantation development. Nevertheless, it is important to determine exactly to what extent their involvement influences the efficiency of plantation development in Indonesia.

2.0 INDUSTRIAL TIMBER AND PULP PLANATIONS IN INDONESIA

2.1 Timber and Pulp Plantation Policies in Brief

Recognizing the serious threat to timber supply, the Ministry of Forestry, in the early 1990's, undertook an important reform by developing the Timber and Pulp Plantation Program with the issuance of Government Regulation 7/1990. This program is part of a national commitment to rehabilitate degraded forestland, to protect existing natural rainforests, and to maintain a resilient timber production system. Gadas (1995) reported that the Government of Indonesia had planned an ambitious industrial plantation program to establish 4.4 million hectares of fast-growing plantations by the year 2000. However, this has been far from achieved; only 1.7 million hectares have been planted from the allocated 7.4 million hectares.

The Ministry of Forestry and the Ministry of Finance jointly issued Regulations 421/1990 and 931/1990 which encompass incentive programs. A zero-interest-rate financing scheme is provided by the Ministry of Forestry from reforestation funds[1] to attract forest plantation investment. The structure of the financial scheme consists of two components: the equity and the loan for establishment costs which have a grace period of 8 and 15 years respectively, depending on the type of plantation (i.e. pulp or non-pulp scheme). This financial support from the Government is available to private companies that enter into joint ventures with state-owned companies. The equity is 35% of the total financial

[1] Many argue that there is no real significant economic incentive to invest in timber and pulp plantations even with the interest free loan facilities as long as logs from natural rainforests are so inexpensive and easily available in black markets (Potter and Lee 1998; Ascher 1999).

support, and the loan makes up the rest (65%). Out of the 35% equity, the Government contributes 14% of the equity (40% of total equity) and the remaining 21% (60% of total equity) is provided by the private firm. The Ministry of Forestry provides half of the required establishment costs (32.5% of total financial support) by way of an interest free loan, and the remaining costs are covered in the form of a commercial loan from reforestation funds.

From 1990 to the end of 1999, the total amount of reforestation funds granted for the timber and pulp plantation development was IDR 1,897.10 billion (USD 179.65 million)[2] of which IDR 835.10 billion (USD 79.08 million) was in the form of government equity, and IDR 1,062 billion (USD 100.57 million) for loans for operational/establishment costs. Pulp and non-pulp schemes (large-scale firms) accounted for 64% of the grants while state-owned companies and transmigration schemes each accounted for 18%.

The Directorate General of Forest Utilization prepares for the issuance of plantation-related policies and plantation rights granted by the Ministry of Forestry after reviewing all requirements and recommendations from the Regional Forestry Office. At the end of every semester, state-owned companies and selected consultants take turns to inspect the planting performance of every plantation company that has participated in the government financial scheme in order to monitor the use of the reforestation funds. Based on these inspections, the Secretary General reimburses the establishment costs according to realized planting areas and standard costs per hectare. The Regional Forestry Office reviews and approves the annual working plan and the salvage cutting target submitted by every firm each year.

Since the fall of the former government regime in May 1998, the call for immediate structural reforms has become top priority in all sectors in Indonesia. The reform movement has been mainly directed at discontinuing former regime-related practices, especially in relation to the domination of the forestry sector by conglomerates, in a bid to achieve "the people's economy". "The people's economy", a fairly new political phenomenon, is aimed at fresh policy initiatives concentrating on the creation of development opportunities for the lower and middle income groups. One obvious outcome has been a stream of policies directed at supporting small and medium-sized enterprises (Sunderlin 1998; Casson 1999; Seve 1999; Islam et al. 2001).

2.2. Timber and Pulp Plantation Schemes

2.2.1 The State-owned Company Scheme

The Ministry of Forestry has laid down that the ownership of revoked logging concessions and expired concession rights (without extensions) shall revert to central administration (i.e. the Ministry of Forestry) under the management of state-owned

[2] Exchange rate used: 10,560 Indonesian rupiah (IDR) = 1 United States dollar (USD)

companies. The revoked concession areas may be allocated to a new timber and pulp joint venture company or established as a state-owned plantation scheme.

The total area of timber and pulp plantations under joint venture ownership involving state-owned companies is about 2,891,751 hectares. The five state companies (INHUTANI I to INHUTANI V) also manage their own plantation areas (also known as “HTI Murni” or state-owned company schemes) covering about 497,448 hectares, in which the size of a plantation area ranges from 7,500 to 50,000 hectares.

2.2.2 The Transmigration Scheme

The resettlement of the outer islands was promoted primarily through a transmigration program.[3] The resettlement project which encompassed plantation development, gave rise to the creation of the transmigration (or social plantation) scheme in 1992 as a result of a joint decree between the Ministry of Forestry and the Ministry of Transmigration. This decree compelled a hundred logging concession holders to develop timber and pulp plantations under the transmigration program.

The Government provides a modest house, a 0.25 hectare parcel of land as a home garden, and rice (for a period of one year) to all transmigrants. Employment opportunities for transmigrants are provided by the plantation companies. Transmigrants do not own rights to any part of the plantation land, thus working on the plantations is their main source of income. The companies in the transmigration scheme have obtained land allocations of between 6,100 to 29,700 hectares, the average allocation being about 11,500 hectares.

Some of the firms within the transmigration scheme receive financial support from the Government. Those which do not receive financial assistance are classified under the self-financed category.

2.2.3 The Pulp Scheme

This scheme is extremely large in terms of landholding size, with areas reaching a maximum of 300,000 hectares. The pulp scheme is divided into prioritized and non-prioritized schemes. Companies under the prioritized scheme are firmly supported by the Government by way of subsidies for their plantations and industries, and tax break facilities. The aim of the prioritized scheme is to make Indonesia a leading global pulp and paper supplier. There are 13 companies partaking in this scheme, and most of them have been granted financial support from reforestation

[3] In the early 20th century, the Dutch initiated the movement of people from densely populated locations in Java to Sumatra, Kalimantan, Sulawesi, and Irian Jaya (the outer islands). The Government of Indonesia, after independence, continued this resettlement program with the objective of economic development, national unity, and national security. The program reached its peak in the mid-1980s. The total number of people resettled from 1905 to 1989 was about 5 million, of which about 3.7 million were moved during the decade 1979 to 1989. However, in 1990, Java, which covers less than 7% of the total land area, was still the most populous island, supporting about 60% of the Indonesian population (Holden and Hvoslef, 1995).

funds and are vertically integrated with pulp and paper industries. Land allocations under the prioritized pulp scheme range between 78,200 to 299,700 hectares. The average land allocation is 200,000 hectares.

The non-prioritized scheme is less supported by the Government. Land allocation for this scheme is smaller (43,000 to 300,000 hectares with an average of 156,300 hectares) than for the prioritized scheme with one exception in Irian Jaya. The Government has granted approval to 16 companies under this scheme, most of them in 1998. Due to the sluggish current economy, however, progress has been far below expectations.

2.2.4 The Non-pulp Scheme

This scheme is aimed at providing raw materials for lumber or construction purposes. In terms of land size, this scheme is smaller than the pulp scheme. Land allocation is in the range of 15,000 to 82,000 hectares, with the average at 25,900 hectares. The maximum land allocation, though, is generally about 60,000 hectares with a rotation of 15 years. Some companies within this scheme receive financial support from government reforestation funds.

2.2.5 The Self-financed Scheme

The Government has compelled logging companies to rehabilitate their areas into timber and pulp plantations. Ideally, there should be equal opportunities for every company to obtain financial support from the Government under the different schemes, as long as the private firm establishes a joint ownership with a state-owned firm. However, this is not always the case. This study defined a fifth scheme called the self-financed scheme which covered firms qualifying for incentives, but not receiving them due to limited (financial support from) reforestation funds and competition from other logging companies. These firms are thus compelled to develop their plantations using their own capital. In such a situation, it is likely that this group of companies contributed to inefficiency, due to inadequate funds for plantation development.

2.3 The Growth of Timber and Pulp Plantations

By the end of 1999, forestlands designated for timber and pulp plantations amounted to a total of 7.4 million hectares. The detailed allocation for each scheme is as follows: 2.6 million hectares (35%) for the prioritized pulp scheme; 2.3 million hectares (31%) for the non-prioritized pulp scheme; 1.7 million hectares (23%) for the non-pulp scheme, and finally 0.8 million hectares (11%) for the transmigration scheme.

The planted area as per the fifth National Development Program (NDP) (1994) was only 8.2% or 610,890 hectares. Out of the total land allocation of 7.4 million hectares, actual planting covered only 24% or 1.7 million hectares by the end of

1999. The percentage of the planted area over the total allocation per scheme was: 42% for prioritized pulp, only 2% for non-prioritized pulp, 20% for non-pulp, and lastly 38% for transmigration. Planting performance substantially declined after the economic and political crisis in 1997. USD 12 billion in investments has, however, been spent to expand the installed capacity of pulp and paper industries by about sevenfold in the last decade The increased demand for raw materials created as a result of such expansion far exceeds the ability and capacity of plantations to meet such demand (Potter and Lee 1998; Seve 1999; CIFOR 2000; *The Jakarta Post* 2000).

2.4 Sustainable Forest Production in the First Rotation

2.4.1 Yield and Economic Viability

The development of a strong, economically viable forest plantation sector rests on sound government policies for the effective management of timber and pulp industries. Timber and pulp plantation programs should be geared towards the objectives of sustained yield and economic viability. FAO's (the United Nations Food and Agricultural Organization) financial analysis of plantation development in Indonesia revealed that the average yield of a plantation should be in the range of 20 to 25 cubic meters per hectare per year for *Acacia mangium* and *Gmelina arborea*. Another more recent economic analysis conducted by Kuusipalo (1994) noted that a mean annual increment (MAI) of 10 to 25 cubic meters per hectare per year was required to obtain an IRR (internal rate of return) ranging from 0 to 17%, which is close to the current bank lending rate. Among the assumptions in the analysis was that the price of logs from plantations was held constant at USD 20 per cubic meters (at the exchange rate of 2,500 IDR = 1 USD). After the economic and political crisis of May 1998, the market price of logs from plantations was about IDR 120,000 to IDR 150,000 or USD 15 to 18.75 (at the exchange rate of 8,000 IDR = 1 USD) at the seller's logpond (port).[4] This price was equal to USD 25 to 34 at the buyer's mill gate, depending on distance and accessibility which determined transportation costs.

It is a well-established fact that low and unstable log prices pose a big hindrance to the development of small and medium-scale timber and pulp industries. In addition, large-scale companies depress the market price in an oligopsonic market (market with few buyers). This situation presents a further obstacle. While the costs of production increase due to high inflation rates and the depreciation of the local currency, small and medium-scale producers find that they cannot sell their logs at expected prices in the oligopsonic market. The resultant effect is that in terms of real

[4] Haughton et al. (cited in Ascher 1999) noted that since the net present values of some plantations were negative, logging was more economically attractive. A rough estimation of IRR using establishment cost data from this study under several scenarios (sensitivity analyses) and a range of yields from 90 to 140 m^3 and prices from IDR 120,000 to 150,000 per m^3 is about 8% to 15% (a wide range) or 10% to 12% (a narrow range). Meanwhile, the lending rates were 20.59% (1993), 17.76% (1994), 18.85% (1995), 19.22% (1996), 21.82% (1997), 39.07% (1998), and 27.66% (1999) (International Financial Statistics Yearbook 2000). In 1998, the lending rate was exceptionally high at a range of 15% to 60% (Indonesian Central Bank 1999).

value, their loans become bigger making it difficult for them to settle their debts. The lower production level of inefficient firms does not help the situation.

The unattractive prospects of timber and pulp plantations have shifted private sector interest towards estate crops[5] which offer more promising returns through shorter rotation periods and higher market prices (Sunderlin and Resosudarmo 1998; Potter and Lee 1998).

A consulting firm, Data Consult (1999) described the economic crisis in 1998 in a monetary perspective: the exchange rate on the US dollar increased from IDR 4,650 at the end of December 1997 to its highest value of IDR 15,150 at the end of June 1998. This was an increase of 225.8% within only a six-month period. The inflation rate increased from below 10% prior to 1997 to 75% in 1998.[6] The local currency, Rupiah (IDR), has depreciated tremendously. Currently, the exchange rate has stabilized at IDR 8,000 to IDR 9,000. The bottom line is that this condition demands a higher log yield to be produced from timber and pulp plantations to achieve a viable IRR and the establishment of a long-term sustainable production system.[7] Accordingly, the mean annual increment (MAI) should be at a level above 25 cubic meters per hectare per year. Can this be achieved?

Some large companies that use genetically improved seed have reported a harvest volume level of only 90 to 140 cubic meters per hectare on eight-year-old plantations (resulting in a MAI of 11.5 to 17.5 cubic meters per hectare per year) due to a low survival rate. Unskilled labor, lack of efficient supervision, and frequent forest fires were among the main factors that contributed to the poor survival rate of the plantings (saplings) (Teguh, Kirmadi and Teddy 2000). [8]

Approximately the same harvested timber volume, and sometimes even less, is reported by state-owned companies. Production is only at a MAI of 11.5 to 17.5 cubic meters per hectare per year. Based on Data Consult's estimation, the raw material requirement for pulp industries alone is 12.32 million cubic meters based on an

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[5] It is most likely that the predominance of estate crops, i.e., oil palm or rubber plantations over timber and pulp plantations, and the discouraging performance of timber and pulp plantations, are among the reasons for Decree 614/99 issued by the Ministry of Forestry which stipulate the establishment and development of mixed plantations.. The decree seems to be counterproductive to overall timber and pulp plantation and social forestry policies. Diversification of timber and pulp plantations into oil palm and rubber is not consistent with efforts to establish a sustainable timber production system. Moreover, as indicated by Kartodihardjo and Supriono (1999) and Harnoto (Personal communication, 2000), the regional spatial development planning (known as RTRWP – Rencana Tata Ruang Wilayah Pembangunan**)** has a tendency to value a piece of forestland in terms of the monetary value of estate crops rather than for their long-term environmental and ecological value.

[6] The inflation rates were 9.24% (1994), 8.64%(1995), 6.47% (1996), 11.05% (1997), 75.14% (1998), and 25% (1999) (Media Indonesia, January 10, 1999; Statistical Yearbook of Indonesia 1999).

[7] A fairly recent phenomenon is where some large plantation companies manage to obtain approval from the Ministry of Forestry to delay repayment installments of loans from reforestation funds and to bring forward the harvesting deadline from eight to five years. Wallace and Silver (1983) found a similar case of FIP (Forestry Incentive Programs) in coastal Georgia where harvesting tended to occur sooner when encouraged by exogenous incentives.

[8] Data from annual inventory provided by R&D staff of large-scale companies. Personal communication with Teguh and Kirmadi, Pakanbaru, and Teddy, Samarinda, 2000.

installed capacity of 3.04 million tonnes of pulp.[9] Yet, the average planting achievement until the year 1998 was only about 239,000 hectares. Thus, in order to meet the raw material requirement for pulp and paper industries and to protect the remaining rainforests, timber and pulp plantations should have a MAI of 51.5 cubic meters per hectare per year. The challenge for the Government is to improve and reform plantation development so that planted areas and MAIs are increased. In particular, the goal should be increase realized planted areas to 500,000 to 600,000 hectares per year. On average, current realized planting was only at about 200,000 hectares per year.

Most pulp industries undoubtedly remain excessively dependent on natural rainforests due to insufficient raw material from plantations. Illegal logging practices have been unavoidable as a consequence. Some references estimate illegal logging at a range of 8 to 30 million cubic meters per year (Kartodihardjo and Supriono 1999; Rude 2000).

2.4.2 Threat of Forest Fires

The economics of long-term forest investments in the timber and pulp plantation program are remarkably fragile, accentuated by the incidence of forest fires. The loss of lives and plantations attributable to wildfires in the tropics is great. Two of the largest wildfires occurring in the time frames 1982 –1983 and 1997 –1998 during prolonged dry seasons caused by strong El Nino southern oscillations (ENSO) wrought disastrous effects on huge areas in Indonesia. Between those two wildfire periods – in 1987, 1990, 1991, 1993, and 1994 – less severe droughts occurred which were also accompanied by wildfires (Mori 2000; Mori et al. 2000).

The frequent incidence of wildfires shows how serious the threat of fires is. In Indonesia, wildfires have resulted in huge losses of natural rainforests and plantations over vast areas. In Kalimantan alone, a fire in 1993 burned down 3.6 million hectares of rainforest. The estimated loss of standing and growing stock was more than USD 5 billion (Lennertz and Panzer 1984, cited in Panayatou and Ashton 1992; Mori 2000). Meanwhile, in 1997 and 1998, droughts and forest fires hit many parts of Indonesia. Nugroho (1999) revealed that a total of about 9.7 million hectares was burned, of which 4.8 million hectares were forests. Estimated economic losses from these fires amounted to USD 9.3 billion. Besides the severe droughts brought about by ENSO, reckless human activities (such as burning to clear forest plots) were the other primary cause of the wildfires.

[9] Many existing pulp and paper industries are dependent on tropical rainforests for logs; these are obtained by way of salvage cutting permits. For instance, dependency on the tropical rainforest of one large pulp and paper company, built in 1994 with an installed capacity of 700,000 tonnes of pulp per year (equal to 3.08 million m^3 of logs), was about 75% as at 1999 (Data Consult Inc. 1999). Ascher (1999) stated that over-consumption of raw material coupled with cheap raw material inputs (illegal logs) is a consequence of too many government subsidies (including exemptions) to downstream processing (i.e., pulp and paper mills). The company mentioned is a good example of this – it expanded its installed capacity to more than 1 million tonnes of pulp per year in the year 2000.

Of the 19 companies selected in East Kalimantan as samples for this study, 13 of them were ravaged by wildfires from 1997 to 1998, with burned areas ranging from 48.2 to 39,879 hectares. In South Kalimantan, three of nine sample companies lost 1,111 to 3,486 hectares of plantation areas to wildfires.

3.0 THEORY AND RESEARCH METHODOLOGY

3.1 Stochastic Frontier Theory and Methodology

The stochastic frontier production function, proposed by Aigner, Lovell and Schmidt (1977) and Meeusen and Van den Broeck (1977), considered the error or disturbance term which consists of two components (U_{it} and V_{it}).

V_{it} is the disturbance term with zero mean. As in a general model, the disturbance term has a two-sided independent, identical normal distribution [$V_{it} \sim N(0, \sigma_V^2)$]. The disturbance term reflects random effects outside the control of production processes, including statistical noises, measurement errors, topography, and the effects of weather, etc. The inefficiency part (U_{it}) has a one-sided distribution which is a non-negative truncation of the $\sim N(0, \sigma_u^2)$. The component U_{it} is independent of V_{it} (Aigner et al. 1977; Meeusen and Van den Broeck 1977).

Pitt and Lee (1981) considered a stochastic frontier production model associated with panel data in which there are N firms involved over T time periods in a mathematical equation as follows:

(Model 1)

$$Y_{it} = f(X_{it}\ ; \beta)\ \exp(V_{it} - U_{it}) \quad i = 1, 2, \ldots\ldots, N$$
$$t = 1, 2, \ldots\ldots, T$$

where

Y_{it} = the production of i th firm in the t th time period

$f(.)$ = a preferred functional form (the Cobb-Douglas)

X_{it} = the k by 1 vector of factor inputs of the i th firm in the t th time period

β = a k by 1 vector of unknown parameters

V_{it} = $i.i.d \sim N(0, \sigma_V^2)$,

U_{it} = $i.i.d$ positive truncation of $\sim N(0, \sigma_u^2)$

The production function is defined as the maximum possible output for a given set of inputs. The frontier production concept can be distinguished from the regression function concept, which provides the mean output for a given set of inputs. Given the factor input values, inefficiency exists if the level of production or output is less than what must be the case of a fully technically efficient firm (Battese and Tassema 1993). Consequently, a boundary or frontier is defined by the production function as a benchmark to estimate the output efficiency of a company. Deviation of observed outputs from the frontier represents failure to achieve the maximum possible output given the inputs. In the stochastic frontier production concept, the technical efficiency of an individual firm is defined as the ratio of observed output to the attainable frontier output, given the level of input used by the firm.

The frontier production concept featuring input-output values is illustrated in Figure 1. The horizontal axis, X, shows the inputs associated with producing the output, Y. The productive operations of two firms are represented by i and j. To get the output, Y_i, Firm i uses input X_i. The frontier output for Firm i is A. The frontier production function is represented by f(Xi, β), and is a measure of the maximum possible output for any particular input X_i. The observed value representing actual production may deviate from the frontier because of both V_i and U_i.

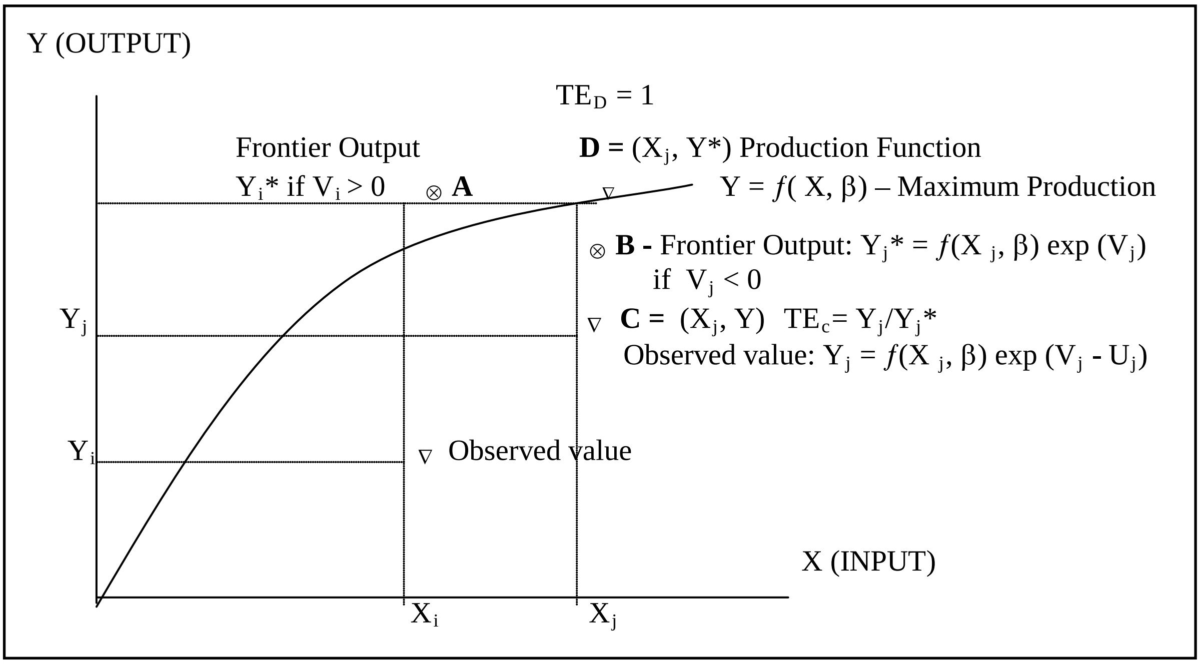


Figure 1. Technical Efficiency of Firms in the Stochastic Frontier Production Function (Input – Output Space)

If the corresponding random errors are greater than the corresponding inefficiency effects (i.e., $V_i > U_i$) due to favorable conditions, the frontier output (A) is greater than (i.e., above) the output derived from the production function analysis. The production function is the deterministic component of the frontier model which is Y=exp(xβ). Similarly, Firm j uses inputs X_j to produce Y_j. Frontier output for Firm j is B, which is below the production function output because the corresponding random errors are smaller than the corresponding inefficiency effects (i.e., $V_i < U_i$)

due to unfavorable conditions. The production function output is found to settle between the frontier outputs. As V_i and V_j are not observable, then the frontier outputs Y_i* and Y_j* are not observed. A value of the technical efficiency of the firm which produce output Y_j with corresponding input X_j, indicated by point C, is obtained by Y_j/Y_j*. Any points, which are located along the curve of the production frontier function, have a technical efficiency value of 1. Values of technical efficiency range between zero and one. If a technical efficiency score of a firm is 0.60, this means that on average or in a corresponding year, the firm achieves 60% of the production possible for a fully efficient firm having comparable input levels.

A number of studies have explored the determinants of technical efficiency using a two-step procedure. However, in this procedure, assumption of U_{it} as technical efficiency in the first step, contradicts the assumption of U_{it} in the second step where U_{it} is assumed as a function of explanatory variables. Battese and Coelli (1995b) proposed a solution using a simultaneous estimation of the parameters of the stochastic frontier production together with the inefficiency model, given that the technical efficiency effects are stochastic. In this regard, it can be further assumed that the average level of technical efficiency (U_{it}) is a function of factors believed to affect technical efficiency as presented in the following equation:

(Model 2a)

$$\mu_{it} = \delta_0 + \delta` Z_{it}$$

where μ_{it} represents non-negative, independently distributed random variables. Z_{it} is a column vector of hypothesized efficiency determinants, and δs are unknown parameters to be estimated. Based on the stochastic frontier model (1) and the inefficiency model (2a) in simultaneous estimation for the i^{th} firm at t^{th} observation, the technical efficiency (TE) is defined as exp ($-U_{it}$):

(Model 2b)

$$TE_{it} = Y_{it} / Y_{it}\,*$$

$$= f(X_{it}\,;\beta)\ \exp(V_{it} - U_{it}) / f(X_{it}\,;\beta)\ \exp(V_{it})$$

$$= \exp(-U_{it}) = \exp(-z_{it}\delta - W_{it})$$

The stochastic frontier model allows the testing of hypotheses using traditional maximum-likelihood methods and provides the estimation of standard error. The maximum likelihood estimates (MLE) are asymptotically efficient (smallest variance) and consistent (Aigner et al.1977). To obtain the values of parameters β, σ^2 and γ, analyses were performed by using the computer program FRONTIER Version 4.1, in which MLE is the primary method used. The value of γ is the basis of iterative maximization processes in MLE. Basically, there are three steps in the program. The ordinary least square (OLS) estimation is used in the first step to provide parameter estimates of β, and σ^2. The OLS procedure gives unbiased estimates of parameters with the exception of the intercept β_0 and σ^2. Using parameterization of γ, μ, and η, and grid search processes, the MLE makes iterative processes based on a number of values ranging from 0 to 1 to find the maximum (or largest) values of log likelihood. The program utilizes a Davidon-Fletcher-Powel maximization routine to produce the value of log likelihood at the maximum (largest) value (Coelli et al. 1998); Battese and Coelli (1995a) and Battese and Corra (1977) denote the log-likelihood function using re-parameterization of the model with $\sigma^2 \equiv \sigma_V^2 + \sigma_U^2$ and $\gamma \equiv \sigma_U^2/\sigma^2$ as follows[10]:

$$L^*(\theta; y) = -\frac{1}{2}\left(\sum_{i=1}^{N} T_i\right)\{\ln(2\pi + \ln\sigma^2\} - \frac{1}{2}\sum_{i=1}^{N}\sum_{i=1}^{Ti}\{(y_{it} - x_{it}\beta + z_{it}\delta)^2/\sigma^2\}$$
$$- \frac{1}{2}\sum_{i=1}^{N}\sum_{i=1}^{Ti}(\ln\phi(d_{it}) - \ln\phi(d^*_{it}))^2$$

where:

$d_{it} = z_{it}\,\delta/(\gamma\sigma^2)^{1/2}$

$d_{it}^* = \mu_{it}^*/(\gamma\,(1 - \gamma)\sigma^2)^{1/2}$

$\mu_{it}^* = (1 - \gamma)\, z_{it}\,\delta - \gamma\,(y_{it} - x_{it}\beta)$

$\sigma_* = (\gamma\,(1 - \gamma)\sigma^2)^{1/2}$

$\theta = (\beta', \delta', \sigma^2, \gamma)'$

The generalized likelihood ratio statistic provides the testing of the hypothesis associated with the parameter estimates and the U_{it}'s distribution. Griffiths et al.(1993) described the likelihood ratio test as:

$$\lambda_{LR} = -2\,\{\ln[L(H_0)] - \ln[L(H_1)]\}$$

where $L(H_1)$ represents the maximum value of the unrestricted log-likelihood and $L(H_0)$ represents the maximum value of the restricted log-likelihood.

Given that H_0 is true, λ_{LR} has an approximate $\chi^2(J)$ - distribution, where J is the number of restrictions under H_0. H_0 should be rejected when $\lambda_{LR} > \chi^2_c$, where χ^2_c is a reliable critical value from $\chi^2(J)$ - distribution. The results from the first and fifth hypothesis tests will determine a specification for γ, η, μ, and the time-invariant behavior of the coefficients of the explanatory variables for the other hypothesis tests.

[10] See Battese and Coelli (1993) (pp 19-22) for a detailed presentation of the joint density function, and the likelihood function and its partial derivatives with respect to the parameters of the model.

3.2 Empirical Application

3.2.1 The Estimation of Technical Efficiency

In this study, the model proposed in Battese and Coelli (1995a) for the frontier production function was applied to measure the technical inefficiency of firms involved in timber and pulp plantation development in East Kalimantan, South Kalimantan, South Sumatra, and Riau (Indonesia). The production technology of each firm was assumed to be characterized by a Cobb-Douglas function as follows:

(Model 3a)

$$\ln(Y_{it}) = \beta_0 + \beta_1 (DC_{it}) + \beta_2 \ln(LAND_{it}) + \beta_3 \ln(Adm_{it}) + \beta_4 \ln(Lbr_{it}) + \beta_5 \ln(Skilled_{it})$$

$$\beta_6 \ln(EQUIPT_{it}) + \beta_7 (GS_{it}) + E_{it}$$

(Model 3b)

$$\ln(Y_{it}) = \beta_0 + \beta_1 (DC_{it}) + \beta_2 \ln(LAND_{it}) + \beta_3 \ln(Adm_{it}) + \beta_4 \ln(Lbr_{it}) + \beta_5 \ln(Skilled_{it})$$

$$\beta_6 \ln(EQUIPT_{it}) + \beta_7 \ln(C_{it}) + \beta_8 (GS_{it}) + E_{it}$$

where:

Y_{it}	is the realization of planting x survival rate (number of trees that survived) for the i th firm, i = 1,2, ...N = 32 firms, in the t th year of observation, t = 1,2, ...T, with T = 4;
DC_{it}	is a dummy variable that takes the value of 1 if the plantation company is also the owner of the timber concession company and 0 for owning only a timber and pulp firm, for the i th firm in the t th year of observation;
$LAND_{it}$	is the total acreage of plantations in hectares as approved by the Ministry of Forestry, for the i th firm in the t th year of observation;
Adm_{it}	is number of administration employees hired within a year, for the i th firm in the t th year of observation;
Lbr_{it}	is number of workers for fieldwork hired within a year, for the i th firm in the t th year of observation;
$Skilled_{it}$	is total number of skilled employees/technicians hired within a year, for the i th firm in the t th year of observation;

$EQUIPT_{it}$	is the number of light and heavy equipment and vehicles used in the plantation program, for the *i* th firm in the *t* th year of observation;
C_{it}	is a portion of the costs of other inputs (like labor and machinery) over total costs incurred within a year for the *i* th firm in the *t* th year of observation;
GS_{it}	is a portion of the Government's financial support over the total operational/establishment costs.
βs	are the unknown parameters to be estimated, the values of which may vary with the year of observation, *t*. As a simple linear function used in the analysis, the values of β s represent the elasticity of output with respect to input (Xs).
E_{it}	is a random variable whose distributional properties are defined by the equation: $E_{it} = V_{it} - U_{it}$.

3.2.2 Determinants of Technical Efficiency

What are the characteristics that appear to be associated with the degree to which firms are technically efficient in timber and pulp plantation development? Determining the sources of efficiency is always a contentious process. The determinants can be the size of firms, the type of firm (public vs private, local vs foreign), location, entrepreneurship of the owner, management scheme, labor origin and so on (Schmidt 1986; Wu 1994). These characteristics have been widely recognized as having a significant effect on efficiency levels in agricultural sectors.

The stochastic frontier production model proposed by Battese and Coelli (1995b), Battese et al. (1996), and Ngwenya et al. (1997) was adopted in this study to measure the effects of plantation schemes, plantation size, productivity and the involvement of local people on efficiency. Model (4) below was applied:

(Model 4)

$$U_{it} = \delta_0 + \delta_1 D_{1it} + \delta_2 D_{2it} + \delta_3 D_{3it} + \delta_4 D_{4it} + \delta_5 D_{Lit} + \delta_6 D_{Mit} + \delta_7 (Inv_{it}) + \delta_8 (Prod_{it}) + W_{it}$$

where:

U_{it}	is the efficiency measure from the stochastic frontier production analysis for the *i* th firm with *i* = 1 .... 32 in the *t* th year of observation;
D_{1it}	is a dummy variable that takes the value of 1 for the social forestry/transmigration scheme and 0 if otherwise, for *i* th firm in the *t* th year of observation;

D_{2it}	is a dummy variable that takes the value of 1 for the self-financed scheme and 0 if otherwise, for i th firm in the t th year of observation;
D_{3it}	is a dummy variable that takes the value of 1 for the pulp-production scheme and 0 if otherwise, for the i th firm in the t th year of observation;
D_{4it}	is a dummy variable that takes the value of 1 for the non pulp-production scheme and 0 if otherwise, for the i th firm in the t th year of observation.
D_{Lit}	is a dummy variable that takes the value of 1 for a large* plantation and 0 if otherwise, for the i th firm in the t th year of observation.
D_{Mit}	is a dummy variable that takes the value of 1 for a medium-sized* plantation and 0 if otherwise, for the i th firm in the t th year of observation.

*Plantation size classification is as follows:

Larger than 100,000 hectares: large.
Between 40,000–100,000 hectares: medium
Less than 40,000 hectares: small

Inv_{4it}	is the involvement of the local people as workers in the industrial timber and pulp plantation for the i th firm in the t th year of observation. Involvement is measured by the number of local workers divided by the total number of workers.
Prod_{it}	is a productivity of local workers measured by the ratio of local workers' income to migrant workers' income for the i th firm in the t th year of observation.
W_{it}s	are assumed to be non-negative, random, independently distributed variables, arising from the truncation of the normal distribution at zero with variance σ^2 and mean, $z_{it}\delta_i \sim N(z_{it}\delta_I, \sigma^2)$.

3.3 Data Collection

A survey was conducted by the author from October 1999 to July 2000 in four provinces. The non-probability purposive sampling design was used for province selection with safety as the major consideration. Four provinces were selected for this study: East Kalimantan, South Kalimantan, South Sumatra, and Riau. These four provinces are among the leading provinces in the logging industry as well as in timber and pulp plantation development in Indonesia. The incomplete panel data used in this study for the technical efficiency analyses was collected from 47 firms involved in the timber and pulp and plantation program in the four provinces, from the fiscal years 1994/95 to 1998/99. Of these, only 32 firms had complete information to enable inclusion into the regression analysis. Although others wanted to participate, they lacked sufficient data to be included in the study.

The total areas under timber and pulp plantations in East Kalimantan, South Kalimantan, South Sumatra, and Riau as approved by the Ministry of Forestry are about 1,434,546 hectares (20% of the total), 325,864 hectares (4% of the total), 662,138 hectares (9% of the total), and 1,247,844 hectares (17% of the total), respectively. With respect to forest-based activities (logging and industries), most large-sized forest companies have conducted their activities, namely the production of logs from natural rainforests, in these provinces during the last 25 years.

4.0 TESTS, EMPIRICAL RESULTS AND DISCUSSIONS

4.1 Tests of Hypotheses of the Simultaneous Model of the Stochastic Frontier Production Function – Model (2a)

The log likelihood-ratio calculated from unrestricted and restricted likelihood-ratios (asymptotic λ tests), and corresponding χ^2 critical values at the 5% level of significance will determine a rejection or an acceptance of the null hypothesis. The λ values are presented in Tables B.2 and B.3.

The first null hypothesis in the efficiency model, H_0: $\gamma = \delta_0 = \delta_1 = \delta_2 = \ldots\ldots\ldots. = \delta_8 = 0$, is rejected. This result establishes that the random technical inefficiency effect is evident in the firms analyzed.

The null hypothesis explored in test 2 is H_0: $\delta_1 = \delta_2 = \ldots\ldots.. = \delta_8 = 0$, which specifies that all variables involved in the inefficiency effect model (4) have no effect at all on the level of technical efficiency. This test is performed to assess if the variables included in the model are useful or significant determinants of the inefficiency of firms. The conclusion of the test is that the joint effect of the variables on technical inefficiency is statistically significant. The results also suggest that analysis for this study can proceed using the simultaneous model (2a) since the determinants are useful or significant in the model.

The next null hypothesis explored in test 3 is H_0: $\delta_1 = \delta_2 = \ldots\ldots.. = \delta_4 = 0$, which indicates that scheme variables in the inefficiency effect model (4) do not account for technical efficiency. The conclusion of the test is that the joint effect of scheme variables on technical inefficiency is statistically significant.

The last null hypothesis in the efficiency model, H_0: $\delta_5 = \delta_6 = 0$, is concerned with determining whether the composite variable of size is significantly different from zero. The hypothesis is rejected in favor of stochastic inefficiency effects due to the presence of various sizes of plantation firms.

The parameter estimates from the analysis of inefficiency effects (Table B.1) showed that variables of transmigration, pulp, non-pulp, and productivity were not significantly different from zero based on asymptotic t tests. For those variables, the generalized likelihood-ratio test was conducted. This test is known to be more robust than the t-test.

For both the stochastic frontier production function with seven (model 3a) and eight (model 3b) variables, it appeared that the transmigration, non-pulp and productivity variables were not statistically significant in explaining variations in technical inefficiency effects, although the tests showed statistical significance for pulp variables for both models (3a) and (3b).

Average technical efficiency estimates based on scheme classifications (Appendix 3 – Figure C.2) indicated sizeable differences between pulp and non-pulp schemes and the rest of the schemes. This seemed surprising in view of the insignificant effects of non-pulp variables in the previous test. In the light of this, a simple non-parametric statistical test proposed by Mann and Whitney[11] was performed to analyze how significant the differences in the efficiency levels between non-pulp schemes and state-owned schemes were. The state-owned scheme variable is a hidden variable in inefficiency model (4). This dummy variable under the composite variable of scheme was not included in the model to avoid multicollinearity problems. In effect, what was done was to hide the effect of the state-owned scheme variable in the intercept. The test results confirmed that the values of the test statistic (T) were seven for model (3a) and nine for model (3b), while the corresponding critical value of the Mann-Whitney statistic ($w_{1-\alpha/2}$) was eight. Since T is greater than the critical value for model (3b), the null hypothesis, H_0; that the two schemes have identical distribution, is rejected for model (3b) but not for model (3a). Therefore, the technical efficiency mean for a non-pulp scheme is greater than that of a state-owned company only in model (3b). In other words, the non-pulp firms are more efficient that the state-owned firms.

4.2 Parameter Estimates of the Stochastic Frontier Production Models (3a) and (3b)

In Table B.1 showing the stochastic frontier production model (3a) with seven variables, the elasticities of output for type of company (Dc), land (L), administration employees (Adm), labor (Lbr), and equipment (Eq) have the expected positive signs. However, only variables of Dc, Lbr, and Eq are significantly greater than zero at the 5% significance level of t value. These variables have significant effects with respect to output with elasticities of 0.615, 0.669, and 0.239 respectively. The elasticities of output with respect to L (0.132) and Adm (0.009) are relatively small and insignificantly different from zero. The skilled labor variable (Sk) and financial support (Gs) coefficients are unexpectedly negative with elasticities of –0.162 and

[11] The non-parametric test is aimed at dealing with unequal sample size based on combined ranking of all data from smallest to largest. To estimate the difference between certain parameters of two populations or to test hypotheses about two populations is the primary inferential objective. See Daniel (1978) for details.

–0.086 respectively. The variable of skilled labor (Sk) is significantly different from zero, while the variable of financial support (Gs) is insignificantly different from zero. In the model with eight variables (model 3b – Table B.1), the signs and all parameter estimates are quite similar to previous estimates in the model with seven variables (model 3a).The costs of other inputs variable (C) is negative and significantly different from zero with an elasticity of –0.483. Note that a positive coefficient here denotes that the variable contributes to increasing planting performance.

Inconclusive evidence for the land variable (L) was found, indicating that land size in the stochastic frontier production model did not have any bearing at all on planting performance. Further inquiry was required to examine this variable along with other inconclusive variables in the stochastic frontier production model and the inefficiency model using the generalized likelihood-ratio tests. The results of the generalized likelihood-ratio tests are given in Tables B.2 and B.3 for models (3a) and (3b) respectively. Only significant variables are presented in the tables.

4.2.1 Discussion on Parameter Estimates of the Stochastic Frontier Production Models (3a) and (3b)

In the models:

DC_{it}	is a dummy variable that takes the value of 1 if the plantation company is also the owner of the timber concession company, and 0 for owning only a timber and pulp firm for the i^{th} firm in the t^{th} year of observation;
$LAND_{it}$	is the total acreage of plantations in hectares as approved by the Ministry of Forestry, for the i^{th} firm in the t^{th} year of observation;
Adm_{it}	is the number of administration employees hired within a year, for the i^{th} firm in the t^{th} year of observation;
Lbr_{it}	is the number of workers for fieldwork hired within a year, for the i^{th} firm in the t^{th} year of observation;
$Skilled_{it}$	is the total number of skilled employees/technicians hired within a year, for the i^{th} firm in the t^{th} year of observation;
$EQUIPT_{it}$	is the number of light and heavy equipment and vehicles used in the plantation program, for the i^{th} firm in the t^{th} year of observation;
C_{it}	is a portion of the costs of other inputs (like labor and machinery) over total costs incurred within a year for the i^{th} firm in the t^{th} year of observation;
GS_{it}	is a portion of the government's financial support over the total operational/establishment costs.

Based on the stochastic frontier analyses of both models, the efficiency of a firm appeared to be heavily dependent on the input factors of labor (Lbr), equipment (Eq), and type of company (Dc – vertical integration with logging concession companies). Elasticity of the type of company (Dc) variable showed that subsidiary companies are significantly different from non-subsidiary companies in terms of planting performance. Presumably, the vertical integration provides more flexibility and availability in terms of resource/input allocation such as cash flow and the mobilization of equipment within the holding company. This shows that a plantation firm that is owned by a logging concession or an industrial forest-based holding company is more efficient than a stand-alone firm.

As stated previously, the land variable (L) was reexamined using generalized likelihood-ratio tests. The null hypothesis, $H_0 : \beta_2 = 0$ denoted that the coefficient of land (L) was not statistically significantly different from zero. For model (3a), the land variable (L) appeared to have a significant effect on the planting performance while for model (3b), it was not statistically significant. The log likelihood ratio values for the land variable (L) were 2.716 and 2.004 with corresponding $\chi^2_{0.90}$ having a critical value of 2.706. Other insignificant variables were administration workers (Adm) and financial support (Gs).

The parameter estimates presented above imply that in the first rotation, both small and large landholding companies experienced sizeable inefficiencies affected by different factors. As discussed in section 2.3, planting performance was only 2% to 42% depending on the scheme. A similar case was found in the agricultural sector where the relationship between efficiency and scale was mixed i.e., large companies were sometimes found to be less efficient than small ones . Alvarez and Arias (1998) and Van Zyl et al. (1995) found many empirical results from agriculture-related studies which showed that land size was not a determining factor in productivity (output) and efficiency levels.

In recent years, numerous conflicts have arisen and aggressive claims made over land and forest resources in various parts of the country; these conflicts share some common features. Forest licensing to private owners by way of concession and plantation rights has been the major cause for reduced public access to forest resources. Dwindling access to what is left has frequently drawn massive protests from local communities (Lohmann 1996; Arnold 1997). Disputes have developed into violent outbreaks often with the confiscation of equipment and vehicles. When conflicts occur, planting is inevitably cancelled. Unless conflicts are trivial or goodwill prevails, it is seldom a single-solution situation.

As is the case in most developing countries, plantations in Indonesia are more dependent on workers than on machinery due to the abundance of labor. The analysis showed labor to be the most important factor in planting performance, with elasticities of 0.669 (model 3a) and 0.662 (model 3b) which are much greater than those of other coefficients. This is consistent with the findings of most efficiency studies in the agricultural sector based on stochastic frontier methodology.

The equipment variable also showed a significant effect on planting performance even though its parameter estimate was far below that for labor. Most medium and large-scale companies understand the crucial role that heavy equipment plays, especially in site preparations and road maintenance which are, in turn, necessary for the successful performance of subsequent activities. For small-scale firms, equipment is generally for workers' use and seedling transportation. Farm tractors, dump trucks, four-wheel drive vehicles, and motorcycles are normally used on small-sized plantation areas. Site preparation in small-sized companies is carried out with very limited mechanization.

Contrary to expectations, the elasticities for skilled labor/technicians for both models (3a and 3b) were negative and significantly different from zero. This implies that the performance of skilled labor has not been optimized. A visit to the firms revealed that many of the workers did not know much about the job requirements of their work. There could, however, be other reasons for the low performance of skilled labor but there is inadequate information available on this. In fact, the classification of "skilled labor" itself could be questioned. High school graduates with a long-term field experience, vocational high-school and college graduates in forestry and agriculture, and university graduates majoring in agriculture and forestry, were considered as skilled labor. Given such a broad classification, the most obvious observation is that a company could simply have too many so-called "skilled" workers.

The management style of the plantation companies is another possible factor contributing to low planting performance. The majority of plantation companies sampled in this study are run as family enterprises where most of the important management positions in the company are filled by family members, the owner's trusted partners, and the employment of skilled workers meets the government employment quota only partially. As a result, the expertise of the available skilled workforce has not been fully tapped. A persistent reluctance to allow professional outsiders into senior management limits technical expertise and contributes to lowered labor productivity (Errington and Gasson 1994; Weidenbaum 1996; Dwiprabowo et al. 1997).

Similar to the case of the skilled worker, the skill of administration employees has not been optimized. The elasticity of the administration employees variable does not affect output variability. This could again be due to concession holders appointing trusted friends or relatives (who may, however, be less qualified) to crucial positions in finance and/or administration.

The elasticities of output with respect to the government financial support (Gs) variable in both models (3a) and (3b) do not justify the variation in the output. In the field, with the exception of large companies, the recipients of government financial support organize their plantations in the same manner as their non-recipient counterparts. They also face the same problems of volatile labor supply, unimproved seed, poor planting stock, limited equipment, lack of technical expertise and manual site preparation. The cause of low performance is attributable to a lack of silvicultural thresholds or detailed silvicultural guidelines in the field. What is needed is for the Government to provide detailed guidelines for sound plantation practices such as proper site preparation, seed selection, fertilizer usage and silviculture that would increase survival rates. These guidelines would be particularly important to small-scale firms.

Much has been written on government subsidies for plantation programs; these have not resulted in satisfactory planting performance or increased productivity. Government incentives such as the cost-share payment of non-industrial private forestry investment in the U.S (the Government reimbursed up to 50% of total establishment costs) did not affect the magnitude of private reforestation investment. This finding supports the capital substitution argument that government incentives merely substitute self-motivating investment (Gregersen et al. 1975; De Steiguer 1983; Wallace and Silver 1983). It also favors the current Ministry of Forestry's policy (Directive 922/1999) on the privatization of plantation operations, especially for large-scale companies (which are more financially independent) – the aim is to gradually eliminate government financial support while increasing privatization.

The negative elasticity of output in respect to the variable of costs of other inputs is predictable. It was found that the total cost per hectare for critical activities, namely nursery and site preparation, and planting, were below the government standard. However, costs of other inputs were much higher than the standard cost. This is consistent with the results of a study by Foeh et al. (1993) in South Sulawesi which found that total realized costs had not been appropriately utilized for main activities, leading to high costs of other inputs which reflected inefficiency in the plantation companies. It is, therefore, concluded that there will be no significant positive impact on planting achievement no matter what the magnitude the government's financial support (Gs) is. The average cost per hectare is presented in Table 2. However, the detailed costs of major activities are not presented because this information is not available. Existing performance could have been low in quality and quantity given the realized costs per hectare if it had been assessed based on sound plantation practices. Reliable data from some of the sample companies showed that plantation stands were under-stocked. In other words, the standard cost per hectare was excessively high for such low quality planting by the majority of the sample companies.

Table 2. Average Costs per Hectare from Samples and Government Standard Costs

Source	*Standard Costs per hectare (IDR)*				
	1994/95	*1995/96*	*1996/97*	*1997/98*	*1998/99*
Government standard - With mechanized site preparation	2,882,500	3,049,500	3,049,500	3,049,500	3,743,000

- With manual site preparation	2,469,500	2,630,500	2,630,500	2,630,500	3,435,000
	Realized Costs per hectare (IDR)				
From sample (32 companies)	1,961,719	2,726,728	2,462,382	3,468,787	4,243,989

4.3 Parameter Estimates of the Inefficiency Model – Model (4)

In Table B.1, the values for the self-financed (δ_2), and involvement (δ_7) coefficients which are 0.896 and 0.746 for δ_2, and 1.219 and 1.140 for δ_7, for models (3a) and (3b) respectively, are significantly different from zero. The positive coefficients for these two variables denote that they contribute towards greater technical inefficiency in timber and pulp plantation companies.

The coefficients for medium-scale (–1.862 and –1.757) and large-scale[12] (–1.435 and –1.583) variables have negative signs and are significantly different from zero, indicating that larger scale plantations are associated with lower levels of inefficiency. As noted previously, eventually the coefficients of pulp (– 4.708 and – 4.476) and non-pulp (–0.763 and –1.337)[13] variables have a significant negative effect on inefficiency based on the generalized likelihood tests and the non-parametric statistical test with the exception of statistical insignificance for the non-pulp scheme in model (3a) (See section 4.1).

On the expansion path, the scale elasticity is the sum of all input elasticities. If the sum exceeds 1.0, there is increasing returns to scale. Based on the empirical results of model (3a) and model (3b), the scale elasticities were estimated to be 1.307 and 1.224, implying increasing returns to scale. This means that a unit increase in all inputs will generate a greater than one unit increase in output. The presence of some scale economies denotes that large-scale plantation firms tend to be more efficient in the use of their inputs. This result is inconsistent with the current policy of the Ministry of Forestry (Decree 728/1998) which limits the size of landholdings in every province in accordance with “the people’s economy” principles that strongly advocate the reduction of conglomerates in the forestry sector.

4.4 Estimated Technical Efficiencies

The efficiency score for an individual firm is presented as the average of the scores from a four-year observation period (1994 to 1998). The average estimated technical efficiencies for firms obtained from model (3a) with seven explanatory variables for 1994/1995 to 1998/1999 in Appendix 3 – Table C, range from 0.12 to

[12] It is worth mentioning that if the costs of other inputs variable is considered in model (3b), the coefficient of the large-scale company variable tends to decrease, denoting greater efficiency compared with the result in model (3a).

[13] Pulp and non-pulp variables within the scheme appeared to become more efficient when the costs of other inputs are added to the model. In model (3a), the non-pulp variable is not significantly different from that of state-owned companies.

0.93 with the mean technical efficiency estimated at 0.60. A histogram of the frequency distribution of predicted technical efficiencies is presented in Appendix 3 – Figure C.1.

Large companies, on average, tend to have higher efficiency scores than medium and small-scale companies, with average efficiency scores of 0.86, 0.74, and 0.52 for model (3a) and 0.88, 0.77, and 0.52 for model (3b), respectively (Figure C.3). The differences in the efficiency scores between small companies and medium and large-scale companies are proven to be significant (Table B.1). The technical efficiencies, on the basis of schemes, show that pulp (0.91 and 0.92) and non-pulp (0.76 and 0.80) schemes have better efficiency scores compared with their counterparts i.e., those under the self-financed scheme (0.45 and 0.46), transmigration scheme (0.58 and 0.57), and the state-owned companies (0.57 and 0.56). On average, the self-financed scheme has the lowest technical efficiency score (Figure C.2).

Fifty percent of the firms analyzed in model (3a) with seven explanatory variables have technical efficiency scores below the mean figure. Forty-seven percent of those firms are under the self-financed scheme. Meanwhile, 34% are under the transmigration scheme, while state-owned companies make up about 19%. All companies within the pulp and non-pulp schemes have efficiencies above the mean figure. In terms of size of the plantation company, companies that are positioned below the mean figure are mostly the small-scale companies.

4.4.1 Discussion on Parameter Estimates of Inefficiency Model (4) and the Estimated Technical Efficiencies

Within the scheme variable, the self-financed companies were found to be the most inefficient schemes in the program. Generally, self-financed companies are neither well-prepared nor well-equipped to establish a long-term commitment to a plantation program. Limited budgets, poor road infrastructure, the use of unimproved seed, lack of equipment, incompetent technicians, greater seasonal fluctuations in field labor availability, and manual site preparations are the range of limitations too often found in the self-financed companies.

The transmigration scheme was the result of the Government's enforcement over the timber concession holders to establish timber and pulp plantations; this was an obvious money-losing operation (Ascher 1999) because the yield and profitability of small-scale companies are low due to inadequate resources for investment. Oftentimes, the stands are under-stocked and the quality of planting materials is poor. Thus, the survival rates in these plantations are quite low. It is thus not surprising that there are very few firms who are interested to enter into joint ventures with these companies. If joint ownership does not have vertical integration with a pulp and paper mill, the plantation company tends to behave like a self-financed company. In many locations, the transmigration scheme has been unable to prevent transmigrants from moving away. It is commonly found that only 40% to 50% of the transmigrants remain with a company after two years. On average, state-owned companies sampled are at about the same efficiency level as those in the transmigration scheme.

The pulp companies are more advanced in research and development, tree improvement, expertise, and the use of technology; they are more capital-intensive and have better access to factor inputs and a more secure market compared with those in the other schemes. The average planting achievement of the pulp scheme is the highest at 42% of the total allocated plantation area. Unlike the pulp scheme, however, the non-pulp scheme faces more uncertainty due to longer rotations, a relatively undeveloped market, and inconsistency in log quality. In terms of planting performance, only 20% of the total allocated area has been planted.

Cubbage (1982) asserts that tract size is an important constituent in forest management and harvesting operations from economic and social perspectives. It is likely that a less efficient operation is correlated to smaller rather than larger tracts. The most apparent rationale for this is that larger firms have the potential for greater planting productivity (output) through rationalization of inputs, equipment specialization, reduction of resource indivisibilities, and methods development due to larger economies of scale.

Negative coefficients of large (D_L: -1.435 and -1.583) and medium-scale (D_M: -1.862 and -1.757) (Table B.1) companies are significantly different from zero at 10% level of critical t-values. These results justify the previous contention that large and medium-scale companies are more efficient than small-sized ones. The sign and magnitude of the coefficients of the dummy variables show that small plantations i.e., less than 40,000 hectares in size, are less efficient than larger landholdings.

The Government's rationale for a mandatory tree-planting program, which affects small-scale plantations within the transmigration scheme, fares poorly against the yardstick of sound economic measures. Small-scale plantations have been analyzed to be inefficient in the first rotation and experts doubt that Indonesia has the expertise to develop them at this point in time. Some of the reasons are the inadequacy of competent human resources to provide the necessary technical support, insufficient good quality planting material, and general limitations in the Government's budget for plantation development. This is not to say that small-scale plantations should not be considered for the future. However, unless there is an improved level of technology, management and input factors, a reduction of landholding size (dividing large plantations into many small ones) would not only have a direct negative impact on planting performance but also indirect negative impacts from the decreased marginal productivity of non-land inputs.

The issue of migrant workers versus local workers is an intriguing one in the timber and plantation program in Indonesia as well as in other developing countries. In general, the salient nature of labor supply over time is unstable. Naylor (1989) and Islam et al. (2001) indicate that income distribution and wage differentials among regions stimulate a flow of migrant workers from relatively low to high-income regions but this within-country migration is generally temporary. The diverse nature of employment and sectors being developed prohibit wages from being equalized across regions.

Most migrant workers in timber and pulp plantations come from densely populated areas in south-eastern Central Java, southern East Java and the arid regions of eastern Indonesia such as West Timor. Migrant workers from Java – after a fixed-term contract – return to their regions where they would own a modest stake in land or a family farm.

To some extent, hiring migrant workers is not a wise option as it is more costly than local labor during off-farming seasons. However, migrant workers tend (although not always) to stay longer (unseasonal) as compared with their local counterparts. The number of days worked, level of schooling and work experience, and strong motivation to work represent the characteristics of migrant workers that attract plantation company employers. Budget constraints may, however, limit the number of migrants hired. The seasonal availability of local labor (therefore, a lack of readily available labor at other times), and tight competition between companies, is the existing scenario faced by the plantation companies. Therefore, many companies relinquish some site preparation and planting fieldwork under "a subcontract system" to a third party on a piece-rate basis.

The coefficient of the local people's involvement variable is positive and statistically significant (1.219 and 1.140) for models (3a) and (3b), which implies that firms with a greater proportion of local workers tend to be more inefficient. The fluctuations in labor availability contribute to this inefficiency. The local people's involvement has also been too low. Irawanti et al.(1996) revealed that only about 5% to 6% of local people were involved as full-time workers in the plantation program in Riau. This low level of local people's involvement appears in contradiction with the Government's plan to have local communities reap the benefits of the forests.

A survey of local people's involvement (Table A) shows that seasonal variations may be due to a disinclination or even ignorance on the part of plantation companies to employ more local workers. The survey indicates that almost half (48%) of the decision-makers surveyed were not familiar, even generally, with government regulations stipulating the involvement of local people. However, there is also an indication that local people do not feel comfortable working with strict rules. Responses from the survey showed that 10% of both migrant workers and decision-makers (companies) considered local workers as having difficulties adjusting to a fast-moving and tough work environment. Yet, ironically, 17% of local worker respondents had been working as pioneers for the companies.

Does the empirical evidence for local people's involvement also indicate that on average, the productivity of local people is lower than their migrant worker counterparts? The hypothesis that the productivity of local workers is equal to migrant workers is not rejected (Table B.1). This empirical finding was inconsistent with the responses to the question on local people's involvement. From the survey, 74% to 83% of respondents stated that local people's productivity was lower than their migrant worker counterparts. This reflects the observation of the “work habit” of local employees in working shorter work days/hours compared with migrant workers.

There is a possibility, however, of measurement errors in this data. As a contract system is generally predominant, the use of productivity variables should account for how many days it takes a contract to be completed to measure the real level of productivity. In this study, productivity was measured based on the income of the workers. It did not consider the length of time it takes for workers to finish their contract job. This dimension could have made a difference in the results of the regression analysis.

There are many plausible reasons for the low involvement of the local people. One observation is that the seasonal nature of field labor availability may be related to the accessibility of off-farm job opportunities in certain regions. From the survey question on the reasons for the existing level of involvement, 43% to 57% of respondents revealed that there were other kinds of jobs available besides working on timber and pulp plantations. Seventeen to twenty-seven percent of respondents said that agriculture was the primary livelihood of the local people. Seventy-three percent of migrant worker respondents said that local workers were seasonal workers because of their subsistence farming practices. The vast majority of local people still depend on agricultural farming or estate crops in the more developed communities. As agricultural farming is critical to the local people’s welfare, they do not willingly give it up. In such situations, a labor shortage occurs during peak agricultural seasons in almost all the local communities. Absenteeism of local workers over weekends, at the end of the month or after pay-day, disrupts timber and pulp plantation operations. Many local workers are casuals who move in and out of jobs rapidly, resulting in a high turnover rate. Employers, therefore, hesitate to make any efforts to improve these workers’ skills through training.

Illegal logging is also mentioned as a seasonal source of livelihood by 7% to 16% of respondents. The economic development in certain areas, i.e., greater accessibility to nearby markets and more developed infrastructures bring about the side effect of a higher demand for timber. The Government’s capacity to supervise and control forestry-related operations and enforce forestry regulations has been paralyzed by the recent economic crisis. Inevitably, there are forest areas where there have been little or no property rights enforcement, thus making them vulnerable to typical abuses by individuals arising from such free and uncontrolled access.

Local people’s preferences for different sources of off-farm livelihoods depend, to some extent, on relative income levels and the nature of work. Thirteen to sixteen percent of respondents cited the low level of wages in timber and pulp plantations as a reason for the (low) degree of involvement by locals. A study done by Potter and Lee (1998) in Jambi also confirms that workers obtain low wages from companies – about IDR 5,000 (USD 0.47) per day.

5.0 CARBON SEQUESTRATION

5.1 Carbon Sequestration in Timber Plantations

It is expected that large-scale plantation programs will provide an alternative strategy in overcoming the global warming issue. A plantation's failure to achieve and sustain a sufficiently high yield and survival rate (due to inefficiency) would diminish the rate of carbon sequestration expected of it. Carbon sequestration represents a definite positive environmental value of timber plantations. Low efficiency of a timber plantation leads to decreased total biomass, roughly 50% of which is carbon.

It is estimated that the extent of agroforestry and forest plantations that is potentially available globally for sequestering carbon is about 345 million hectares, with the carbon fixation rate at a maximum level of 1.5 GtC[14] annually. Currently, the level of carbon released to the atmosphere is estimated at 3.2 GtC per year. Krutila (1991) cited in Panayatou and Ashton (1992), estimated that the carbon storage value of the Malaysian forests is about USD 2,950 to 3,682 per hectare. Ladrach (2001) revealed that a tonne of sequestered carbon may have a value of USD 20. The World Bank's projection of carbon credit value is around USD 20 to 70 per tC. Swisher and Masters (1992) estimated the marginal costs of reducing CO_2 emissions in south Central USA to be in the range of USD 80 to 100 per tC and USD 5 to 15 per tC in Central America.

Large-scale forest plantations are widely believed to be a hedge against climatic changes. A number of studies have reported on the carbon sequestering potential of tropical forest plantations. Brown et al. (1986) estimated that in 1980, the net carbon sequestered from the atmosphere was 0.03 – 0.11 x 10^9 tC per year in a tropical plantation with a total area of 11.1 million hectares. This amount may replace the net release of carbon from temperate biomass due to land use changes and forest harvesting. Trexler (1992) estimated that the carbon fixation rate in the tropics for plantations was 12.2 to 15.7 tC per hectare per year. Schroeder (1992) calculated the mean carbon storage potential based on nine selected tropical plantation species. The results show that about 8 to 78 tC per hectare can be sequestered in tropical plantations.

More reliable information about sequestered carbon in plantation biomass as well as on the effect of fires, different silvicultural systems, age classes of the stands and species on sequestered carbon, is demanded due to growing concerns about the marketing of carbon credit.

[14] 1 x 10^9 tC = 1 GtC (gigatonne of carbon). One tC is equivalent to 3.67 tCO_2 (Kagi 2000).

5.2 The Estimation of Carbon Sequestration Potential of Tree Plantations

The biological potential of plantation forests to sequester carbon is estimated based on MAI and rotation length. Carbon sequestration is estimated from standing biomass. It is assumed that the growth rate is the same across the whole block (based on average). The amount of carbon in standing biomass is determined by multiplying the total plantation area by the biological potential of the plantation forest to sequester carbon. The product is then multiplied by the carbon content of the wood. Schroeder (1992) and Winjum et al. (1997) proposed a formula called mean annual biomass carbon (MABC) to estimate the amounts of carbon in standing biomass.

Two main species, *Acacia mangium* and *Gmelina arborea*, were considered in this study for the purpose of field measurements. The field measurements were not intended to extract very accurate data, but were used for a discussion of the supplementary issue of carbon sequestration. Due to accessibility problems and time constraints, field measurements were conducted only for 36 companies. However, only 30 companies provided satisfactory field measurements for plantations with age classes from one to five years. For a comparison, the measurement results of some companies are presented in Tables 3 and 4. It is important to note that both species mentioned above are widely planted in timber and pulp plantations in Indonesia. The high frequency of wildfire incidents made some firms opt for *Gmelina arborea*. This species, compared to *Acacia mangium*, is more resistant to fire. In Indonesia, however, research on *Gmelina arborea* has been insufficient to conclusively prove its superiority.

Annual carbon (C) storage in tropical plantations and forests range from 0.8 to 24 tC per hectare per year based on GTZ's (Gessellschaft fur Techniche Zusammenarbeit Gmbh-GTZ – a service company in international development cooperation, owned by the German Federal Government) extensive study on carbon uptake in 1993 (Kagi 2000). Two corresponding species are presented here for reference comparison. Halenda (1989) conducted a study on above-ground production of a 6.6 year-old *Gmelina arborea* plantation in Sarawak, Malaysia. It was reported that the total above-ground biomass was about 92.1 tC per hectare or a mean annual biomass increment of 12.9 tC per hectare per year. Lim (1988) estimated the above-ground biomass in a four-year *Acacia mangium* stand in Peninsular Malaysia and reported a total biomass of 90.4 tC per hectare or a mean annual biomass increment of 18 tC per hectare per year.

Table 3. Mean Annual Increment (MAI) of *Acacia Mangium*

No.	*Source of Data*	*MAI by Age Class (m^3/ha/year)*					*Average*
		1	*2*	*3*	*4*	*5*	
1	Company*	6.18	5.82	12.35	14.14	17.40	11.23
2	Field Measurements*	5.5	12.47	15.27	17.33	19.97	14.12

Notes : * Primary data from 15 plantation areas
** Secondary data from 15 companies

Table 4. Mean Annual Increment (MAI) of *Gmelina Arborea*

No.	*Source of Data*	*MAI by Age Class (m^3/ha/year)*					*Average*
		1	*2*	*3*	*4*	*5*	
1	Company*	7.09	10.05	15.12	16.28	17.04	13.12
2.	Field Measurements **	3.18	13.34	22.28	19.06	25.20	16.61

Notes : * Primary data from 13 plantation areas
** Secondary data from 15 companies

This study addressed the current achievement of plantation yield when the average yield is valued in terms of sequestered carbon using the mean annual biomass carbon (MABC) formula developed by Schroeder (1992) and Winjum et al. (1997) which is as follows:

MABC = MAI x D x F x 0.5 (in tC/ha/year)

where MAI is in m^3/ha/year

D — is the wood density in t/m^3

F — is the age dependent value developed by Brown et al. (1986) to account for biomass in other plant components such as roots and branches. Winjum et al. (1997) proposed using 1.6 to represent the value of F.

0.5 — represents the carbon content in biomass. Peh and Khoo (1984) noted that the value of D is 0.483 for *Acacia mangium* and 0.42 for *Gmelina arborea*.

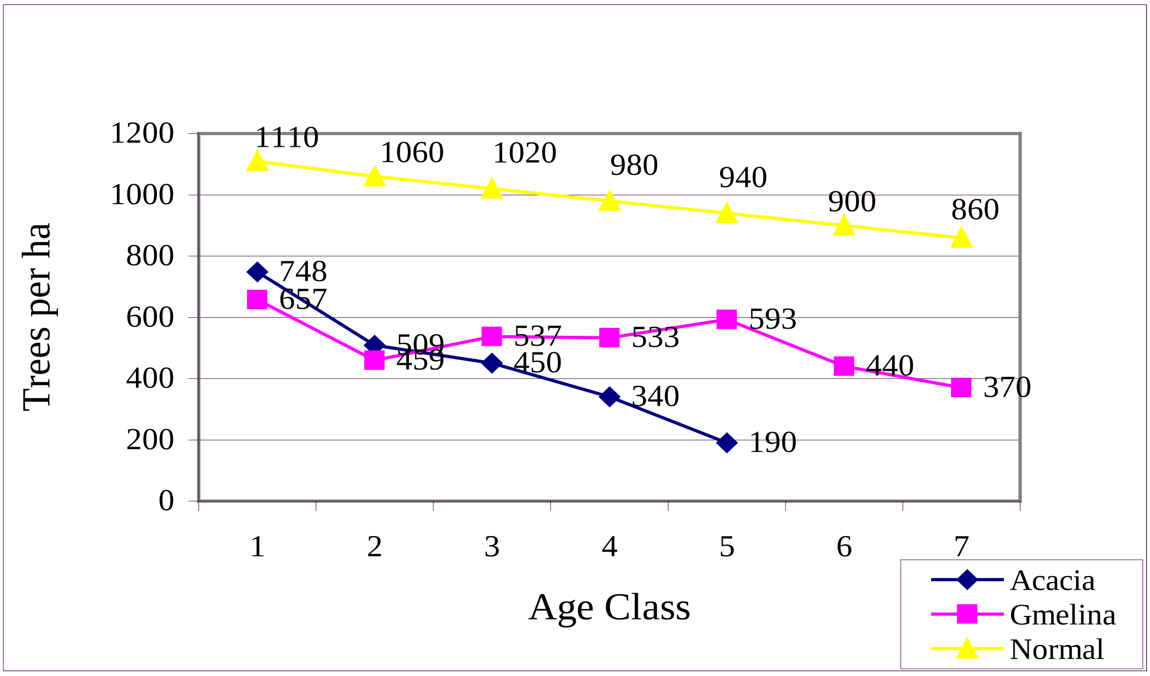
Based on MAI data presented in Tables 3 and 4, the mean annual biomass increments for *Acacia mangium* and *Gmelina arborea* are about 6.73 to 7.72 tC per hectare per year and 5.72 to 8.47 tC per hectare per year, respectively for a 5-year-old stand i.e. a total above-ground biomass of 33.65 to 38.6 tC per hectare for *Acacia mangium* and 28.60 to 42.35 tC per hectare for *Gmelina arborea*. These results are smaller compared with the studies conducted in Malaysia and elsewhere (Table 5). There appeared to be three reasons for the low estimations.

Table 5. Estimation of Average Carbon Sequestration Rate: Above-ground Biomass in Tropical Plantations

Species	*Age (year)*	*Above-ground Biomass (t/ha/yr)*	*Country*	*Source*
Eucalyptus deglupta	8	13.1	Costa Rica	Lugo et al. (1988)
Gmelina arborea	5	12.9	Costa Rica	Lugo et al. (1988)
Acacia mangium	-	7.7 to 20.4	Indonesia	Tuomela (1997)

Note: Cited from Montagnini and Porras (1998) and Koskela et al. (2000)

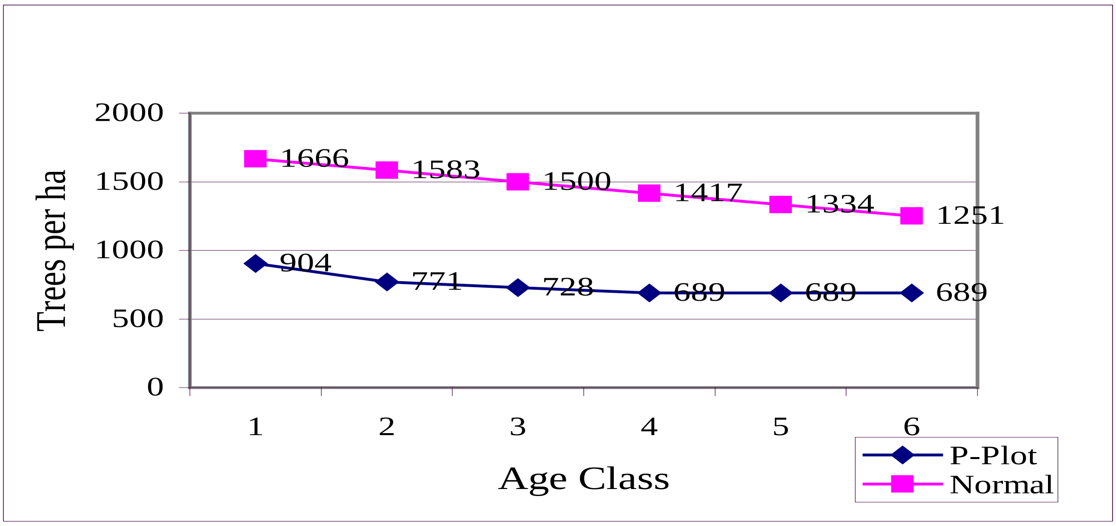
Firstly, the number of trees per hectare was quite small due to poor field control and forest fire incidences. Data from two large companies in Kalimantan and Riau showed that due to these problems, stand per hectare was only 20% to 67% for *Acacia mangium*, and 43% to 63% for *Gmelina arborea* compared with the normal standing stock per hectare of the first company (Figure 2). For the second company, the stand per hectare was 49% to 55% in terms of the normal standing stock per hectare for *Acacia mangium* (Figure 3). Secondly, too often, companies (with the exception of large companies) applied local and unknown sources of seed. Figure 4 shows the difference in MAI between the use of genetically improved and unimproved seed. Thirdly, the lack of technical knowledge of plantation development was a common obstacle.



Source: Planning Department of a company in Samarinda[15]

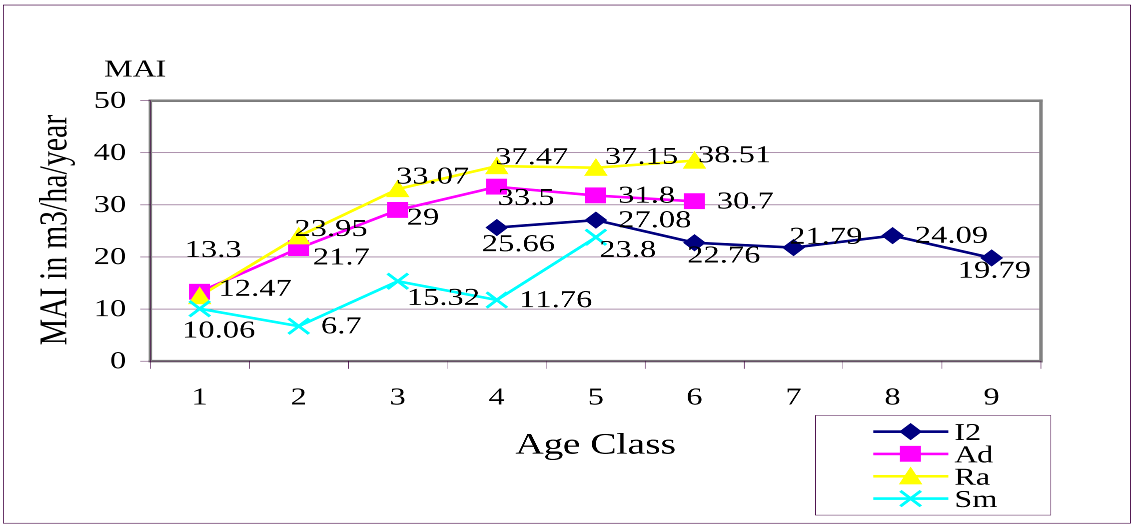
Figure 2. Average Number of Trees per Hectare (*Acacia Mangium and Gmelina Arborea)*: An Example of the Effects of Forest Fires and Improper Management Control in the Field Operations of a Company in East Kalimantan

[15] This data is based on regular surveys conducted every year from entire production areas (non-permanent plots). Spacing is 3 x 3 meters. The first graph from above is the number of trees based on normal stocking. . Personal communication with Teddy, Samarinda, 2000.



Source: Planning Department of a company in Riau[16]

Figure 3. Average Number of Trees per Hectare (*Acacia Mangium*): an Example of the Effects of Improper Management Control in the Field Operations of a Company in Riau



Source: Two companies' permanent plot measurements in Riau, a company's measurement in South Kalimantan and a company's measurement in East Kalimantan

Note: I2, Ad, Ra, and Sm in the key are the companies' names

Figure 4. Mean Annual Increments (MAI) of Different Companies[17]

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[16] Spacing is 2 x 3 meters. Personal communication with Teguh, Pakanbaru, 2000.

[17] The two top graph lines represent MAIs taken from companies in Riau using genetically improved seed on permanent plots; the third is the MAI from a company in South Kalimantan using mixed seed – unimproved and improved seed – on non-permanent plots and the fourth is the MAI from a company in East Kalimantan using unimproved seed on non-permanent plots and which suffered forest fires.

Certainly, determinants of yield such as the use of genetically improved seed, spacing, standing stock (survival rate), species and provenance options, and the quality of planting material play a crucial role in maintaining a successful sustainable plantation program. Rasmussen (1996) noted that seed sources and the physiological and physical quality of seeds is generally unrecorded in the existing tree seed supply system in Indonesia. There is a lack of concern among seed-users (i.e., foresters and companies) with respect to proper seed quality and procurement for the timber and pulp plantations.

In most cases, the companies prefer to obtain affordable seed rather than good quality seed. The market price for the most commonly used seed is about IDR 20,000 to 30,000 (USD 1.89 to 2.84) per kilogram. Some large companies produce and sell slightly better quality seed to other companies. The cost of this type of seed is about IDR 50,000 to 70,000 (USD 4.73 to 6.63) per kilogram. Meanwhile, only a few companies (large-scale ones) use high quality seed from Australia and Africa - this costs about IDR 2 to 5 million (USD 189 to 473) per kilogram (for *Acacia mangium)*. This indicates that a long-term perspective towards achieving a sustainable plantation production system is seriously lacking in Indonesia, even at the very basic level of securing proper planting material.

Smith et al. (1998), after reviewing several references on plantation development with respect to CDM (Clean Development Mechanism) in carbon sequestration projects, concluded that the contribution from plantations in the tropics was only at 20% to 30% level, with plantation failures at a high rate. The main cause for these failures was the lack of technical knowledge. Also, as local people were generally not involved in plantation development, large plantation companies were vulnerable to tenure conflicts and custom-related land claims. This also describes the situation faced by most small and medium-scale plantation companies in Indonesia. However, findings from this study are not intended to conclude that there is no hope for improvement in the future, as large-scale companies are convinced that a higher yield can be achieved through a sustainable production system. The big challenge for the authorities and all stakeholders now is how to replicate what has been achieved by a few successfully-established plantation companies for many other less successful ones.

6.0 CONCLUSIONS

There are striking differences between the technical efficiencies ranging from 0.12 to 0.93 (Table C), of the sampled companies under the industrial timber and pulp plantation program. This analysis found an average technical efficiency of 0.60, which reveals that there is considerable room for improvement in planting performance. On average, the firms did not make any improvements in terms of their efficiency from 1994 to 1998, probably due to this being the early stage of plantation development in Indonesia. The spread of efficiency rating shows that only a few companies (19%) achieved satisfactory planting performance and efficiencies of more than 0.8.

It was seen that the type of company (variable Dc) i.e., the vertical integration of plantation companies with holding companies (timber concession companies), was a crucial determinant in explaining the variation in planting achievement. Landholding size did not appear to be a crucial determinant of acreage planted because large, medium and small-scale plantations face different types of obstacles. For example, it took a long time for large plantations to settle disputes with local people. For medium and small-sized firms, the major drawbacks are improper site preparation, seasonal availability of workers, inadequate expertise of workers, inadequate funds, and so on.

From the available data, it was found that the planting performance in terms of acreage for all schemes was far below (only 2% to 42%) the allotted land area given to the companies. This condition also indicates that substantial portions of the land are still subject to conflicts between local people and plantation companies over overlapping interests.

Human capital, especially field labor, is an important input in determining planting performance. However, the use of skilled labor did not appear to affect planting performance. The isolation of the administration employees variable was also insignificant in explaining the variation in planting achievement. Equipment is also considered a crucial factor in determining planting achievement even with a parameter estimate far below that for labor. The use of full labor-saving technology in the forestry sector in Indonesia appeared to be neither socially nor economically permissible. In particular, the rental rate for heavy equipment is expensive compared with labor costs. There is also pressure to use local labor in forestry plantations.

Like many other references, this study found no evidence to show that financial support provided by the Government affects output or efficiency. This is seen in the results of the coefficient of the government support (Gs) variable in Table B1. This supports the capital substitution argument that government incentives merely substitute self-motivating investment. It also favors the current policy objective (Ministry of Forestry Directives 922/1999) of the privatization of plantation operations.

This study found that the elasticity of output with respect to the costs of other inputs is significantly negative. In fact, the total costs per hectare for critical activities, namely nursery and site preparation, and planting, were below the government standard costs per hectare.

The analyses of determinants of efficiency from inefficiency model (4) combined with a non-parametric statistical test, provided significant evidence that can be the basis for improvement efforts and further policy studies. The efficiency analysis of the plantations under the different schemes show that the self-financed companies are the most inefficient. The levels of efficiency for pulp and non-pulp schemes (model 3b) are significantly greater than that of the transmigration scheme. The transmigration scheme, particularly in small-sized plantation areas, appeared inferior in terms of technical efficiency. On average, state-owned companies sampled were at about the same efficiency level as those in the transmigration scheme.

Scale of the company was found to be an important determinant of efficiency levels. This empirical evidence for the composite variable of size was consistent with the increasing returns to scale in the stochastic frontier production model. The larger the scale of a company in terms of its capital investment and management setup, the more efficient is the planting performance.

The empirical findings also showed that the coefficient of productivity was effectively zero, which indicated that the productivity of local people was about the same as that of migrant workers. This, however, conflicted with opinion surveys which indicated that the productivity of local people was inferior. The involvement variables appeared to inversely affect efficiency levels significantly and positively. It was found that the seasonal working habits of local people was the main cause of their (higher) inefficiency. Surveys conducted in this study revealed that the need for alternative cash incomes, the availability of other job opportunities in certain places, the low wages in the timber and pulp plantation program as compared with other forestry-related jobs, and subsistence farming were among the main reasons for the seasonal working behavior of local community workers.

7.0 POLICY IMPLICATIONS

The results of this research must be interpreted with caution as firms were not randomly selected for this study; rather, the purposive sampling technique was used. This study provides an overall measure of technical efficiency, identifying differences in technical efficiencies among different schemes and plantations of different sizes, and providing measures of local involvement and productivity. The main implications of this study appear in the form of recommendations for policy reviews or further policy studies as discussed below.

7.1 Recommendations for Further Policy Studies

This study revealed that with the existing level of technology, better efficiency can be achieved in larger landholdings. However, an effective conflict resolution between local communities and plantation companies is a prerequisite for efficient planting performance. The decree 728/1998 by the Ministry of Forestry regarding the limitation of landholdings, should be reconsidered. The promotion of community-based forest management for the local people's welfare, through the division of existing plantations into smaller pieces, should not be at the expense of the benefits of economies of scale.

Small-scale plantations (smallholdings) for local communities should not proceed as a national program unless and until the Government is well-prepared with strengthened institutional arrangements for a sound, ongoing tree improvement program; the provision of adequate supplies of improved seed; the development of qualified extension institutions and services; and the establishment of a well-structured protection system or proper marketing channels for small-scale plantation products for smallholders who are unable to get fair market prices. Constructive collaboration between the Government and large plantation firms is required to establish successful small-scale plantations. In the past, institutional capacities were extremely inadequate to boost plantation programs. In fact, there have been no improvements in terms of efficiency during the years 1994/1995 to 1998/1999 as proven in this study. This recommendation is based on the finding that small-sized plantation firms tend to be inefficient as discussed earlier.

The average technical efficiencies of the different schemes show that the transmigration scheme is inferior in planting achievement and efficiency. Moreover, evidence from other studies has revealed that the transmigration scheme is not the best solution for enhancing the living conditions of locals. To improve the welfare of migrant and local workers, modified transmigration schemes with cash crops (such as rubber, coffee, herbs and spices) and larger land allocations should be considered in new policy formulations. It is recommended that the Government take measures to support bigger sized firms through mergers with large-scale companies that own pulp and paper operations.

Empirical evidence showed that government financial assistance does not improve planting achievement. Accordingly, the Ministerial Directive 922/1999 concerning the Government's objective of the gradual elimination of governmental financial support and the gradual transfer of ownership to the private sector should be effected immediately. Policy improvements should be more concerned with strengthening the capacity of privately-owned plantation companies to meet global competition. However, government financial assistance may still be required for smaller plantations and for certain modified social forestry or transmigration schemes. The transmigration scheme may be fully privatized by extending the scheme to those areas free from custom-related land claims.

Public and private investment directed toward developing human capital can be expected to increase output even in the absence of new technologies. Nevertheless, advanced technology and technical skills will be crucial in the near future to improve the capacity of the land in producing a sufficient timber volume per hectare. These areas should be given priority in training and education initiatives. Skilled workers are expected to play a key role in the development of a sound plantation program. The findings showed that those classified as skilled workers are numerous, but they may not, in fact, be skilled workers. Firms should be aware of this. Training of workers on the technical aspects of forestry development should be continuously provided to increase the efficiency of operations. Firms should make this their own responsibility.

7.2 Policy Issues

Among the current obstacles to achieving optimal planting are: inconsistent worker availability (namely due to seasonal working habits), inappropriate seed handling, inferior seed quality, and ineffective supervision over field activities. Timber plantations have been facing substantial competition for labor from the estate crops market. All these factors directly affect the quality of planting and subsequently, survival rates and productivity. These aspects are related not only to internal issues within the companies, i.e., management capability, but also to Government support by way of public institutions and services (for example, the establishment of information centers for the labor force).

Seed supply in terms of quality, quantity and consistency, is uncertain. The establishment of seed centers with extensive operations ranging from species selection and trials to genetic archives should be given top priority by the Government.

Strengthening institutional capacity and coordination is essential in restructuring the timber and pulp plantation program. Over the years, much has been written, proposed, and discussed on the potential benefits that might be generated from establishing the organization of tree seed centers in Indonesia. Although institutional arrangements for a proposed national seed center have been initiated, progress has been slow. Long-term seed supply and tree-improvement cooperative programs and other similar setups between stakeholders (universities, the Ministry of Forestry, and forest industries) should be properly established to secure better quantity and quality of planting performance. The success of industrial timber and pulp plantations depends heavily on the continuous supply of essential inputs like genetically improved seed, proper equipment, and competent labor, all of which strengthened institutional capacity would make possible.

To alleviate the pressure on the natural rainforests in it being used to provide excessive raw material for forest-based industries, and to upgrade the performance of the timber and pulp plantations, reducing the number of forest-based industries should be prioritized, targeting those that do not have direct sources of raw material. More importantly, as Hyde et al.(1992) stated, it is most unlikely that industrial timber plantations can be successfully established when there are large volumes of timber from natural rainforests available at low cost. Thus, an imposition of higher levies (i.e., reforestation fees), a more stringent sustainable forest management practices code, and firm environmental restrictions should bring the marginal cost of extraction up to the (cost) level of establishing a sound timber plantation. Otherwise, there is little sense for the timber and pulp plantation program to continue.

The salvage cutting permit, also known as Ijin Pemanfaatan Kayu (IPK), from forest conversion areas has long been suspected as a mechanism used to disguise illegal logging. This permit, in fact, was the cause of the stumpage value of logs falling to a very low level – a great disincentive to plantation companies. The moratorium on this permit may reduce the dependency of pulp industries on natural rainforests and should greatly enhance plantation performance.

The Government regulation that requires plantation companies to hire more local people is ineffective. With structural changes occurring in so many areas after the fall of the old regime, the participation of the local people cannot be considered in a narrow sense as only workers – local people are demanding better opportunities to enhance their livelihood. Programs like the nucleus estate smallholders (PIR) scheme or appropriate agroforestry schemes in which there is vertical integration through partnerships between groups of smallholders with large-scale industries are more likely to be preferred by local communities – this should be more vigorously promoted by the Government along with NGOs. This would allow local people, as smallholders, to cultivate their own small-scale plantations and sell their products while still being able to derive additional income as wage workers in plantation companies. Such an arrangement requires a sustained commitment from the Government to allocate land titles to individuals, favoring local people. Locals have long-standing experience and expertise in diverse farming practices and tree planting ranging from traditionally unmanaged rubber plots to well-managed agroforestry systems.[18]

In Uruguay, Latorre (1995), cited by Carrere and Lohmann (1996), suggested that an alternative policy might be considered to provide an incentive to firms that are concerned with the well-being of local people – this would encompass Government subsidies for companies serious about developing partnerships with local people. There have been successful cooperation efforts worldwide (in the Philippines, Chile, Brazil, Australia, China, India, Thailand and South Africa) between world-class pulp and paper firms and forest communities.

The Government should be a leading agent in R&D programs in the near future by providing adequate investment for research, with greater involvement by state-owned companies. Species selection (such as fire and disease-resistant species) to avoid the high risk of failure, should be prioritized as forest fires, pests and disease are threats to sustainable plantation management. State-owned plantation areas may also function as seed production and research development areas in cooperative research development programs.

18 Rubber agroforestry systems in Sumatra and Kalimantan occupy more than 2.5 million hectares and provide income for more than one million farmers. Other valuable agricultural commodities such as coffee, cocoa, resin, illipe nut and fruits are also cultivated by these farmers, but rubber agroforests are the most commonly grown. During the growing period, rubber agroforests require limited labor; the farmers can therefore, diversify to other activities to generate more income (Dove 1993).

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APPENDIX 1

Survey on Involvement of Local People in Industrial Timber and Pulp Plantation Development

Table A. Responses to the Local Worker-related Questionnaire

No.	Object/Concern	Response (Percentage) A	B	C
1.	Knowledge about government regulations on local people's involvement in the industrial timber plantation			
	- Know	52	-	-
	- Do not know	48	-	-
2.	Opinion on the number of local people involved compared with migrant worker involvement			
	- Too little	71	57	60
	- At about the same number	10	17	20
	- More than migrant worker	19	26	20
3.	Reasons for the existing number of local people involved			
	- The only job available	3	3	-
	- Close to villages/surrounded by villages	22	23	27
	- Other jobs available in nearby areas			
	- other companies	10	23	20
	- other livelihoods (farming, fishing, estate crops, and trading, etc)	17	27	23
	- illegal logging (forest looting)	16	7	7
	- Unfit for/unsuited to work pressure/working with company/company's working rules	10	-	10
	- Low wage rate and prefer not to work in the field	16	-	13
	- Far from sources of migrant workers	6	-	-
	- Been working with company since the beginning	-	17	-
4.	Productivity of local people compared with migrant workers			
	- Lower	74	-	83
	- About the same	26	-	7
	- Higher	-	-	10
5.	Opinion on local people's work habits			
	- Seasonal	-	-	73
	- Year long	-	-	27
6.	Capability of local people			
	- Able to do all types of work	-	-	63
	- Only able to do certain type of work	-	-	37

Notes: A – Company decision-makers (site heads/camp managers)
B – Local workers
C – Migrant workers

APPENDIX 2

Data Analysis Results of The Stochastic Frontier Production and Inefficiency Models

Table B.1 Maximum-likelihood Estimates for Parameters of the Stochastic Frontier and Inefficiency Models (Models 3a – 7 Variables and 3b – 8 Variables)[19]

Variables	*Parameters*	*Parameter Estimates (Model 3a - 7 Variables)*	*Parameter Estimates (Model 3b - 8 Variables)*
Constant	β_0	1.708 (0.519)	2.059 (0.5290)
Dc	β_1	0.615 (0.162)**	0.558 (0.154)**
Ln (L)	β_2	0.132 (0.083)	0.115 (0.079)
Ln (Adm)	β_3	0.009 (0.064)	- 0.005 (0.063)
Ln (Lbr)	β_4	0.669 (0.084)**	0.662 (0.077)**
Ln (Sk)	β_5	- 0.162 (0.075)**	- 0.146 (0.075)**
Ln (Eq)	β_6	0.239 (0.089)**	0.258 (0.087)**
C	β_7	-	- 0.483 (0.221)**
Gs	$\beta_{7/8}$	- 0.086 (0.089)	- 0.099 (0.084)
Intercept	δ_0	0.701 (0.650)	0.693 (0.641)
Transmigration	δ_1	- 0.217 (0.429)	- 0.226 (0.395)
Self-Financed	δ_2	0.896 (0.414)**	0.746 (0.395)*
Pulp	δ_3	- 4.708 (5.047)	- 4.476 (4.452)
Non-Pulp	δ_4	- 0.763 (0.918)	- 1.337 (1.079)
Large	δ_5	- 1.435 (0.757)*	- 1.583 (0.751)**
Medium	δ_6	-1.862 (0.866)**	-1.757 (1.046)*
Involvement	δ_7	1.219 (0.633)*	1.140 (0.613)*
Productivity	δ_8	- 0.816 (0.581)	- 0.653 (0.543)
	$\sigma_s^2 = \sigma_v^2 + \sigma_u^2$	0.625 (0.147)*	0.584 (0.151)**
	$\gamma = \sigma_u^2/\sigma_s^2$	0.904 (0.040)**	0.898 (0.045)**
Log Likelihood		-102.35	-100.13

Note: ** denotes significance at 5% level of t-values
* denotes significance at 10% level of t-values

[19] The standard errors are presented below the corresponding parameter estimates.

Table B.2 Summary Statistics for Tests of Hypotheses Involving Parameters of the Stochastic Frontier and Inefficiency Model – (3a) (the Generalized Likelihood Ratio Test)

Null Hypothesis H_0 :	*Log-likelihood*	*λ Calculation*	*$\chi^2_{0.95}$ Critical Value*	*Decision*
$\gamma = \delta_0 = \ldots \delta_8 = 0$	-126.78	48.856	17.670	Reject
$\delta_1 = \delta_2 \ldots\ldots\ldots \delta_8 = 0$	-122.741	40.778	15.507	Reject
$\delta_1 = \delta_2 \ldots\ldots\ldots \delta_4 = 0$	-114.476	24.248	9.488	Reject
$\delta_5 = \delta_6 = 0$	-106.646	8.590	5.991	Reject
$\beta_2 = 0$ Land = 0	-103.71	2.716	3.841 2.706*	Do not reject Reject
$\delta_3=0$ Pulp=0	-104.253	3.802	3.841 2.706*	Do not reject Reject

Notes: Log likelihood for the no-restriction model: -102.352
* denotes $\chi^2_{0.90}$

Table B.3 Summary Statistics for Tests of Hypotheses Involving Parameters of the Stochastic Frontier and Inefficiency Model – (3b) (the Generalized Likelihood Ratio Test)

Null Hypothesis H_0 :	*Log-likelihood*	*λ Calculation*	*$\chi^2_{0.95}$ Critical Value*	*Decision*
$\gamma = \delta_0 = \ldots\ldots \delta_8 = 0$	-123.97	47.68	17.670	Reject
$\delta_1 = \delta_2 \ldots\ldots\ldots \delta_8 = 0$	-120.235	40.210	15.507	Reject
$\delta_1 = \delta_2 \ldots\ldots\ldots \delta_4 = 0$	-110.988	21.720	9.488	Reject
$\delta_5 = \delta_6 = 0$	-104.735	9.214	5.991	Reject
$\beta_2 = 0$ Land = 0	-101.132	2.004	3.841 2.706*	Do not reject Do not reject
$\delta_3=0$ Pulp=0	-101.692	3.120	3.841 2.706*	Do not reject Reject

Notes: Log likelihood for the no-restriction model: -100.130
* denotes critical value of $\chi^2_{0.90}$

APPENDIX 3

Technical Efficiency Estimates

Table C. Ranking of Companies Based on Average Technical Efficiency Estimates

Model with 7 Variables			*Model with 8 Variables*		
Rank	*Company #*	*Technical Efficiency*	*Rank*	*Company #*	*Technical Efficiency*
1	7	0.93	1	7	0.93
2	4	0.92	2	4	0.92
3	25	0.91	3	25	0.91
4	12	0.90	4	12	0.91
5	10	0.88	5	10	0.88
6	9	0.81	6	9	0.84
7	28	0.75	7	28	0.74
8	31	0.70	8	29	0.71
9	1	0.69	9	31	0.71
10	15	0.68	10	6	0.69
11	30	0.67	11	1	0.68
12	29	0.66	12	15	0.65
13	5	0.65	13	30	0.65
14	3	0.60	14	5	0.61
15	2	0.60	15	26	0.59
16	6	0.60	16	21	0.58
17	8	0.59	17	8	0.58
18	32	0.59	18	3	0.58
19	21	0.58	19	2	0.56
20	14	0.56	20	32	0.56
21	18	0.54	21	14	0.55
22	26	0.54	22	11	0.54
23	13	0.53	23	18	0.53
24	11	0.53	24	20	0.52
25	20	0.51	25	13	0.50
26	16	0.41	26	16	0.39
27	24	0.38	27	24	0.38
28	19	0.38	28	19	0.37
29	17	0.34	29	17	0.35
30	22	0.33	30	22	0.34
31	23	0.23	31	23	0.25
32	27	0.12	32	27	0.13

Note: After 2nd analysis (8 variables), the technical efficiency estimates of 12 companies decrease, 6 companies remain with the same scores, and 14 companies increase their scores.

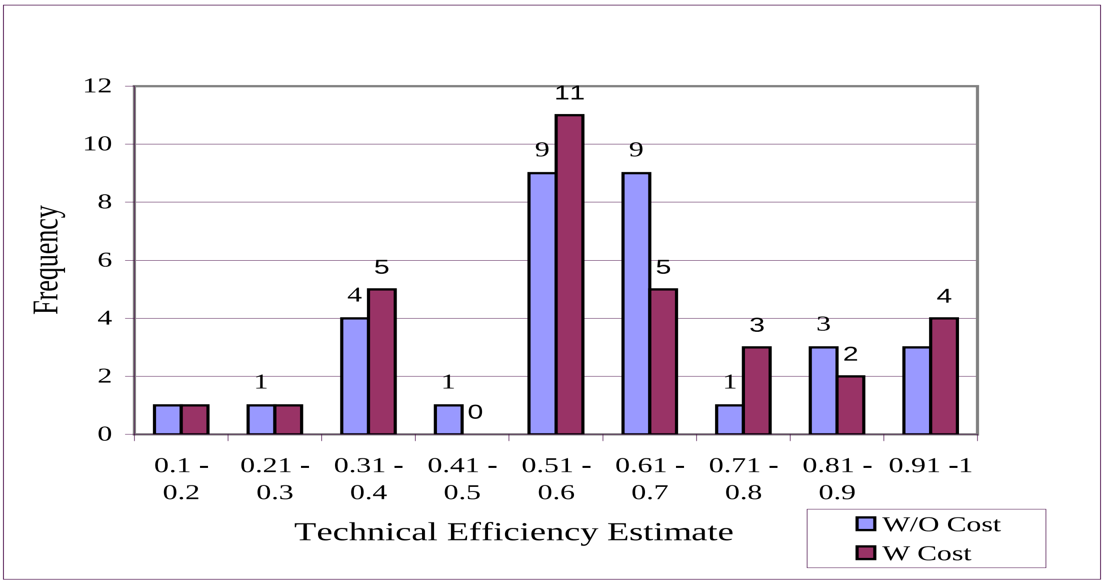

Figure C.1 Distribution of Technical Efficiency Estimates in Decile Ranges

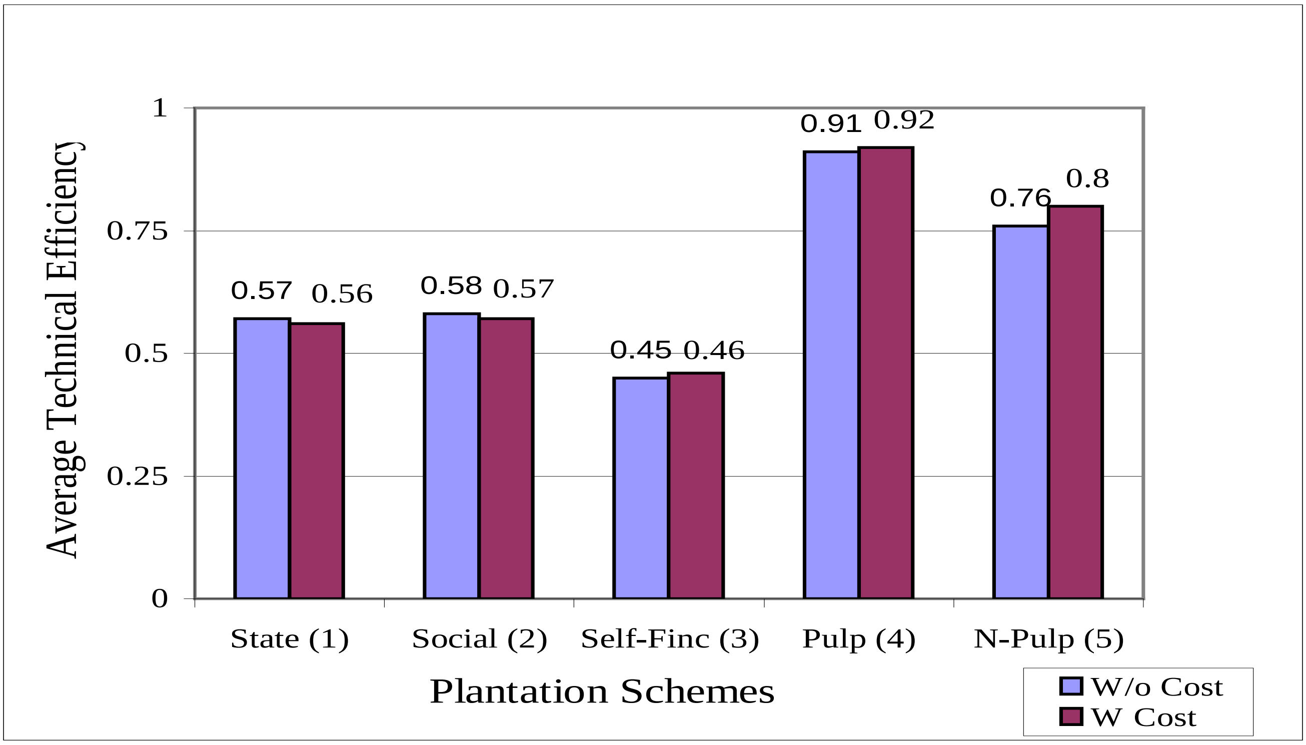

Figure C.2 Average Technical Efficiencies Based on Plantation Scheme

Figure C.3 Average Technical Efficiencies Based on Size of Plantation Area

APPENDIX 4

Glossary

Asymptotic t Tests. This is a property of a function where the variance decreases as the sample size increases.

Carbon Sequestration and Carbon Fixation Rate. It is the ability of a tree or a plant to absorb carbon from the air for the photosynthesis process.

Carbon Storage Value. The amount of carbon stored in a tree i.e. in its leaves, branches, trunk, roots, etc.

χ^2 critical values; * difference between $\chi^2_{0.90}$ and $\chi^2_{0.95}$. χ^2 (read as chi-square) is defined as the sum of squares of independent, normally distributed variables with zero mean and unit variances. The difference between $\chi^2_{0.90}$ and $\chi^2_{0.95}$ is the confidence limit.

Cobb-Douglas Function. The exponential (non-linear) production function named after Cobb and Douglas (1928). The function defines the physical relationship between outputs and inputs.

Critical t-value. This measures the number of standard errors between the sample and population means.

Davidon-Fletcher-Powel Maximization Routine. Computer programming to maximize a function that was named after the programmers/ inventors**.**

Decile Ranges. A 0.10 range or a one-tenth range of efficiency scores.

Elasticity. Percentage change in the level of output given a percentage change in the level of input.

Error or Disturbance Term. In a regression model, $y = a - bx$, the difference between the actual value of the dependent variable and the value predicted from the model for a given value of the independent variable (denoted by x), measures the error term.

Generalized Likelihood Ratio. The ratio of the maximum likelihood function under restriction to the maximum likelihood function without restriction.

Grid Search Process. This process uses the co-ordinates of location in a graph or curve to seek the maximum value of a function.

Input-output Space. Defines the value of output on the y-axis and input on x-axis.

Iterative Maximization Process. Maximization process of a function initiated by setting a certain range of numbers say, 0.1 to 0.9. The iteration process (i.e. the process of getting the solution) will stop when the value of the function is maximized.

k by 1 vector. An array of input variables used in a model plus the coefficient of the intercept variable, which here, is 1.

Log-likelihood Function. The logarithm of the likelihood function. The likelihood function gives a measure of how well the probability distribution function defined by the parameters fits the given data sets. If a parameter set maximizes the likelihood, then, these parameters will define the best fitting probability distribution function for the data set, using that particular model.
Source: www.maths.uwa.edu.au/~rkealley/diss/node25.html

Mann - Whitney Non-parametric Statistical Test. It is used to test the null hypothesis that two populations have identical distribution functions against the alternative hypothesis that the two distribution functions differ only with respect to the location (median),

if at all.
Source: www.cas.lancs.ac.uk/glossary_v1.1

Maximum-likelihood Methods. A statistical estimation method of finding the highest (maximum) probability (likelihood) that the observations from a random sample follow a certain distribution or a certain functional relationship.

Mean Annual Increment (MAI). The average net annual increase in the yield (expressed in terms of volume per unit area) of living trees at a given age. MAI is calculated by dividing the yield of a stand of trees by its mean age.

Non-probability Purposive Sampling Design. A sampling design based on the purpose of the study and the researcher's judgement. This sample is obtained without random drawing.

Ordinary Least Square (OLS) estimation. A procedure that minimizes the sum of squared residuals around a regression line in the process of producing the best fit possible.

Panel Data / Unbalanced Panel Data. Combination of time series and cross-sectional data. Unbalanced means that some data is not available.

Parameterization. A process of generating a quantity or value to describe a statistical population.

Positive Truncation / Non-negative Truncation. The normal (bell-shaped curve) function has a zero mean. The non-negative truncation is found in the right portion when the curve is divided into two similar portions.

Regression Function. A function that relates a dependent variable with independent variables.

Restricted and Unrestricted Log Likelihood. Restriction is placed on the function when one or more than one variable/s is/are restricted, i.e. when its/their value is set to zero.

Species and Provenance Options. Choices of tree species from various origins or sources.

Standing / Above Ground Biomass. The amount of carbon stored in the above -ground part of a tree (leaves, branches, trunk, etc. but not the roots).

Stochastic Frontier Production Function. Production function obtained from maximum possible output.

Stochastic. Random

Technical Efficiency. Measures the level of output relative to the maximum possible output that a given set of inputs can produce.

Tract Size. The size of plantation area.

Vertical Integration. Type of ownership where several subsidiary companies are under the control of a holding company.