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Project FireFight South East Asia
The Economics of Fire Use in Agriculture and Forestry - A preliminary Review for Indonesia

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WWF

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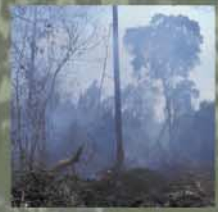
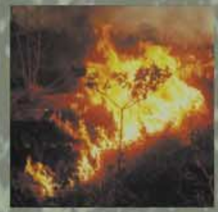
Dr. Anne Guyon & Dr. Dicky Simorangkir



The Economics of Fire Use in Agriculture and Forestry: A preliminary Review for Indonesia

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Background picture:
Eucalyptus plantation in Congo by Dr. Takeshi Toma, Cifor

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Preface

The forest fires of 1997 and 1998 created enormous ecological damage and human suffering and helped focus world attention on the problem. There is a growing concern within **WWF - The World Wide Fund for Nature** and **IUCN - The World Conservation Union** that action is needed to catalyse a strategic international response to forest fires. There are no 'magic bullets' or 'instant solutions'. The issues to be addressed are complex and cut across many interests, sectors, communities, nations and regions. WWF and IUCN believe that action only take place when fires are burning, with little attempt to address the underlying causes.

This is why the two organisations have joined forces and developed **Project Firefight South East Asia** to secure essential policy reform through a strategy of advocacy using syntheses and analyses of existing information and new outputs. More specifically, the project aims to enhance the knowledge and skills of key stakeholders with regard to forest fire prevention and management and, where necessary, to facilitate the adoption of new and/ or improved options. The project works at the national and regional levels across South East Asia to support and advocate the creation of the legislative and economic bases for mitigating harmful anthropogenic forest fires.

As the problem of forest fires lies beyond the capacity of national governments and international organisations to handle alone, the project pursues a multiple stakeholder approach. By combining WWF's extensive network of National Organisations and Programme Offices in South East Asian, IUCN's broad-based membership, world-renowned scientific commissions, and collaboration with ASEAN governments, UN agencies, EU projects, CIFOR, ICRAF, RECOFTC, universities, etc., the project ensures popular participation, public awareness, policy outreach and programmatic impact in connection with fire-related issues.

Project FireFight South East Asia undertook studies focusing on three areas of fire management: community-based fire management, legal and regulatory aspects of forest fires, and the economics of fire use in South East Asia. The expected results of these studies are the identification of political, private sector and civil society stakeholders and the legal, financial and institutional mechanisms appropriate to South East Asia that can positively influence their fire-related behaviour. In addition, national and international policies, which promote, or fail to discourage, forest fires are identified.

This report is concerned with the economic aspect of fire use, which is critical for a comprehensive understanding of the underlying causes of forest and land fires, and ultimately necessary for sustainable fire management. It reviews existing knowledge on the financial costs and benefits of using fire in agriculture and forestry, with particular attention on the positive and negative economic impacts of fire use in land clearing activities. It is anticipated that the result will promote and encourage the use of alternative methods of fire use, such as zero burning, and support relevant stakeholders, particularly South East Asian governments and private companies, in formulating appropriate solutions for more responsible fire use.

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List of Abbreviations

ACIAR	Australian Center for International Agricultural Research
ADB	Asian Development Bank
ANU	Australian National University
APHI	Association of Indonesian Concession Holder
ASB	Alternatives to Slash-and-Burn
ASEAN	Association of South East Asian Nations
BAPPENAS	Badan Perencanaan Pembangunan Nasional (National Development Planning Agency)
CBA	Cost-Benefit Analysis
CEC	Cation Exchange Capacity
CGIAR	Consultative Group for International Agricultural Research
CIDA	Canadian International Development Agency
CIFOR	Center for International Forestry Research
CIRAD	International Center for Cooperation in Agricultural Research for Development
CPO	Crude Palm Oil
DANCED	Danish Cooperation for Environment and Development
dbh	diameter breast height
DFG	Deutsche Forschung Gemeinschaft
EEPSEA	Economy and Environment Program for South East Asia
EU	European Union
FDRS	Fire Danger Rating System
FFB	Fresh Fruit Bunch
FFPCP	Forest Fire Prevention and Control Project
FSC	Forest Stewardship Council
GTZ	Gesellschaft für Technische Zusammenarbeit (German Agency for Technical Co-operation)
HPG	Haze Prevention Group
HTI	Hutan Tanaman Industri (Industrial timber plantation)
ICRAF	International Centre for Research on Agroforestry
IFFM	Integrated Forest Fire Management Project (GTZ)
IFSSP	Indonesian Forest Section Support Programme (European Union)
IOPRI	Indonesian Oil Palm Research Institute
IRRI	Indonesian Rubber Research Institute
IUCN	The World Conservation Union
JICA	Japanese International Co-operation Agency
LCC	Leguminous Cover Crops
LEI	Lembaga Ekolabel Indonesia (Indonesian Ecolabel Institute)
MPOB	Malaysian Palm Oil Board
NOAA	National Oceanographics and Aeronautics Administration

NTT	Nusa Tenggara Timur (East Nusa Tenggara)
NPV	Net Present Value
ODA	Overseas Development Agency
PIPOC	PORIM International Palm Oil Congress
PFFSEA	Project FireFight South East Asia
PNG	Papua New Guinea
PORIM	Palm Oil Research Institute of Malaysia
PPI	Potash and Phosphate Institute
RM	Malaysian Ringgit
Rp	Rupiah
SCKPFP	South and Central Kalimantan Production Forest Project
SOM	Soil Organic Matter
UNEP	United Nations Environment Program
WRI	World Resources Institute
WWF	World Wide Fund for Nature

Executive Summary

Prescribed and uncontrolled fires used on small areas cause little or no significant environmental or economic damage. However, problems arise when fires escape management or are widespread and uncontrolled, particularly in peat areas. Then they may damage natural ecosystems or properties, cause transboundary haze.

The use of fires also exerts financial and economic impacts that have to be identified and understood before appropriate solutions can be formulated for more responsible fire use. This report reviews existing knowledge on the financial costs and benefits of using fire in agriculture and forestry – especially for land clearing – for different types of holdings. It also compares burning with zero-burning method, which has been developed by large-scale commercial companies in South East Asia, especially in Malaysia, in the last 20 years.

Smallholders, on the other hand, do not have the resources to invest in zero burning techniques. Instead, establishing appropriate institutions and clearly defined tenure will help to promote responsible fire use among local communities.

The financial analysis of the costs and benefits of fire versus zero burning indicates that zero-burning methods are not more expensive – and may actually be more cost effective in the long term – than burning, especially for replanting oil palms or rubber trees, or clearing low secondary vegetation or heavily logged-over forests. Burning is more economical for clearing high-volume forest because it is more difficult and time consuming to dispose of high volumes of piled wood mechanically.

Various agencies and institutions have identified zero burning as an appropriate approach to reduce the incidence and intensity of transboundary haze and smoke events. Although Indonesian companies may be persuaded to use zero burning for financial reasons, they are deterred by its relatively complex and technical operation that requires new skills and investment in heavy equipment. Plantation managers are reluctant to adopt the new practice because they dislike the 'messy' appearance of mechanically cleared sites with their high windrows of residues. Contractors who lack the funds to acquire new technology further complicate the adoption of zero burning.

Likewise, implementing a fire management system in a forest concession or a plantation requires initial investments in training and acquisition of equipment. Unfortunately, fire management is usually a target for cutback during any economic crisis, especially after several incident-free years.

When comparing the relatively low financial costs of zero burning and fire management with the enormous socio-economic costs of fire damages, it is clear that there is a market and institutional failure in fire management. Laws and regulations penalising irresponsible fire use are seldom enforced. For the moment, the most significant pressure to exact a cost on irresponsible fire users is through the public image.

A combination of factors has slowed down planting and burning operations since 1997/98. Even so, significant fire and haze events have taken place repeatedly even during normal years with no prolonged droughts. If commodity prices increase in 2002, and with an expected El Niño event in the near future, extensive fires originating from large planting operations may recur.

In conclusion, some recommendations to reduce irresponsible and dangerous use of fire include:

- Promote responsible fire use in land clearing among local communities and smallholders;
- Promote zero-burning method for commercial plantations as a cost-effective method in the long-term;
- Develop a system to sanction dangerous practices and reward good behaviour;
- Ensure that land use policies incorporate responsible fire use at all levels;
- Identify key locations for potential large fires; and
- Set up a monitoring system to prevent irresponsible fire use, and provide training and incentives for responsible fire use.

1. The bottom line

The incidences of large wildfires and haze in Indonesia during the El Niño events in 1982/83, 1987, 1991, 1994 and 1997/98 have generated an increasing concern among international donors, governments, environmental non-governmental organisations (NGOs) and scientists. Most people agree that those uncontrolled fires are a disaster of exceptional magnitude, with adverse environmental effects on Indonesia and its neighbours, which should be prevented *at all costs*. Indeed, there has been a spate of internationally-funded initiatives aimed at monitoring, preventing and controlling fires in Indonesia especially after 1983 and 1997. Major contributors are the United Nations agencies, European Union (EU), Consultative Group for International Agricultural Research (CGIAR), World Wide Fund for Nature (WWF), The World Conservation Union (IUCN), Gesellschaft für Technische Zusammenarbeit (GTZ), Japanese International Co-operation Agency (JICA), as well as agencies from Canada, United States of America, Scandinavian countries and Australia, amongst others (Dennis, 1998).

These initiatives, in addition to nationally funded ones, have generated a large amount of literature on the causes, patterns, and impacts of fires. The studies indicate that most wildfires originate from fires used for land preparation purposes, and suggest major policy changes in land use and natural resource management. The majority of these publications, however, focus on qualitative or biophysical issues. Apart from some studies conducted after the major fires of 1997/98, very few discuss the economic aspects of the fires. The apparent consensus about the devastating impacts of wildfires is so strong, that the costs and benefits of the use of fire, which is at the root of the problem, have been overlooked.

Most people agree that those uncontrolled fires are a disaster of exceptional magnitude, with adverse environmental effects on Indonesia and its neighbours, which should be prevented at all costs.

Fire has always been part of the Indonesian landscape and society as a tool in land clearing, a weapon to solve conflicts, and as a hazard when it gets out of control (Tomich *et al.* 1998a). Most Indonesians who are below 25 years of age have lived with repeated fire and haze episodes since their childhood. In 1998, a foreign journalist interviewed villagers in East Kalimantan who, amidst a blinding and choking haze, told him: *"the fires and smoke have always been there, they keep coming back every few years… we're used to it."*[1] . In a country where millions of people drink unsafe water or commute two hours a day on motorbikes behind vehicles discharging diesel fumes, two months of haze every three years is perceived as a minor problem.

Likewise, many government and private sector leaders used to be no more concerned with the fires than with the numerous other environmental and human costs that accompanied the development of the country. As Potter and Lee mentioned: *"'Development' in Indonesia has for long been read as 'Development at all costs'."* (Potter and Lee, 1998, in Bompard and Guizol, 1999).

[1] D. Liebhold, pers. comm.

The situation started to change after the 1997/98 fire, which dwarfed preceding outbreaks, and coincided with dramatic political changes in Indonesia. Many organisations started airing their concerns for the environment. While the fires had for long been blamed officially on natural causes and shifting cultivators, internationally funded projects using satellite data, including FFPMP-JICA in Bogor and Jambi, IFFM-GTZ in Samarinda, FFPCP-EU in Palembang, and ODA in Palangkaraya, established that fires started by large private companies to clear their land were the main culprits in creating haze (Byron and Shepherd, 1998; Ellen and Watson, 1997). Meanwhile, nearly everyone in the country had been directly affected in one way or another through the destruction of forests and plantations, disruptions in air and maritime transport, or indirectly, through the negative image of being the cause of the massive haze that afflicted neighbouring countries.

As a result, more stakeholders are now ready to put some efforts into preventing fire losses in Indonesia. Yet not all may believe that fires should be avoided *at all costs.* Some may still consider, even if they would not admit it publicly, that fires may be a *price to pay for economic growth.* Many, perhaps, will still use fire if they benefit from it, leaving it to others to bear the costs.

Without accurate and convincing information, not much may be done to prevent a new large fire episode during the next extended drought or El Niño.

It is therefore more imperative to have financial and economic assessments to back-up claims for changes in policy and practices. Even in a wealthy country like the United States, a considerable amount of research is devoted to the economics of fire management. Before spending money on fire control, the authorities need to establish the point at which it is preferable to prevent a fire rather than to accept its costs (Rideout and Omi, 1990; Butt, 1995).

Today, a few good studies conducted after 1997/98, especially those by Badan Perencanaan Pembangunan Nasional (BAPPENAS)/Asian Development Bank (ADB) (BAPPENAS, 1999a and b) and the Economy and Environment Program for South East Asia (EEPSEA)/WWF (Glover and Jessup, 1998 and 1999), have provided a better account of the economic costs of the forest fires. Yet more needs to be known about the costs and benefits of using and managing fire. Information on the costs of responsible use of fire, alternatives and how they can be promoted to make them financially attractive, and who pays the price when fire is used irresponsibly are still missing. Decision-makers need such information especially during an economic crisis to help them set priorities. Without accurate and convincing information, not much may be done to prevent a new large fire episode during the next extended drought or El Niño, which may reappear in 2002.

1.1. What we know, what we don't

The numerous studies conducted after the last fires, especially since 1997/98, have yielded a number of widely accepted results, which are used as the basis of this review.

1.1.1. The fires behind the smoke

When discussing the impact of the fires, a distinction between the haze and the fire itself should be made.

What drew global attention to the Indonesian fires is the transboundary haze, i.e. thick smoke from Sumatra and Kalimantan that was carried by winds to southern

Thailand, Malaysia, Singapore, Brunei and southern Philippines. The haze lasted for several weeks and exacted a huge economic toll due to disrupted transport and the effect on health (Glover and Jessup, 1999). It severely damaged the image of Indonesia in the eyes of tourists and investors.

Part of the haze originated from large-scale land clearing fires burning vegetation on dry land. However, most of it came from peat fires (Anderson *et al.,* 1999). Escaped fires used for clearing peat swamps may remain active underground for months or, in the case of coal, even years, presenting a major suppression problem (Cossalter and Cauvin, 1998; Nicolas and Beebe, 1999a; Nicolas and Bowen, 1999).

The 1997/98 hazes was a regional phenomenon, affecting 70 million people in several countries across South East Asia, both in the short and long term. While those who caused the haze might have escaped immediate consequences or suffered none at all, local stakeholders bore more instant and significant losses, depending on the kind of vegetation damaged. When fire strikes agricultural land, the social and economic effects are very direct: crops and plantations are destroyed. For companies, it amounts to a destruction of assets, for farmers, it may mean the loss of their livelihood (Mayer, 1989). When forest or grassland burns, entire communities ultimately may be affected by the resulting environmental degradation, through impacts on water cycles and soil fertility.

The most comprehensive economic impact study of the fires estimated the costs at US$ 9.3 billion for the 1997/98 fires (BAPPENAS, 1999b). What is still unknown is the local impact: the impact by region and, perhaps more importantly, by category of stakeholders. This information is needed to reach decision-makers who, in Indonesia, are increasingly found at the local level.

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1.1.2. The hands behind the fires

The studies on the causes of fires indicate that nearly all fires in Indonesia are anthropogenic in nature, generally for land management purposes (land clearing for agriculture, grazing, fishing, or hunting). Controlled small-scale fires (below 100 ha) have little or no adverse impact, but large-scale fires, besides causing more smoke, are more difficult to manage and control.

The impact of the large, damaging 1997/98 wildfires that escaped the intended boundaries was magnified by the long drought and the presence of large quantities of fuel in a landscape affected by two decades of rapid change. Logged-over forest concessions with combustible wastes, young timber plantations of semi-deciduous species invaded by scrubs, and *Imperata cylindrica* grasslands resulting from large land clearings with no weed control, especially in transmigration areas, provided ready fuels for fires.

Several fires were also intentionally lit or allowed to escape as a weapon in land conflicts (Tomich *et al.,* 1998a) – either, allegedly, by large companies wanting to force farmers to accept a lower price for land they wanted to buy (Gouyon, 1999a) or by farmers seeking revenge on large companies or other parties they felt had unfairly acquired land they considered as theirs (ASB, 1998). In some cases, land-use policies may have provided a perverse incentive to large-scale fires, which accelerated the destruction of forests, and made it easier for officials to convert forestland to agricultural uses (Bompard and Guizol, 1999).

Clearly, the fires were caused by a combination of factors. One challenge is how to use this knowledge to predict the areas at risk during the next El Niño.

1.1.3. The fires during the next El Niño

Wildfires and haze are of relatively minor significance during average years (Bowen *et al.*, 2000). During a normal year, burning can in fact be a challenging task when vegetation has high moisture levels. In 1997/98, some large companies appeared to have made use of the long drought to clear more extensive tracts of land. Unfortunately, during long droughts, often but not always linked with El Niño, fire control is more difficult.

El Niño conditions occur on average every 4-7 years, and it is suggested this frequency appears to have been increasing during recent decades (Armanto and Widayana, 1998). Scientists have been anticipating the next El Niño event to happen in 2002. Unfortunately, their early warnings are not generating enough interest or concern as the memory of the previous one fades.

Wildfires and haze are of relatively minor significance during average years. During a normal year, burning can in fact be a challenging task when vegetation has high moisture levels.

Due to the economic and political crisis, and despite the donor support, few practical changes have been made to prevent the re-occurrence of large wildfires in Indonesia. The next El Niño will certainly result in a fire and haze event, but how large and damaging it will be depends on two factors: fire hazard (existing fuel load) and fire risks (sources of ignition).

International projects like the Integrated Forest Fire Management Project (IFFM) in East Kalimantan, the Forest Fire Prevention and Control Project (FFPCP) in South Sumatra, the JICA initiative and the Canadian International Development Agency (CIDA) Southeast Asia Regional Fire Danger Rating System (FDRS) contributed considerably to map fire hazards. In particular, they have identified the areas, which have burnt in 1997/98, which are hence degraded and at great risk to burn again. Degraded peat swamp forest is particularly vulnerable (Anderson and Bowen, 2000). Since there are more degraded forest areas (logged or damaged) than in 1997, the fire hazard may actually be greater now. The situation might be worse due to logging activities and the expansion of agricultural land into peat swamp forest.

There is even more uncertainty about the sources of ignition. When El Niño struck from 1982 to 1998, Indonesia was undergoing rapid forest exploitation and land conversion, especially to oil palm and timber plantations. In 1997, for example, 266,000 ha were planted with oil palms (Casson, 2000). This development was fuelled by abundant capital in an economy that expanded annually by 7%, and by booming palm oil and paper pulp prices. Obtaining large tracts of land was easy, under the rules and practices of the time, which included corrupt activities. Land ownership claims by local people were ignored in most cases.

The political and economic context has changed since then. From a high US$ 626 per tonne in mid-1998, the price of crude palm oil (CPO) has fallen below US$ 200 in the beginning of 2001 (Sargeant, 2001), close to the US$ 170-180 standard production costs for palm oil. This is an unusually serious crisis in an industry subject to fluctuating prices, usually between US$ 200 and 1,000 per tonne (Hamilton, 1998). In 1999, planting programmes were down to 177,000 ha (Casson, 2000), and some believe that they may be lower now.[2] Likewise, paper pulp prices have declined after

[2] G. De Taffin, pers. comm.

a short-lived peak to US$ 900 per tonne in 1995 and a brief recovery to US$ 700 per tonne in 2000 they have been on the decline again until December 2001 (Equity Research Associates, 2002).

As a result of the dismal financial condition of all Indonesian conglomerates, Malaysian companies have acquired and now own 1.2 million out of the 3.3 million ha of oil palm plantations in Indonesia (Tropis, 2001). Yet they may not be investing in plantations, as long as commodity prices are low and finances are tight.

Besides poor commodity prices and scarce finances, conflicts with small-scale farmers are another reason behind the slowdown of the planting programme. With the decentralisation and democratisation in Indonesia, villagers near large plantation companies have voiced their claims for compensation arising from past land acquisitions by companies. Plantation managers are pressured by villagers asking for compensation for real or alleged wrong doings, and prefer to solve the existing conflicts before extending planted areas. Potentially, should the prices of CPO rise to US$ 500-600 again and should the political environment be conducive, companies may be tempted to resolve these conflicts and resume planting.

Before 11 Sept 2001,[3] everybody expected the CPO and other commodity prices to rise in 2002. With the deepening of the world economic crisis, it seems that the CPO price may remain low throughout 2002, subject to the usual uncertainties of international commodity markets.

Another changing element is the emergence of small-scale investors. Before 1997, tree planting was conducted either by very large companies planting tens of thousands of hectares, or by very small-scale farmers owning an average 2 to 10 ha. In Sumatra and Kalimantan, there are now more middle-size developments belonging either to local entrepreneurs or to groups of wealthy farmers pooling their resources.[4] They typically develop between 100 and 10,000 ha at once. They are particularly active in shrimp and fishpond development in the swamps. However, the exact magnitude and pattern of this development and its likely impact on fire risks are unknown.

Precise information on the planting programmes and activities of commercial plantation developers is also incomplete because most companies do not reveal their plans. They may overstate planting rates to retain land rights and boost shareholders' confidence, or they may conceal actual planting activities to avoid being caught using fire or clearing land in disputed areas. However, evaluating the fire danger and taking preventive measures require updated knowledge of the trends in land-use changes that may impact fire risks, especially oil palm planting, Hutan Tanaman Industri (HTI – industrial timber plantation) expansion and other agricultural activities. These data should be collected for priority fire-prone areas, especially those that have burnt in 1997/98 and the peat swamps.

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[3] On September 2001 the United States was hit by terrorist attack, which led to the death of thousands of people, the demolition of the World Trade Center building and damage of the Pentagon building. It affected very much the global economy, including commodity prices in the world market. However, during the finalization of this review in April 2002, it seems that the world crisis does not seem to be deepening at this stage. There is a talk of recovery, particularly in US and Europe.

[4] H. Simanjuntak, Director of Plantation Protection, Indonesian Ministry of Agriculture, pers. comm.

What is known is that careless use of fire for agricultural development in the proximity of degraded fire-prone vegetation is a recipe for disaster. The locations of fire-prone vegetation are also well documented. What remains unknown is where development and high fuel loads coincide. Information about users and locations of fire should also be available. All these details are urgently required before the advent of the next El Niño so that prevention activities can be planned with local stakeholders.

1.1.4. To burn or not to burn?

Careless use of fire for agricultural development in the proximity of degraded fire-prone vegetation is a recipe for disaster.

One course of action and the most likely to have immediate effects is to encourage the users of fire to prevent wildfires. They can do so in two ways, either by resorting to other means of land clearing, or by using fire in a responsible and controlled way. It is therefore important to identify these users. Basically, they can be grouped in two categories, i.e. small-scale farmers and commercial operations (from middle-size ones to conglomerates).

Commercial operations can choose to use alternative methods, such as 'zero-burning', for land clearing. These methods are well developed in Malaysia where they have become the norm for second rotation and much forest clearing. The leaders of the industry in Indonesia claim that they are practising zero-burning as well, but the majority of plantation managers and contractors have yet to be persuaded that this is cost-effective. Hence, Chapter 2 will compare burning versus zero-burning method for land clearing by commercial companies, with emphasis on the financial aspects. The discussion will encompass all the incremental costs and benefits of using fire versus zero-burning, taking into account land clearing and land immobilisation costs,[5] fertilisation, crop protection and yield.

The comparison will be extended to small-scale farmers, albeit a limited version for two reasons. Firstly, there are few practical alternatives other than burning available to these farmers. Secondly, the fires in these cases are usually confined in scale and cause minor damages, with a few exceptions such as *sonor* swamp rice in southern Sumatra.

Another point considered in this review is the costs and benefits of using fire in a responsible manner, i.e. the costs of fire management, which includes the probability of fires escaping and resulting damages. The costs of risking wildfires and paying the consequences (e.g. claims by affected communities, fines, negative image) will have to be weighed against the costs of implementing a fire control system, as presented in Chapter 3.

The economic impact on other stakeholders, apart from the users of fire, is addressed in Chapter 4, to be followed by comments and recommendations for follow-up studies in Chapter 5.

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[5] Land immobilisation costs are costs that accrue when land is left idle, i.e. unproductive. This aspect may be important for comparing burning versus zero-burning practices, as the latter does not require a waiting period for residues to dry before they can be burned.

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The financial analysis of fire use can be conducted using a cost and benefit analysis (CBA) matrix, computing the net present value (NPV) of a given land management system using fire, and comparing it with alternatives. The prices are based on prevailing market rates. The simplest method consists of calculating the incremental costs and benefits of using fire versus zero-burning.

The main difficulty is the identification of alternative methods of land use or livelihoods. This means looking at the next best alternative if a land manager does not use fire. The discussion is obviously different for large companies with greater financial resources to access and purchase land at national or international market rates than small-scale farmers with limited cash and land.

Actors were grouped into two categories according to access to resources for land clearing. *The first category*, commercial plantations, includes three scales of ownership with relatively similar cost structures for land clearance:

- Large-scale plantation companies (above 10,000 ha), often owned by local or international groups or conglomerates: The law forbids them to use fire for land clearing. However, it is poorly enforced and many companies continue to burn, as National Oceanographics and Aeronautics Administration (NOAA) satellite analysis indicated. In Indonesia, most cases of land clearing by large companies are for the development of oil palm or HTI of fast growing species. Until 1998, these companies could acquire large tracts of land cheaply. They could access capital at, or even below, international market rates, especially through programmes subsidising interest to nucleus-outgrowers schemes, in which the company developed smallholder plantations around its own. Under these schemes, they could benefit from cheap transmigrant labourers. Nowadays, the situation has changed and these companies have to face conflicts over land rights, and tight capital access.
- Middle-size plantations (from 1,000 to 10,000 ha) belonging to individuals or local companies: These are mainly oil palm plantations, shrimp and fish farms. Before the crisis, their development was rather limited or overshadowed by that of large conglomerates. They have since increased in size, especially where land is becoming scarce. They depend on domestic finance, often partly on their own equities, and local labour.
- Groups of wealthy farmers (landowners controlling more than 20 ha per family) pooling their resources together to clear the land (usually between 100 and 1,000 ha): This has always existed but is becoming more common, especially for oil palm plantations, shrimp ponds and fish farms. Their access to finance is more restricted than the previous groups, but they are still able to use their own funds and financing from local banks.

Although the stakeholders of the three categories may access land, capital and labour at slightly different rates, they share the same capacity to obtain relatively large tracts of land, and to mobilise capital for funding land development and hiring large numbers of labourers. Thus, they are able to use heavy machinery instead of fire to clear land, either on their own or through contractors. To simplify the process in this review, the CBA is assumed to be similar for a large company, a middle-sized company or a group of wealthy landowners. Subsequent studies may need to examine the three categories in greater details.

The second category, with markedly different access to resources, comprises the small-scale farmers, developing land individually or in small groups clearing less than 20 ha together. They use fire systematically to clear land for cash and food crops, fishing, hunting or grazing. They depend a lot on unused and unclaimed land within their village boundaries. Clearing land and planting crops, preferably perennials, is the only secure way for them to claim land tenure. Family or locally recruited workers are employed to work on the farms. Capital is a main constraint, forcing them to rely on their own limited funds, or to borrow money from private lenders or sometimes from local banks at high interest rates and limited time periods.

2.1. Fire versus zero-burning in commercial plantations

2.1.1. The history of zero-burning

Zero-burning methods of land clearing were first developed on a commercial scale in Malaysia, following the enactment of its Environmental Law in 1974, strengthened by the Environmental Quality (Clean Air) Act in 1978, which was again reinforced in 1998. It prohibits open burning and imposes a maximum fine of RM 500,000 (US$ 190,000)[6] and/or five years of imprisonment.

The literature of zero-burning in Malaysia is mostly based on experiences of a few leading companies, such as Mentiga, Harrison & Crossfields, United Plantations or Golden Hope, which has received a UNEP Global 500 Award for its environmental record. Some of these companies are active in Indonesia. Leading Indonesian tree crop companies that are known for using zero-burning routinely include P.T. London Sumatra (Lonsum), Sinar Mas and Socfindo.[7]

A review of the Malaysian literature provides insights into the changes in land clearing methods following the enactment of the Environmental and Clean Air Acts and the general structural evolution of the sector. Articles dating back to the 1960s and 1970s presented 'clean clearing and burning' methods, with no mention of zero-burning. In the early 1980s, the advantages of burning was still advocated by some (Ling and Mainstone, 1983). In the late 1980s and 1990s, zero-burning and 'clean clearing and burning' were compared in numerous papers, with the intention to make a case for zero-burning (see for example Rosenquist, 1987; Ramli, 1997 and 1999; Hashim *et al.,* 1993; Jamaluddin *et al.,* 1999). Recent papers, from the late 1990s and early 2000s, discuss only zero-burning methods, since it is now so widespread that comparisons with burning methods seem pointless. In fact, zero-burning has become the standard method for land clearing in the Malaysian plantations, at least for replanting purposes (see for example Ho and Chiang, 1999; Loh and Sharma, 1999; Ooi *et al.,* 2001).

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[6] US$ 1.00 = Malaysian Ringgit (RM) 2.63 (1998)

[7] J.C. Jacquemard, CIRAD, pers.comm.

2.1.2. Financial analysis of zero-burning in plantations (oil palm and timber): Methodology

The comparison of the costs and benefits of burning and zero-burning for commercial oil palm plantations takes into account several cost components: land clearing, plantation management, fertilisers, crop protection. It also considers yield differences. While the differences in costs of land clearing operations are well documented, there is less quantitative information on other aspects of plantation management.[8]

Even less available are published economic data about zero-burning from industrial timber plantations. Information on land clearing costs was mostly obtained through interviews with practitioners and experts. A few good studies, especially by GTZ and Deutsche Forschung Gemeinschaft (DFG) (see for example Ruhiyat, 1989; Mackensen, 1999; Mackensen and Foelster, 1999; Simorangkir and Mackensen, 2001), have documented the fertiliser needs and costs for HTIs in Indonesia. They were used to estimate fertiliser costs for timber plantations that practise zero-burning.

To compare data from different years using currencies (mostly US$, RM and Rp) that have fluctuated significantly since 1997, all currencies were first converted to US$ using the average parity for the year when the data were obtained. Then they were adjusted the match the US$ rate for the year 2000, using the US inflation rate as the deflator. This method was not applied for 1998 data from Indonesia, because during that year the currency's parity fluctuated so much that the average exchange rate is meaningless. Fortunately, no figures for 1998 from Indonesia were used; due to the crisis, not much land clearing has taken place since, and most of its data date back to 1997. Currency conversion rates are shown in Table 1.

Table 1: Exchange rates and price indices used for the calculations

Year	Exchange rate RM/US$	Exchange rate Rp/US$	US$ price index
1993	2.57	-	0.84
1996	-	2,500	0.91
1997	2.82	2,903	0.94
1998	3.93	10,285	0.96
1999	3.80	7,876	0.97
2000	3.80	8,415	1.00

In all cases, when using data from different sources, differences in locations, types of vegetation cleared, years and cost structures are considered. Preferences are given to data showing a clear comparison of zero-burning versus burning on the same site. Comparing the cost of land clearing using burning on one site with the cost of non-burning on another site is more risky given the variations in unit costs, methods used, vegetation, terrain, and other factors.

[8] Most data were derived from Malaysian companies. They may be biased to some extent to promote zero-burning efforts. Input and advice from independent experts was sought to verify the data.

The calculation was done in several steps. First, the direct costs of land preparation (from the felling of previous vegetation until the land is ready for planting) using fire and non-fire methods are determined based on data from Malaysia and Indonesia. Then, these data are extrapolated to compute the more uncertain and sketchy information about land immobilisation, material inputs and yield over the first five years of the plantation development.

2.1.3. Comparison of direct land clearing costs

2.1.3.1. Types of terrain and vegetation

The main difficulty in estimating the relative cost of zero-burning is that cost depends on the type of terrain and vegetation cleared.

Three main types of terrain can be found: relatively flat dry lands, hilly terrain and peat swamps. The relative cost of zero-burning is much higher in hilly terrain and peat swamps because it is more difficult and time consuming to use heavy equipment.

Four main types of vegetation are involved:

- grasslands/scrublands;
- replanting (clearing plantation crops like rubber or oil palm);
- light/low-volume forest, i.e. secondary forest or heavily logged primary forest; and
- heavy/high-volume forest.

Grasslands and scrub are no longer burnt, but cut or eradicated by herbicides, especially in the case of *Imperata cylindrica*, since cutting and burning will only trigger its regrowth.

Over-mature rubber trees and oil palms are removed, with zero-burning as the favoured method, to replant the area with new crops. The amount of biomass is limited to 90 t/ha at most (see below), and part of it can be exported. In Malaysia, where a lot of oil palm replanting is taking place, trunks are increasingly being used in chip or pulp factories. Exporting the trunks provides immediate monetary returns, and reduces the cost of subsequent clearing operations. It also reduces the problems of pest infestations common in zero-burning areas. The only drawback is the reduced quantities of nutrients from the decaying biomass, but this is clearly offset by the value of the trunks and the savings in windrowing operations and pest control. The same technology may be used in Indonesia when replanting will start on a large scale in a few years from now, especially in North Sumatra.[9]

The amount of biomass in rubber plantations is important (200 t/ha) but half of it can be exported: rubberwood can be sold for at least US$ 400 per ha on average, and often reaches US$ 1,000 per ha (Gouyon, 1999b). The remnant branches can be windrowed and stacked, then reduced manually (using a chainsaw) or burnt. Burning is considered necessary to reduce the risk of fungal root diseases (especially *Fomes lignosus)*. Fires are limited in heat and duration and can be easily controlled.

[9] J.C. Jacquemard, CIRAD, pers.comm.

2.1.3.2. Zero-burning for replanting

Table 2 shows a comparison of land clearing costs for replanting oil palm in Malaysia, one with fire use and the other one with zero-burning technique. The data have been collected from the Golden Hope Plantations in 1993 and 2001.

Table 2: Cost of burning versus zero-burning for replanting oil palm, Malaysia (in year 2000 US$/ha)

	Hashim *et al.*,1993		Yow and Jamaluddin, 2001	
	Burning	Zero-burning	Burning	Zero-burning
Pre-lining/Block design	-	16	-	-
Felling/ Shredding/Stacking	213	266	203	255
Burning or restacking	104	-	39	-
Total before planting	317	283	242	255
Ploughing	83	93	-	-
Lining/Holing/Planting	74	88	126	140
Total after planting	475	463	368	395
Difference in US$ (%)	- 12 (-2%)		27 (7%)	

Sources: Hashim *et al*., 1993; Yow and Jamaluddin, 2001

The figures show a reduction in land clearing costs within eight years as a result of increasing efficiencies in field operations and technique improvements. Moreover, the comparison between both methods support the view indicated above, that zero-burning is not significantly more expensive — and can actually be cheaper — than burning when replanting oil palm.

The comparison between burning and zero burning supports the view that zero burning is not significantly more expensive and can actually be cheaper – than burning when replanting oil palm.

2.1.3.3. Zero-burning for forest clearing

The most controversial case in the use of zero-burning is when forest, especially high-volume forest, is cleared. This is where the mechanical treatment of the biomass is the most difficult, lengthy and costly. It always leaves behind large windrows, which hamper access to the site for planting and maintenance operations.

Table 3 illustrates the differences in land clearing costs for each vegetation type in Indonesia (see also Sargeant, 2001). In many cases, while the type of soil (mineral/organic) is usually indicated, most authors did not specify the type and volume of vegetation cleared, making it very difficult to generate and compare the data.

The costs of land clearing by burning are shown in Table 4. Under a typical mineral soil condition, the additional cost of clearing forest or scrubs without burning is about US$ 50 per ha. These figures can be compared with site comparison of costs of burning versus zero-burning obtained from various sources in Malaysia and Indonesia (Tables 5 to 7)

Table 3: Costs of zero-burning land clearing in Indonesia (in US$/ha)

	Mineral soils					Peat soils	
	Heavy forest	Light forest	Scrub-land	Grass-land	Hills	Dry	Wet
Manual (felling/slashing)	-	-	20	-	20	20	20
Mechanical (bulldozer/excavator)	180	150	-	-	236	220	260
Chemical (herbicide)	-	-	-	65	-	-	-
Total	180	150	20	65	256	240	280

Source: Wahyu Ahmad Pribadi, data presented at a Workshop on Fire Management, Palembang, South Sumatra, 24-25 October 2001.

Note: Converted from Rp at the rate of US$ 1.00 = Rp 10,000. The cost of road construction and drainage (US$ 160 per ha) is not included.

Table 4: Cost of land-clearing by burning on mineral soils in Indonesia (in US$/ha)

	Heavy forest	Light forest	Scrub/grassland
Slashing (manual)	32	32	29
Felling (manual)	41	14	-
Stacking (manual)	-	30	-
Burning	5	3	2
Cleaning (manual)	24	24	6
Weed control (chemical)	-	-	32
Total	131	102	68

Sources: Compiled from Levang (1991) and Penot, CIRAD, pers. comm.

Note: All costs of manual operations are based on a labour cost of US$ 1.50 per day. Weed control includes 6 days of labour plus 5 litres of glyphosate at Rp 45,000 (US$ 4.50) per liter.

The difference between burning and zero-burning in a heavily logged forest — hence equivalent to a 'light forest' — is US$ 33 to 39 (Table 5). The data are from Golden Hope, a company that has been developing zero-burning since the 1980s, and has adopted it as a standard practice since 1989. This table also highlights that land clearing is more expensive in Malaysia than in Indonesia. All operations are conducted mechanically to offset the higher labour costs. This reduces the incremental cost of zero-burning, since heavy equipment is used in all cases.

Table 5: Cost of burning versus zero-burning for planting oil palm on logged-over forest, Malaysia (in US$/ha)

	On peat soils		On mineral soils	
	Burning	Zero-burning	Burning	Zero-burning
Felling/Stacking (Mechanical/Excavator)	244	298	209	263
Burning/Restacking	30	-	23	-
Total before planting	274	298	232	263
Lining/holing/planting	132	140	74	82
Compaction	115	115	-	-
Total after planting	521	554	306	345
Difference in US$ (%)	33 (6%)		39 (13%)	

Source: Jamaluddin *et al*., 1999.

Table 6 provides comparative data for clearing land in 'heavy forest' with and without burning in Indonesia. The cost of using a tractor after cutting and chopping scrub and trees is much higher — an additional US$ 68 to 117 per ha, or a 44 to 70% increase — than the cost of burning. Furthermore, all the costs for oil palm plantations are higher than those for HTI, because they need more open planting areas and better access than timber plantations.

This table also indicates that costs are very site-specific. In East Kalimantan, for example, the cost for cutting and chopping of scrub/underbrush and trees is less than in Riau, because of lower labour costs. Moreover, the company in East Kalimantan conducted its own clearing, while the company in Riau hired a contractor. However, the cost of collecting, piling and clearing residues using tractor is higher in East Kalimantan than in Riau due to the higher operational cost of a tractor, and possibly the different volume of vegetation.

The cost for land preparation in a peat-swamp can be much higher than on dry land; sometimes the area has to be burnt several times. In a study conducted by a concession company in West Kalimantan, land was prepared for a rubber plantation in a logged-over area — originally a peat-swamp forest with a very heavy logging history, which left a secondary forest in poor condition— with a lot of scrub/underbrush and timber residues (Table 7). The company had to burn the area twice, the first time after the scrub/underbrush and trees were cut and hacked, and the second time after the residual of the first burning was collected and piled. Mechanical clearing of the vegetation was three and half times higher than burning.

Table 6: Cost of burning versus zero-burning for HTI and oil palm in 'heavy' forest on mineral soil (in US$/ha)

	HTI			Oil Palm	
	Burning	Zero-burning		Burning	Zero-burning
Province	Riau	Riau	East Kalimantan	Riau	Riau
Cutting of scrub/ underbrush (manual)	27	27	16	54	39
Cutting of trees (chainsaw)	38	38	33	144	57*
Chopping/hacking branches, logs, end logs, etc. (manual)	15	15	9	54	43
Burning	16			12	
Collecting/piling scrub, logs, end logs, etc. and clearing wastes		84	268		242
Total (US$, year 2000)	96	164	326	264	381
Difference in US$ (%)	68 (70%)		-	117 (44%)	

Sources: P.T. PSPI, P.T. KLI, Sinar Mas (unpublished).

* The cost for cutting of trees for oil palm 'burning' is much more expensive than 'zero burning' and therefore seems not plausible. It could only be explained that the area for zero burning has already been logged several times (before cleared) so that there were lesser trees to cut compared to the burned area.

Table 7: Cost of burning versus zero-burning for HTI in peat swamp forest, West Kalimantan (in US$/ha)

	Burning	Zero-burning
Cutting of scrub/underbrush (manual) and trees (chainsaw) — Chopping/hacking branches, logs, end logs, etc. (manual)	90	90
Burning I	9	
Collecting and piling scrub, logs, end logs, etc. and clearing of other wastes	73	727*
Burning II	9	
Total (US$, year 2000)	180	817
Difference in US$ (%)	637 (353%)	

Source: P.T. Alas Kusuma (unpublished)

* In fact, under peat swamp forest conditions burning remains much less expensive because it is more difficult, time consuming and costly to dispose of high volumes of piled wood mechanically. However, the figures show 'too' big difference between both methods. Further investigations couldn't give any explanation for the difference.

2.1.3.4. Conclusion

Zero-burning on mineral soils increases land clearing costs by US$ 50 to 150 per ha in comparison to burning. Cost differences between the two practices are highest on peat soils and when high vegetation volumes need to be removed. The additional cost of zero-burning is generally higher in Indonesia than in Malaysia, due to lower labour costs in Indonesia.

2.1.4. Effect on land immobilisation and planting operations

Data from Malaysia include an additional parameter, i.e. the cost of longer land immobilisation when burning, or reduced fallow due to zero-burning. Some companies, like Golden Hope, claim that with zero-burning, the time needed from the felling of the vegetation (whether logged-over forest or oil palm) to the first planting operations can be reduced by eight months, because there is no need to wait for the vegetation to dry before burning. Adding the net value of oil palm production (value of the fruit bunches minus harvesting costs) during eight months to the benefits of zero-burning makes burning a more expensive alternative (Table 8).

Zero burning on mineral soils increases land clearing costs by US$ 50 to 150 per ha in comparison to burning. Cost differences are highest on peat soils and when high vegetation volumes need to be removed.

Table 8: Benefits of reduced fallow time with zero-burning in Malaysian oil palm plantations (in year 2000 US$/ha)

Previous vegetation and year	Methods	Cost of land clearing	Value of reduced fallow*	Total cost + value	Difference (zero-burning – burning)	
					US$	%
Oil palm, 1993	Burning	475	475			
	Zero burning	623	644	-21	-496	-104
Oil palm, 2000	Burning	564		564		
	Zero burning	636	82	554	-10	-2
Logged-over forest, peat, 1999	Burning	521		521		
	Zero burning	554	90	464	-57	-11
Logged-over forest, mineral soil, 1999	Burning	306		306		
	Zero burning	345	136	209	- 97	-32

* Value of fresh fruit bunches (FFB) produced during 8 months, minus harvesting costs (Golden Hope)

Land immobilisation costs are less important in Indonesia. Oil palm is often planted in areas with a relatively intense dry season, where the optimal date of planting is determined by the start of the rainy season. In such cases, zero-burning cannot accelerate planting. Since the cleared vegetation is usually logged-over forest or scrubland, there is no additional oil palm production to be gained by starting the felling operations later either.

Indeed, data from the Table 6 contradict the common experience in Indonesia, where burning normally requires less time for land preparation than zero-burning. Drying felled vegetation usually takes about four months in Indonesia, as opposed to the eight months in Malaysia. Moreover, when clearing high volumes of vegetation, the time needed to stack and windrow the debris can be extremely long.[10] The benefits of a reduced fallow period in Indonesia will not be applicable for these reasons, which makes zero-burning look less costly than it really is.

Unlike burning, zero-burning is not dependent on the weather, another advantage. If the dry season is too moist, burning can become a difficult operation, and the degree of the burn is a key factor influencing the productivity of crops planted after slash-and-burn. Indeed, in countries like Papua New Guinea (PNG), the lack of a clear dry season makes zero-burning essentially, and the practice has been refined in PNG by London Sumatra.[11] During exceptional long droughts, the use of fire can also become problematic because of the risks of wildfires. A further advantage of zero-burning is that planting activities can be combined and conducted with land preparation activities.

The main positive effect associated with burning is that it leaves a 'clear', 'clean-looking' field for subsequent operations. Plantation managers tend to shun the 'unclean', 'messy' look of plantations after zero-burning, with the piles of dead vegetation between planting rows. Indeed, resistance by plantation managers used to burning is one of the main constraints in adopting alternative methods (Ramli, 1997). However, this is more a matter of habit, training and culture. In the long run, plantation managers trained in zero-burning will become comfortable with it.

The paradox of luxuriant vegetation growing on infertile soils is very striking and has sometimes led to the misconception that soils under tropical rainforest are very fertile

2.1.5. Effects on soil fertility and availability of nutrients

The issue of soil fertility and nutrients availability after slash-and-burn or alternative methods of land clearing has received a lot of attention (see for example Schelhaas *et al.*, 1984; Thurston, 1997; Tomich *et al.*, 1998a; van Noordwijk *et al.,* 1998). Fairhurst reviewed the availability of nutrients after burning and zero-burning (Appendix 2). His findings and the summary of two studies on nutrient management in industrial timber plantations — one in Belem-Para, Brazil (Klinge *et al*., 2001) and the other in East Kalimantan, Indonesia (Mackensen, 1998; Mackensen, 1999; Mackensen and Foelster, 1999; and Simorangkir and Mackensen, 2001) (Appendix 3) — are used as a basis for the calculations below.

The paradox of luxuriant vegetation growing on infertile soils is very striking and has sometimes led to the misconception that soils under tropical rainforest are very fertile. In fact, the rainforest can grow on very nutrient poor soils because it has a closed nutrient cycle and can use the available nutrients very effectively (see for example Lamprecht, 1986). In the short term, fire is an efficient means to convert nutrients contained in the standing biomass into nutrients available to the crops that would otherwise grow only poorly.

Zero-burning has a positive effect on soil properties such as pH, water retention, organic matter content, and nutrient contents according to much of the literature. This may ultimately lead to lower fertiliser application. However, since the nutrients from decaying wood debris left after zero-burning are released only very slowly, the benefits may not be obvious immediately. Whereas a large part of these nutrients are lost to the atmosphere or through leaching during and after burning, whatever remains is in a mineralised form, which is immediately available. This means that a plantation after zero-burning may have higher fertiliser requirements during the early

[10] De Taffin, CIRAD, pers. comm.

[11] A. Vincent, P.T. Lonsum, pers. comm.

years (year 0-2), and lower fertiliser requirements and better yields later (Chandler *et al*., 1983; Pritchett and Fisher, 1987;). Klinge *et al*. (2001), on the other hand, have shown that slash-and-burn did not improve the soil fertility of plantations significantly, but created negative balance of elements stores in the soil. Except for a slight increase in pH through the well-known 'ash-effect' for several years, almost all nutrients important for crop plants decreased over time. In the long term, it seems that the ecological and economic sustainability of plantations can only be guaranteed if the removal of biomass is minimal and the use of fire is avoided.

2.1.5.1. Value of nutrients in standing biomass

In the long term, it seems that the ecological and economic sustainability of plantations can only be guaranted if the removal of biomass is minimal and the use of fire is avoided.

Five types of above ground biomass are considered for calculating the value of the nutrients available before establishing oil palm plantations or HTIs in Indonesia:

- oil palm plantations;
- rubber plantations;
- primary forest/high-volume forest cover;
- secondary forest/light forest cover; and
- *Imperata cylindrica* grasslands.

For all vegetation types, the amount and nutrient concentration in the standing biomass is strongly influenced by soil fertility and management practices. Generally, forest, rubber and oil palm standing biomass contains large amounts of nitrogen (N), phosphorous (P), potassium (K), calcium (Ca) and magnesium (Mg), compared with *Imperata cylindrica* grassland (see Table 2-3, Appendix 2). The amount of biomass in secondary forest varies widely, depending on the volume of timber removed during logging.

Table 9 shows the potential economic value (in fertiliser equivalent) of the standing biomass, before it is removed or burnt, based on the calculation in Appendix 2. The potential economic value of nutrients contained in the biomass ranges from US$ 60 (*Imperata cylindrica*) to US$ 1,800 (rubber) in the following order from lowest to highest:

Imperata cylindrica < oil palm < secondary or logged forest < unlogged primary forest < rubber

The proportion of each nutrient differs substantially for each vegetation type. The value of N ranges from about 5% (*Imperata cylindrica*) to 31% (forest vegetation), while in contrast, *Imperata cylindrica* contains 36% of P but forest vegetation has only 7% of the nutrient.

Table 9: Value of nutrients in standing biomass

Value (US$/ha)						
	N	**P**	**K**	**Ca**	**Mg**	**Total**
Imperata	3	22	14	3	19	62
Oil palm	123	39	195	23	89	470
Rubber	493	273	434	254	395	1,848
Sec. or logged forest	173	38	145	53	141	549
Unlogged forest	345	76	290	107	281	1,099
Percentages of each element in the total value						
	N	**P**	**K**	**Ca**	**Mg**	**Total**
Imperata	5	36	23	5	31	100
Oil palm	26	8	42	5	19	100
Rubber	27	15	23	14	21	100
Sec. or logged forest	31	7	26	10	26	100
Unlogged forest	31	7	26	10	26	100

Source: Fairhurst, 2001 (Appendix 2).

2.1.5.2. Losses and availability of nutrients after burning or zero-burning

Nutrients are lost from the system irrespective of the method of land clearing. Losses after burning are amplified by the lack of soil cover, which results in greater rates of erosion and surface run-off. On the other hand, crop plants are unable to absorb the large amount of nutrients released by burning — even oil palm, with its high nutrient needs, requires less nutrients during the early growth period than what is released from burning unlogged forest vegetation. So significant amounts of nutrients are lost.

Analyses of nutrient availability in various types of biomass before and after burning are found in several publications (e.g. Nye and Greenland, 1964; Jordan, 1985; Rosenquist, 1987; and Schelhaas *et al.*, 1984). Based on the literature, Fairhurst estimated the nutrient stocks following land clearing (Table 2-5, Appendix 2). Using these estimations, the value of nutrients available after land clearing with burning and zero-burning can be calculated. The economic value of nutrients depends on whether part of the biomass is removed during land clearing or not (Table 10). In most cases nowadays, it can be assumed that part of the biomass will be removed. Wood from old rubber trees can be sold if road access is good (Gouyon, 1999b), and at least some of the wood in the forest will be removed for commercial purposes, especially in the HTI. In Malaysia, trunks from old oil palms are being increasingly used commercially, and the same is likely to happen in Indonesia when replanting starts on a large scale. The only case where it is unlikely that biomass will be removed is *Imperata*.

Table 10: Value of nutrients available after burning versus zero-burning (US$/ha)

Vegetation type	Quantity of biomass removed (half/none)		N	P	K	Ca	Mg	Total
Imperata	Half	Burning	0	6	4	1	6	16
		Zero-burning	1	9	6	1	8	25
	None	Burning	0	11	7	2	12	32
		Zero-burning	2	18	11	2	15	50
Oil palm	Half	Burning	6	10	49	7	27	98
		Zero-burning	43	16	78	9	36	182
	None	Burning	12	20	98	14	53	197
		Zero-burning	86	32	156	18	71	363
Secondary or logged forest	Half	Burning	9	9	36	16	42	113
		Zero-burning	60	15	58	21	56	211
	None	Burning	17	19	72	32	84	225
		Zero-burning	121	30	116	43	113	422
Rubber	Half	Burning	25	68	108	76	119	396
		Zero-burning	173	109	173	101	158	715
	None	Burning	49	136	217	152	237	792
		Zero-burning	345	218	347	203	316	1429
Unlogged forest	Half	Burning	17	19	72	32	84	225
		Zero-burning	121	30	116	43	113	422
	None	Burning	35	38	145	64	169	450
		Zero-burning	242	61	232	85	225	845

Source: Fairhurst, 2001, (Appendix 2).

The value of the nutrients left after land clearing and biomass removal is 56% higher with zero-burning for *Imperata,* 80% for rubber, 85% for oil palm, and 87% for forest. This underlines the importance of taking into account the effect of biomass utilisation and burning on the value of nutrient stocks.

It has to be stressed that the figures above are only indicative. The nutrient losses and availability depend on the precautions taken during land clearing activities. In a study of nutrient availability in soils, Mackensen (1999) found that aggressive mechanical land clearing could result in important losses of topsoil and nutrients. This means that the comparisons above are only valid if mechanical land clearing is done in a way that preserves the topsoil.

Klinge *et al*. (2001) show that burning intensity and the amount of exported and burnt residual biomass will determine the nutrient losses after burning (Table 11, see also Appendix 3). Quantitatively, the more biomass removed and burnt, the more nutrients will be lost, as shown in the comparison between two forest plots – one clear-cut and the other burnt. In Area B, where 92 t/ha of residual biomass (leaves, twigs, branches) was burnt, the loss of different nutrients was at least three times higher than in Area A where only 33 t/ha of residual vegetation was burnt, the result of the different volumes burnt. However, as a percentage of the residual store, the difference in nutrients lost was insignificant. It is important to note that much of the nutrients stored in residual biomass is lost by fire: 22-24% of P, 17% of (sodium) Na, 6-22% of K, 13-22% of Ca, 19-40% of Mg, and 62% of S. Moreover, as 91-94% and 94-95% of above-ground C and N respectively are lost to the atmosphere during the fire, additions to the soil of these cannot be expected.

The element losses were further increased by the absence of soil cover, which results in greater rates of erosion and surface run-off, and the poor root system that cannot 'capture' the released nutrients. Fifteen months after both forest areas were cleared and burnt, most of the nutrients released by burning the residual vegetation (29-38% of P, 65-67% of K, 34-36% of Ca, 69-100% of Mg, and 80-81% of S) were volatilisated and leached to deeper soil layers and therefore became unavailable for the growing vegetation. In case of N and Na, the losses even exceed the amount of released nutrients from the residues at 119-143% and 298-595% respectively. Clearing and burning the forest caused additional loss of N and Na from the nutrient stocks in the soil through increased leaching.

Some assumptions were made about the availability of nutrient stocks over a five-year period following burning (Table 12). Clearly, the benefit from nutrient stocks contained in the standing biomass is greater when the biomass decomposes instead of

Table 11: Comparison of element loss by wood export, element store in the residual phytomass and element loss by burning and leaching

	C	N	P	Na	K	Ca	Mg	S
	t/ha	kg/ha						
Plot A*								
element loss by wood export	140	1,397	46	116	688	1,397	175	206
element store in residue	16	343	9	18	109	330	37	42
element loss by burning	15	325	2	3	7	44	7	26
element loss by leaching	166	2	107	66	77	31	8	
loss by burning in % of residual store	94	95	22	17	6	13	19	62
loss (burning + leaching) in % of residual store	94	143	38	595	67	36	100	81
Plot B*								
element loss by wood export	112	828	22	65	330	712	96	160
element store in residue	46	854	29	59	392	848	100	113
element loss by burning	42	804	7	10	87	189	40	70
element loss by leaching	211	2	166	165	102	29	20	
loss by burning in % of residual store	91	94	24	17	22	22	40	62
loss (burning + leaching) in % of residual store	91	119	29	298	65	34	69	80

* 279 t/ha of biomass removed and 33 t/ha remained and burnt

** 223 t/ha of biomass removed and 92 t/ha remained and burnt being burnt, although there is considerable variability depending on agricultural and silvicultural practices. Based on studies by the Indonesian Oil Palm Research Institute (IOPRI), the pulverisation of the debris and planting of cover crops reduce the time needed for decomposition of vegetation after zero-burning significantly (Guritno, 1995).

Table 12: Percentage of the nutrients available each year

	1	2	3	4	5	Total
Burning	80	20	0	0	0	100
Zero-burning	40	30	15	10	5	100

Source: Fairhurst, 2001, (Appendix 2).

2.1.5.3. Value of nutrients released after burning or zero-burning

Table 13 shows the nutrient requirements for oil palm on mineral and peat soils from year 1 to 5. Oil palm was chosen as the reference because it has high fertiliser requirements, so any likely difference in nutrient availability will be greater.

Table 13: Needs of nutrients for oil palm in Indonesia

	Year					
	1	2	3	4	5	Total
On mineral soils, kg/ha						
N	58	68	68	81	81	354
P	27	16	19	28	28	118
K	85	125	98	122	122	553
Mg	14	21	18	28	28	109
Ca	-	-	-	-	-	
On peat soils, kg/ha						
N	45	63	55	81	81	324
P	18	17	20	32	32	118
K	101	139	122	139	139	641
Mg	66	91	94	124	124	70
Ca	144	198	204	270	270	152

Source: IOPRI (unpublished). These data are relatively similar to those mentioned in Rosenquist (1987), Ho and Chiang (1999) or Ooi *et al*. (2001) for Malaysian plantations.

The costs of fertilisers needed to complement the nutrients available from biomass after burning or zero-burning, in the case of oil palm are listed in Table 14. The level of potential savings on fertilisers, which can be obtained by not burning the remaining biomass, is also presented. Taking the most common scenario in Indonesia, i.e. clearing the forest and removing part of the biomass for commercial purposes (e.g. selling the wood), the savings in fertilisers with zero-burning range from US$ 85 to 140 per ha. This is equivalent to 20 to 40% of the fertiliser cost for oil palm during the first five years. The savings are slightly higher for mineral soils, which have higher fertiliser requirements. The higher the fertiliser requirements, the higher the potential savings – until the point when all the biomass' nutrients are exhausted is reached.

Table 14: Costs of fertilisers needed to complement biomass for oil palm on mineral soils (US$/ha)

Vegetation type	Biomass removed	Methods	Year					Total	Difference	
			1	2	3	4	5		US$	%
Imperata	Half	Burning	68	84	79	104	104	439		
		Zero-burn	70	81	76	102	103	432	-7	-2
	None	Burning	59	82	79	104	104	427		
		Zero-burn	62	75	73	100	102	413	-14	-3
Oil palm	Half	Burning	29	70	79	104	104	386		
		Zero-burn	20	38	55	88	96	296	-90	-23
	None	Burning	16	53	79	104	104	356		
		Zero-burn	13	6	31	71	88	210	-147	-41
Sec. or logged forest	Half	Burning	29	68	79	104	104	384		
		Zero-burn	28	39	52	85	94	298	-86	-23
	None	Burning	13	57	79	104	104	357		
		Zero-burn	14	17	32	67	85	215	-142	-40
Rubber	Half	Burning	-	39	79	104	104	326		
		Zero-burn	-	-	12	48	71	131	-195	-60
	None	Burning	-	11	79	104	104	298		
		Zero-burn	-	-	-	15	48	63	-235	-79
Unlogged forest	Half	Burning	-	57	79	104	104	357		
		Zero-burn	-	17	32	67	85	215	-142	-40
	None	Burning	-	36	79	104	104	323		
		Zero-burn	2	-	10	42	67	121	-202	-62

The results are only indicative. The fertiliser requirements, the actual amounts of nutrients present in the biomass and their availability after burning or through decomposition vary tremendously. However, these data support the view of the industry, i.e. that after zero-burning, lower quantities of fertilisers are needed, especially after the second year.

Similar calculations can be done for other crops. In the case of HTI, it is more difficult to evaluate the gains resulting from lower nutrient losses. Despite the popularity of industrial timber plantations, their long-term stand productivity and nutrient supply remain unknown. For this review, the results of studies in *Acacia mangium* and *Eucalyptus deglupta* stands on average plantation sites in East Kalimantan (alisols, acrisols) are used. For detailed information see Appendix 3.

To maintain site productivity despite nutrient losses, it is necessary to replenish the soil with mineral fertilisers. However, as shown by the analysis in Appendix 3, huge amounts of fertilisers are needed to compensate for the nutrients lost, and the immense amounts of fertilisers required per site pose a huge cost for plantation estates. The cost for a standard fertiliser application using 100 g NPK, 40 g TSP and 840 g dolomitic limestone per tree for a stand density of 800 trees per ha was US$ 88 per ha in 1996/97. The costs for different variants of fertilisers to replace the nutrient losses in two plantation stands, A (burning) and B (without burning), are shown in Table 15. The cost for the same fertiliser combination for A is 2,229 % higher for *Acacia mangium* or 1,256 % for *Eucalyptus deglupta*. Even under ideal circumstances, the costs to replace the total losses are 281% (for *Acacia mangium*) or 434% (for *Eucalyptus deglupta*) higher if compared with the company's current expenditure for fertiliser. In the context of this study, it is important to see that not burning can reduce the fertiliser cost to 21-41% for *Acacia mangium* and 24-50% for *Eucalyptus deglupta* stands of the current expenditure levels.

Table 15: Costs of fertilisation in case of compensation of total nutrient losses

Variant	*Acacia mangium*			*Eucalyptus deglupta*		
	A[1]	B[2]		A[1]	B[2]	
	US$/ha	US$/ha	%[3]	US$/ha	US$/ha	%[3]
Standard (NPK, TSP, dolomit)	1,962.55	1,164.37	-41	1,105.30	560.43	-50
Standard (NPK, TSP, dolomit), without NPK-N	865.76	544.34	-38			
Alternative fertilisers (Urea, TSP, potash, dolomit)	530.33	368.19	-31	499.81	382.34	-24
Alternative fertilisers (TSP, potash, dolomit), no N fertilisers	311.46	246.94	-21			

Source: see Appendix 3

* All costs related to 1996/97 (US$ 1 =. Rp 2,200)

[1] harvest volume: 200 m^3, minimal losses by leaching, burning and erosion

[2] harvest volume: 200 m^3, <u>no burning</u>, minimal losses by reduced leaching and erosion

[3] related to the costs of the fertiliser applications for burnt areas (B-A)

The costs necessary to replace the expected nutrient losses range from 9 % to 40% of the plantation total costs, depending on the species, site management and fertiliser.

In summary, replacing nutrients in intensively managed timber plantations constitutes a major operating cost. Standard fertiliser applications account for an average of 4% of the plantation's total costs, which is inadequate. The costs necessary to replace the expected nutrient losses range from 9% to 40% of the plantation total costs, depending on the species, site management and fertiliser to secure long-term nutrient sustainability. It is likely that the increase in costs is even higher since additional costs (e.g. for planning, infrastructure, research or training) are not considered in this estimation.

2.1.6. Effect on costs for crop protection

Pests and disease as well as weed control remain major problems in zero-burning operations, especially after replanting oil palms. This results in additional costs for crop protection, which is not always computed in the CBAs in the literature. Similarly, no mention of any significant differences in weed control cost with either burning or zero-burning was found in the literature. Estimations for these costs in this review are partly based on expert opinions.

Mammalian pests (rats and pigs) are not a major problem. They are a site-dependent hassle and can be controlled by using traps. The two major pests after zero-burning, especially for second rotation oil palm plantations, are the rhinoceros beetle *(Oryctes rhinoceros),* which breeds in the stacked debris, and oil palm root rot (*Ganoderma boninensis)*.

Ganoderma can be controlled by deep ploughing and pesticides (Purbojo, IOPRI, pers.comm.; Yow and Jamaluddin, 2001). *Oryctes* can be contained using a combination of cropping practices (pulverisation, shredding the vegetation debris and covering it with leguminous cover crops), insecticide applications or biological control, like pheromone traps (D. Boutin, CIRAD, pers.comm.; Yow and Jamaluddin, 2001; Loh and Sharma, 1999). Zulnerlin and Fatah Ibrahim (1999) indicated that the cost of insecticides for beetle control ranged between US$18 to 63 per year per ha in the Indonesian plantations of P.T. Lonsum. Another method frequently used in Malaysia to destroy the beetle's breeding grounds is pulverisation of the oil palm biomass, which costs between RM 286 and 347 per ha, or US$ 75 to 90 per ha (Chow and Ooi, 2000, in Ooi *et al.,* 2001; Hashim *et al.,* 1993). This method can also help to reduce other problems such as rat infestation (Ooi *et al.,* 2001). The additional cost of insecticides needed to control *Oryctes* when using zero-burning is about US$100 per ha per year during the first 2 or 3 years of the plantation.[12]

The cost of plant protection can be compared with the value of the potential losses from pests and diseases. According to Liau *et al*. (1991, in Ooi *et al.,* 2001) and Chung *et al.* (1999, in Ooi *et al.,* 2001), the level of fresh fruit bunch (FFB) production lost to beetles in the first year of harvest ranges from 16% (moderate damage) to 40% or even 92% (severe damage). Replacement for dead oil palm can be up to 25% if the damage is severe, costing US$ 17.5 per ha (at US$ 0.5 per plant, with 140 trees per ha). There is additional opportunity cost while waiting for the replaced trees to mature. Rat-related production losses can be as high as 5% and dead oil palm trees replacement up to 25%, and losses due to *Ganoderma* can be up to 30% (IOPRI, unpubished material).

In the case of HTI, the main crop protection problem associated with zero-burning is the risk of fire during the early stages of tree growth, specially for semi-deciduous species. Zero-burning leaves piles of combustible debris between the rows of young trees, thereby increasing the hazard. The cost of associated fire control is estimated at US$ 10 per ha,[13] but the potential losses if a fire breaks out are much higher.

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[12] D. Boutin, CIRAD, pers.comm.

[13] O. Wennstrom, pers.comm.

2.1.7. Yield differences

Several publications from Malaysia note improved growth and production of oil palm after zero-burning, supposedly due to nutrients released from the decaying vegetation and to the better soil properties although a lack of data makes quantification difficult. Hashim *et al.* (1993) reported a yield of 8.66 to 10.72 FFB tons/ha in the first year of harvesting for several zero-burning methods, compared to 8.86 FFB tons/ha by burning, but this difference is not significant. More long-term data from multiple sites would be needed to confirm the allegation.

In the case of HTI, Nursidiq (1992) reported the results of research on HTI stands of *Acacia mangium* and *Eucalyptus deglupta* in East Kalimantan. The growth of Acacia on unburned sites was better than on burned sites, while Eucalyptus showed the contrary. The differences were in the mean stands diameter and height, slenderness, increment, and survival rates.

In general, however, no clear data can be found to support any claims of short-term effects on growth of trees from burning or zero-burning. Certainly the losses of nutrients through harvests in repeated rotations lead to productivity drops, which may be reduced by using zero-burning. Long-term data are still lacking to quantify this effect.

2.1.8. Global cost comparison

2.1.8.1. Oil palm: Financial advantage of zero-burning

Zero-burning tends to generate higher costs for land clearing due to the use of heavy equipment, and these additional costs increase with the volume of the cleared vegetation. The piled vegetation left after zero-burning makes planting and plantation management more difficult, but this can be overcome by changes in practices. Zero-burning also tends to generate higher costs in crop protection, especially when replanting, but it improves soil properties and nutrient status, which translate into lower fertiliser costs, and possibly faster crop development and higher yields.

The relative costs of land clearing with zero-burning depend on labour costs and the type of vegetation cleared. In Malaysia, with higher costs of labour than in Indonesia, the relative costs of using heavy equipment is lower. In Indonesia, there is an important variability between the costs depending on the type and volume of vegetation cleared, the location, the type of soils (peat/mineral), the cost of labour and heavy equipment use. The additional cost for clearing land with zero-burning in Indonesia is US$ 50 to 150 per ha on mineral soils, and can be much higher on peat soils. It increases with the volume of vegetation cleared.

When zero-burning is used on dry, relatively flat land and mineral soils, the benefits gained from better soil properties and reduced fertiliser use over the first five years of the plantation offset the additional costs of land clearing and crop protection. Hence the additional net cost of using zero-burning is minimal (Table 16). This is not necessarily true, however, when clearing high volumes of biomass on peat, hilly areas or other difficult terrains.

When zero burning is used on dry, relatively flat land and mineral soils, the benefits gained from better soil properties and reduced fertliser use over the first five years of the plantation offset the additional costs of land clearing and crop protection.

Table 16: Comparison of costs of oil palm development in Indonesia with burning and zero-burning, on mineral soils (US$/ha)

	Burning			Zero-burning			Difference (zero burning–burning)		
Previous vegetation	Oil palm	Light forest	Heavy forest	Oil palm	Light forest	Heavy forest	Oil palm	Light forest	Heavy forest
Land clearing	100	100	130	120	200	280	+20	+100	+150
Fertilisers (year 1-5)	390	390	360	300	300	220	-90	-90	-140
Crop protection (year 1-3)	30	30	30	100	50	50	+70	+20	+20
Total	520	520	52	520	550	550	0	+30	+30

For a plantation manager, however, the additional costs for land clearing when using zero-burning are certain and immediate. By contrast, the savings from reduced fertiliser use are more speculative, depending on many parameters, and in all cases they only become significant in the future. Due to discounting practices, investors are likely to view them as insignificant.

2.1.8.2. Industrial timber plantations

The differences in land clearing costs for HTI are similar. Additional land clearing costs for zero-burning, however, may be lower because HTI tends to be managed less intensively and clearing does not have to be as complete as for oil palm plantations. Moreover, HTIs that operate pulp mills are able to remove all the dead vegetation above 7 cm in diameter when clearing a forest. Standard land clearing operations may not remove wood above 20 cm or, even in some cases, 40 cm in diameter. If there is a pulp mill in the proximity, then it becomes economical to remove and use small-diameter wood. This may be true for more planting operations, whether they are close to a pulp mill or not: Pulpwood is now being shipped from Indonesia to Australia.[14] However, surveys have indicated that the cost of local transport is still a major constraint for the use of pulpwood (Gouyon, 1999a). If all wood above 7 cm in diameter can be economically removed from a planting site, then zero-burning becomes more attractive.

Since pest control is much less important in HTIs than in oil palm plantations, the additional cost for crop protection after zero-burning is also much lower. HTIs' savings in fertilisers due to zero-burning, however, are much less significant than oil palm plantation's, at least during the first rotation. However, in the long term, HTIs will benefit from the improved soil properties and higher soil nutrient contents after zero-burning.

The resulting CBA indicates that shifting to zero-burning is relatively more expensive for HTI than for oil palm plantation (Table 17). Again, however, this will vary enormously depending on the location (higher relative costs of zero-burning on peat, hilly terrain and high-volume vegetation), labour cost, timber species, and the fertiliser policy of the company.

[14] O. Wennstrom, pers.comm.

Table 17: Comparison of total costs of HTI development in Indonesia with burning and zero-burning, on mineral soils (US$/ha)

	Burning		Zero-burning		Difference	
Previous vegetation	Light forest	Heavy forest	Light forest	Heavy forest	Light forest	Heavy forest
Land clearing	100	130	150	200	+50	+70
Fertilisers (first rotation)	40	0	10	0	-30	0
Crop protection (year 1-3)	10	10	20	20	+10	+10
Total	150	140	180	220	+30	+80

2.1.9. Conclusion: Developing zero-burning methods for Indonesia's large-scale plantation investors is needed

There are still many uncertainties about the relative cost of implementing zero-burning in Indonesia. Zero-burning is now the standard method in Malaysia, while its adoption in Indonesia is still limited.

In Malaysia, labour costs are high, which makes burning more expensive, and many plantations are established on second rotation or land covered by light vegetation, where the costs of mechanical land clearing are lower. Besides, enforcement of the law against burning in Malaysia has hastened the development and adoption of cost-effective zero-burning methods more rapidly by the industry.

The additional costs of land clearing via zero-burning are obvious in the short-term. By contrast, the gains (mostly from reduced fertiliser needs) are uncertain, take several years to fully materialise, are less well documented — and the data is based mostly on Malaysian experiences, not from Indonesian case studies.

It is also important to keep in mind the cheap labour that attracts investors — especially from Malaysia to Indonesia. This advantage is lost during land clearing if mechanised zero-burning is practised. Interviews with plantation managers and other respondents revealed that plantation companies subcontract some operations. Land clearing is often given out to contractors, who will use the cheapest method available. Field-level managers often prefer the ease and 'clean-look' of burning and hence may not follow zero-burning instructions. Large companies with smallholder schemes are likely to contract land clearing to the smallholders. According to various government and non-government sources, in this way companies avoid zero-burning regulations, since it is usually accepted that the ban on burning does not apply to small-scale farmers.

In conclusion, more data are needed on the total costs and benefits of land clearing using zero-burning for the Indonesian context. These data need to be from Indonesia, in conditions to which Indonesian plantation managers can relate to. They need to be disseminated to decision-makers at all levels.

The information is more crucial for peat swamps, where the additional cost of zero-burning is particularly high, because peat swamps are the major fire hazard and new development areas in Indonesia, as well as the main source of transboundary

More data – from Indonesia and under conditions which Indonesian plantation managers can relate to – are needed on the total costs and benefits of land clearing using zero burning. They need to be disseminated to decision-makers at all levels.

haze. There are companies in Indonesia, like London Sumatra, who claim development of plantations on peat soils without burning for a moderate additional cost. If it is the case, their knowledge should therefore be used to develop appropriate methods.

Where land clearing is clearly more expensive with zero-burning (for example on peat soils or under conditions of high-volume biomass), companies could be given incentives to encourage this practice. It could be argued, however, that given the large areas of degraded vegetation in Indonesia, there is no reason to clear high-volume forest, especially in peat areas. The priority should be given to developing plantations on low-volume vegetation, where zero-burning is not more expensive than burning.

It is clear that the shift to zero-burning necessitates more capital and intensive management. It requires investment in adequate heavy equipment, and, perhaps even more important, high investments in the acquisition of new skills and change of habits, which seems to be the main behaviour impediment to the adoption of zero-burning by plantation companies in Indonesia.

Once the transition is made, plantation managers usually prefer zero-burning. This means that there is a good potential for a programme aimed at developing and disseminating zero-burning techniques adapted to the Indonesian context to succeed. However, strong financial incentives (e.g. as rewards for using zero-burning) or penalties for burning are needed to persuade the majority of companies to make this change.

Table 18 summarises the advantages and constraints of zero-burning in qualitative terms.

Table 18: Advantages and constraints of burning versus zero-burning

Impact	Burning		Zero-burning	
	Advantage	Constraint	Advantage	Constraint
On the environment		Air pollution (smoke/haze) Erosion and leaching, increased pollution of water bodies	No pollution	
On fire risks and hazard		Risk of wildfires		Leaves piles of dead vegetation (fuel) that constitutes a fire hazard
On land clearing and planting operations	Simple and easy No need for heavy equipment Eases supervision Applicable in all types of terrain	Requires fire control system Weather dependant	Windrows can be used for contouring More flexibility in scheduling operations	Needs heavy equipment Difficult in hills or swamps Piles of vegetation hamper field supervision and movement

Table 18. Continued

Impact	Burning		Zero-burning	
	Advantage	**Constraint**	**Advantage**	**Constraint**
On soil and fertility	Quick release of nutrients (especially P, K, Ca, Mg)	Affects soil properties (pH, organic matter, structure) Higher bulk density (soil porosity and infiltration decrease) Higher erosion Loss of N, C and part of S to the atmosphere and other nutrients through leaching	Nutrients locked up in the wood are released slowly to the roots of the planted rubber or oil palm when the dead trees decay, hence long-term fertiliser needs are reduced Better soil properties (pH, SOM*) result in better yields and growth	Heavy machinery may compact the soil or disturb the topsoil Nutrients are slowly released and initial growth of the plants can be slower or require more fertilisers (can be improved by pulverising the debris and planting of LCC**)
On pests and diseases	Destroys many pests and diseases	Trees that are not uprooted may propagate root diseases		Higher risk of pests and diseases, especially *Oryctes rhinoceros* and *Ganoderma*, hence higher losses and/or higher costs for control (see above, can be reduced)
On weed control	Suppresses the growth of bushy weeds	*Imperata cylindrica* may grow more quickly	Less problem with *Imperata*	More problem with weed growth (which can be suppressed by spraying herbicides)
On costs and benefits	Less expen-sive to implement in the short term No need for heavy equipment	Reduces soil fertility in the long term, i.e. increases the use of fertiliser	If used properly, will reduce the use of fertilisers and increase yields	Requires heavy machinery and special skills

* SOM = Soil Organic Matter

** LCC = Leguminous Cover Crops

2.2. Fire versus zero-burning for small-scale farmers in Indonesia

Small-scale farmers use fire for a variety of purposes, depending on ecosystems and farming systems. Several types of fire use depending on the agro-ecosystem in Indonesia are identified below.

2.2.1. Fire use in humid forest ecosystems (slash-and-burn)

Fire is commonly used by small-scale farmers in very humid, tropical forest ecosystems (above 2000 mm of annual rainfall, with a moderate dry season). This encompasses most of Sumatra (except the driest, deforested parts of Lampung), Kalimantan (except the driest parts in Southeast Kalimantan), most of Sulawesi (except the driest parts in Central and South Sulawesi) and West Papua. Fire is used for clearing primary or secondary forest in slash-and-burn systems, prior to planting rice or other crops, often mixed with rubber, rattan, coffee, fruit trees, and, increasingly, oil palm.

Much has been written about what is often called shifting cultivation – a misleading term giving the impression that it is used by nomadic farmers, while in fact most slash-and-burn farmers in Indonesia live in permanent villages, often located far from their swidden farms. It has been the predominant agricultural system in Indonesia for centuries, and still is in many parts of Sumatra, Kalimantan and West Papua.

The advantages of slash-and-burn are well documented (see Levang, 1991; Ketterings *et al*., 1997 and 1999). Based on surveys of small-scale farmers, these advantages, ranked in order of importance, include the following:

- It is the easiest method — and often, the only feasible one for smallholders — to reduce the biomass and clear the area for planting crops.
- Ash acts as a fertiliser. Most tropical soils are infertile and most nutrients are contained in the biomass. Burning releases the nutrients, even if a significant quantity is lost to the atmosphere or through leaching. This effect is especially important in the first year, when 80% of the nutrients are released.
- Burning improves soil structure, enabling faster establishment of crops (the soil loosens and crumbles).[15]
- Burning reduces competition from woody/scrub species. Again, this is most obvious during the first one or two years, after which scrubs start sprouting from roots or seeds, and *Imperata cylindrica* begins to spread.
- Burning reduces the incidence of pests and diseases.

Some of these statements may seem to contradict the results from the comparison of burning versus zero-burning in commercial plantations. This is because the crops planted are different. The positive effects of burning are especially important for food crops during one or two years after slash-and-burn. This is why rice and other annual crops are seldom planted for more than two years after burning, and the yield in the second year is on average 40% lower while weeding requirements increase. The positive effects are potentially less important for tree crops like rubber, rattan, oil palm, cocoa or coffee, which are now grown in association with food crops by most

[15] However, some studies show that forest fires cause high bulk density — the fine textured ash fills the soil macropores —thus lowering soil porosity (see e.g. Kusumandari, 1999).

small-scale farmers in Sumatra, Kalimantan, and Sulawesi.

For tree crops, there is no economically feasible alternative to burning for small-scale farmers. Theoretical alternatives include:

- Slash-and-windrow or slash-and-remove wood. This would require either mechanisation, or high labour inputs. The sales of the wood could pay for the labour, but in most cases smallholder fields are too far away from the main roads, and the value of the wood does not match removal and transportation costs (Gouyon, 1999a). The use of tractors or bulldozers is usually too expensive for farmers, especially when their fields are scattered or located far from roads.
- Slash-and-mulch. This is only feasible if the volume of the biomass is very low. Thurston (1997) has documented the use and advantages of this system in several countries. It seems for the moment that it cannot replace the functions of burning in Indonesia (Ketterings *et al.,* 1997 and 1999).
- Underplanting, i.e. planting new crop in the shadow of the previous tree cover. This is sometimes used by rubber farmers, but does not enable a sufficient growth of the young trees. Besides, underplanting poses problems of pests and diseases.

Two additional cost factors have to be considered for zero-burning. One is the actual clearing *per se,* which must be performed mechanically and is therefore too expensive to most small-scale farmers. The other is crop protection. Farmers using zero-burning might not be able to afford the pesticides required, and could then suffer losses from pests, diseases and weeds. One potential advantage is reduced spending on fertilisers, but since farmers use little fertiliser on tree crops anyway, they would not benefit much. The immediate release of nutrients after burning benefits the food crops more than the slow release that follows the slash-and-mulch system.

In most cases, small-scale burning in dry forest or agroforestry ecosystems is usually well controlled and poses no significant economic threat to neighbouring land, at least when practised by indigenous farmers with secure tenure.

For all these reasons, small-scale farmers in forest-like ecosystems (including smallholder plantations and agroforestry) have to rely on fires. Aware of this problem, the government exempts farmers from the burning ban. Otherwise, the farmers would face major income losses, and many would actually have to abandon farming (Ketterings *et al.,* 1997 and 1999).

In most cases, small-scale burning in dry forest or agroforestry ecosystems is usually well controlled and poses no significant economic threat to neighbouring land, at least when practised by indigenous farmers with secure tenure. In 1997/98, cases of escaped fires into neighbouring large-scale plantations might have been related to land conflicts that will not be solved by burning bans, but rather by equitable land allocation policies.

Smoke is a problem when many farmers burn their dry lands at the same time, but this is insignificant in comparison to the haze generated by escaped peat fires from large-scale land clearings (Bowen *et al.,* 2000).

The only cases when small farmers could and should be encouraged to use alternative methods is when they have access to finance and large areas of land (above 100 ha), as found in two situations:

- when wealthy farmers (usually large-scale landowners or traders) group their resources to develop tree plantations, especially oil palm; and
- within nucleus and smallholder schemes controlled by large companies. In

such cases, the companies could teach the farmers zero-burning technologies, but experience has shown that on the contrary, they allow contractors and farmers use fire. This should be discouraged since the schemes are usually large scale and the fires may be difficult to control, especially if lit by contractors or by migrant farmers with little experience in fire control.

2.2.2. Fire use in swamps

There are two main cases of fire use by farmers in swamp ecosystems. The first one is the use of fire for clearing land for fishing. Such fires can usually be large and poorly managed, and therefore are potentially hazardous to neighbouring concessions (Suwarso, 2001). The only option would be to find alternative livelihoods for these farmers, but this is difficult unless the government or the companies are ready to invest to help them develop perennial crops, for example. Even this alternative is particularly difficult in swamp areas.

Another example of fire use in swamps is *sonor* rice in Sumatra. *Sonor* is cultivated on dried-up swamps after long droughts, usually during El Niño years. The farmers often obtain financial backing from wealthy urban traders to plant rice. It is an important economic product during drought years because rice production in other areas is down and the price of rice soars on national and international markets. In South Sumatra, 10% of the province's rice production during the drought season is from *sonor* rice (Bompard and Guizol, 1999). Unfortunately, *sonor* rice farmers tend to burn more areas than they need and the fire can easily reach peat areas where it can burn for a long time. Again, the only alternative would be to provide these farmers with a better livelihood strategy during long dry seasons, such as the development of perennial crops.

2.2.3. Fire use in grassland ecosystems

Grassland ecosystems, dominated by the climax species of *Imperata cylindrica*, can be found in fire-prone areas of Indonesia, especially where there are sharp dry seasons and high population densities, like Southeast Kalimantan and some parts of Sumatra. Some farmers have developed farming systems, which are adapted to this vegetation, and routinely use fire.

Dove (1981) documented such a case in the lowlands of the Riam Kanan Basin, in Southeast Kalimantan. This area is covered largely with stands of *Imperata cylindrica*, which were created during the past century by the swidden practices of the local Banjarese population. With increased population and less forestland, the Banjarese developed an indigenous technology to exploit the grasslands. First, the grass is slashed, burnt and ploughed by cattle. One dry-rice crop can be cultivated each year for up to seven consecutive years, at which point the land is fallowed for three years. Yields average 3,000 litre of threshed and unhusked rice per ha, making a 40:1 return on the seeds planted. The Banjarese technology also involves periodical burning of the grassland to stimulate sprouting of young shoots to feed the draft animals (Dove, 1981). In this system, fire is used to maintain *Imperata* over other weed species that are even more difficult to control. Again, no economic alternative exists, unless farmers could start using herbicides, which is too expensive (the cost of herbicides is about US$ 60 per ha annually).

Grist and Menz (1997) tried to estimate rubber smallholders' costs and benefits of using fire versus alternative methods of weed control in *Imperata* areas of Sumatra.

Burning is shown to exacerbate soil degradation both directly through loss of soil nutrients and indirectly through erosion. Nevertheless, burning is still demonstrated to be the most profitable method of *Imperata* control in an upland 'shifting cultivation' system. Changing factor prices may alter this. A 25% reduction in herbicide prices would make herbicide use more attractive than burning. If off-site costs are considered, *Imperata* control with herbicide may be preferable to burning.

The economic crisis has actually increased prices of herbicide, but their value may have declined compared to labour costs and inflation. For example, in 1997 one litre of herbicide (glyphosate) was worth Rp 22,000 and labour cost was Rp 2,500 to 5,000 per day. The current price of herbicides is Rp 45,000 per litre while labour cost in Sumatra has risen to around Rp 10,000 to 15,000 per day.

2.2.4. Fire use in semi-arid ecosystems of eastern Indonesia

Eastern Indonesia has a semi-arid climate with large areas of savanna vegetation, and consequently the region is fire-prone. The land is used mainly for low-yielding subsistence agriculture and the region has major forest and land degradation problems. Fire is an essential component of traditional and current land management. Prescribed fire is used in slash-and-burn cultivation for clearing land, controlling weeds and increasing nutrient content. Fire is also used to promote new grass growth for cattle grazing and to provide some protection from wildfire. Some fire and grazing regimes encourage the invasion of grazing lands by shrubs, threaten lives, property and forestry reserves, and contribute to the regional atmospheric pollution. Fire has impacts on soil and water conservation, which all affect the long-term productivity of the land. (Myers *et al*., 2000). The extent, severity and impacts of the fires appear to be increasing with population and due to lack of alternatives.

A workshop organised by a ACIAR – Government of Indonesia co-operation project provides some useful and rare information on the use of fire within land-use systems in eastern Indonesia, especially in relation to shifting cultivation, slash-and-burn and grazing (Russell-Smith *et al*., 2000). Most of the papers of the workshop proceedings refer to the economic impacts of fire use and fire management without providing any data. Some papers, however, include a quantification of land use changes (e.g. expressed in biophysical terms such as hectare, vegetation cover) that could serve as a base for economic impact evaluation. This still leaves a lot of room for documenting the economics of fire use in eastern Indonesia and finding alternatives where necessary.

The vast majority of farmers in Indonesia use fire ...because of a lack of feasible economic alternative ...it is clear that nothing will change unless serious investments are made to provide farmers with alternative sources of livelihood, or they are encouraged to control their fires better.

2.2.5. Conclusion: No alternative to fire for small-scale farmers

The vast majority of farmers in Indonesia use fire as an essential component of their farming systems because of a lack of feasible economic alternative. In most cases, these fires are well controlled and pose little environmental and economic threats. Where fires may be harmful, like in the swamps, it is clear that nothing will change unless serious investments are made to provide farmers with alternative sources of livelihood, or they are encouraged to control their fires better. More detailed studies are needed to assess the use of fire in Indonesia and its consequences.

3. The costs and benefits of responsible fire use

3.1. The economics of fire management

The financial analysis of fire use needs to include fire management. Each use of fire bears with it the risk of escaped fire, and the consequences have to be evaluated. Hence for a user of fire, two extreme choices can be considered:

- Controlled use of fire, integrating fire management measures to ensure that prescribed fires do not escape and become wildfires; and
- Uncontrolled use of fire, without any particular attempt at preventing wildfires and establishing fire management systems. In this case, however, the user may have to bear additional costs in the form of fines, conflict settlement, and unfavourable public relations.

The literature on the economics of fire management (see e.g. Rideout and Omi, 1990) presents a standard method — Cost + Net Value Change' (C + NVC) — for evaluating the effectiveness of fire control systems. Butt (1995) used this approach to evaluate the costs and benefits of the IFFM project in Samarinda, East Kalimantan. This provides a framework for evaluation even if some variables cannot be quantified accurately. The concept is to compare the cost of fire control with the value of the damages avoided. When the cost of the next unit of fire control exceeds the value of the next hectare saved, it is more efficient, from the user's perspective, to accept fire damage.

The C + NVC model consists of two components:

- C is the cost of fire control or avoidance of the wildfires, which includes pre-suppression and suppression costs (Butt, 1995). Pre-suppression costs occur before any fire takes place. They include prevention efforts, making firebreaks, or the fixed costs of establishing a fire management system, such as training fire crews, acquiring and maintaining tanks and pumps. They are considered as fixed costs. Suppression costs are incurred when using the fire control system to put out a fire.
- NVC (Net value change) is also called the value of fire damage. In a financial analysis, it is the estimated market value of the resources lost or gained in the fire. A relevant evaluation is incremental: NVC = value of resources without the wildfire — value of resources with the wildfire.

The NVC can be calculated as follows:

$$NVC = R \times N \times V$$

where:

R =	Risk of fire, or probability of a wildfire occurring
N =	Number of hectares burnt
V =	Value of the costs or benefits incurred by the fire user due to the accidental burning of each hectare during a wildfire.

There are two major uncertainties in this equation:

- Assessing the risk of wildfires is extremely difficult, mainly because this risk is very different between an average dry season and a long drought during an El Niño event. Hence, practices of controlled fires that may be adequate during an average year may prove insufficient during an El Niño event.
- The costs and benefits (for the initial fire user) of an escaped fire are complex, especially in the Indonesian context where many uncertainties lie in the legal system.

3.2. The costs of being irresponsible

When a fire escapes, the potential costs for the user take the form of conflict settlement, including legal costs, and negative public relations and image.

3.2.1. The economics of conflict

The first costs incurred by the party responsible for a wildfire are the direct costs of the conflict and litigation if the fire has damaged a neighbouring private property, such as:

- costs of lawyers, negotiators, trials, or even armed guards and militia if the conflict escalates;
- time spent in negotiation;
- costs of damages carried out in retaliation by the wronged party during a conflict; and
- costs of a settlement or penalties, such as bailouts, fines, jail sentences, or direct compensation payments.

In theory this is relatively simple to calculate. In practice the lack of transparency of the Indonesian judiciary system makes it virtually impossible to estimate hidden costs other than on a case-by-case basis. These costs are significant and are escalating under the present situation. Documented cases are scarce, but two examples are found in the literature.

Recently, a Malaysian manager of P.T. Adei Plantations and Industry, an oil palm plantation company, was found guilty of using fire for land preparation and causing smoke problems and peat destruction. He was sentenced to two years' imprisonment and fined Rp 250 million (US$ 25,000). However, the High Court has ruled in favour of the company at the appeal, reducing the jail sentence to one year and the fine to Rp 100 million (US$ 10,000). While this may look serious, is actually a relatively small amount of money. If a company has to spend an additional US$ 100 per ha for zero-burning, clearing 300 ha with fire and paying the fine is still cheaper. It remains to be seen whether the manager will serve time or be bailed out. This case is the first successful example of such punishment in Indonesia. In comparison, Malaysia's maximum fine for burning is US$ 190,000 and five years in prison. The relatively benign fine indicates that being irresponsible is still economically affordable in Indonesia.

Such rulings -insufficient levels of fines and sanctions- have instigated small-scale farmers to take punitive action themselves. Gönner (1998) estimated that a conflict with neighbouring farmers has cost London Sumatra that operates in District Kutai, East Kalimantan, huge losses since their camp was invaded and occupied by farmers for six months, which means that all their equipment was immobilised. Such cases should be investigated to determine the amount of losses incurred. They may be more costly than the legal system.

3.2.2. The economics of public relations

Local community relations

Another damaging effect of uncontrolled fire is the indirect, long-term cost of damaged relationships between the fire users and the local community.

Companies with poor relationships with the community cannot expect understanding from enraged neighbours who are likely to make higher claims in all conflicts. A recalcitrant small-scale farmer will likewise suffer the consequences of antagonising the community, perhaps to the point of reduced access to resources.

These costs are even more difficult to estimate, but again evidence from the field suggests that they are important. They are one of the main reasons why small-scale farmers set up fire control systems. Large companies are considering the option too since the costs of managing conflicts with local communities and individuals are exerting an increasing toll on their operations.

Government relations

A poor image can also affect relations with government officials and result in increased payments for taxes, land acquisition, or other fees and charges. Furthermore, forest concession and plantation companies that have been warned by the government (Ministry of Forestry) for using fire in land clearing activities experience difficulties by having to follow costly and more strict government administrative procedures. This has happened to many companies since the severe fire outbreaks of 1997/98. In 1999, the Timber Utilisation Permit (IPK/Ijin Pemanfaatan Kayu) granted to four plantation and six forest concession companies were revoked temporarily.

Large companies with national and international operations, or those that are publicly listed, are affected even more by negative images as the consequences spread beyond immediate neighbourhood and government relations.

Financial institutions

Wildfire incidences can reduce a company's credit. This is mostly true of large plantation companies, which depend on international financial institutions. As stated by Hamilton (1998):

> *"Palm oil businesses have a major public relations problem. Since the recent El Niño, the industry's image of causing damage to natural resources has spread from the rather narrower environmental pressure group audience to a more general audience whose perception has become negative. The poor environmental image is now being widened to encompass social issues. Reputable international financiers are acutely conscious of environmental and social risks and will seek comfort from clients that are fully mitigated."*

It is mostly NGOs and similar watchdog groups, which attract the attention of banks to the wrongdoings of the companies they finance. At the same time, they also attract the attention of the public in the developed countries where these international banks have their main client base. Greenpeace, Sawit Watch, Friends of the Earth, Profundo and AIDenvironment, have actively campaigned for various European banks, especially in the Netherlands, to stop financial support for companies involved in environmental destruction and violations of indigenous people rights (Wakker et al., 2000). It led three banks: Rabobank, Fortis and ABN AMRO, to issue separate policy statements and a joined declaration in which they pledged that "Oil palm plantation companies submitting investment proposals to [them] should not be involved in burning and clearing tropical rainforest; respect local communities' rights and demands; respect Indonesia's law and relevant international conventions" (Focus on Finance, 2001).

Uncontrolled fires in the vicinity of pulp and paper company P.T. MHP (Musi Hutan Persada) in South Sumatra, other example, has resulted in questions raised by environmental NGOs at the Japanese parliament – since the *Acacia mangium* scheme of P.T. MHP was co-financed by Japanese development funds.[16]

There are a number of reasons why an international bank may want to stop financing a company with bad social and environmental records. First, it may affect its own image in its home market. Second, the resulting costs will affect the profitability of the operation. Finally, poor social and environmental behaviour is often considered an indicator of poor management in general. Hence, financial institutions are now paying much more attention to the lobbying efforts of NGOs.

Shareholders' value

If the company is listed, negative publicity can directly affect its value since a poor image will result in less demand for the company's stocks. This is one of the major concerns of the large pulp and paper or oil palm companies that have set up the Haze Prevention Group (HPG).[17]

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[16] Ryu-Ichiro Abe, JANNI, pers. comm.

[17] O. Wennstrom, HPG, pers. comm.

A recent study evaluated that 60% of European consumers are ready to pay an average 6 to 10% more for certified wood products.

Market access

International NGOs and pressure groups are trying to direct consumers away from products of companies with poor social and environmental records. As a result, consumers in industrial countries, especially in Europe, have become increasingly socially and environmentally conscientious and aware. However, translating this awareness into purchasing decisions is complicated for numerous reasons.

The WWF and other NGOs have tried to explicitly link palm oil products, rainforest destruction and indigenous peoples' abuse (see Potter and Lee, 1998b). Threats of boycott are occasionally being made. They are unlikely to be taken very seriously by oil palm companies, for several reasons:

- Firstly, the history of boycotts shows few successes. Rarely have boycotts, especially international ones, affected industries in the long term (with some notable exceptions such as of Outspan oranges from South Africa and Home Depot in USA).
- Secondly, for a boycott to succeed, the boycotted products must be limited, easily identifiable, and easily substituted. This is not the case of oil palm products from Indonesia, since palm oil is used in a wide range of products in combination with other oils and fats.
- Thirdly, the bulk of the growth in palm oil demand comes from emerging Asian countries like China, where consumer awareness in social and environmental issues is less developed. Hence it is very unlikely that consumer pressure may hurt careless users of fire. The 'bad image' pressure is much more efficiently applied through banks, governments, shareholders and direct action by NGOs and communities.

There is a little more scope for net value change to determine market access for forestry companies. The Forest Stewardship Council (FSC) and the LEI (Lembaga Ekolabel Indonesia/Indonesian Ecolabel Institute) are jointly operating a certification scheme for forest products derived from sustainably managed forests (including natural forests concessions and industrial forest plantations like pulp and paper, rubberwood, teak). This scheme is backed-up by reputable NGOs like the WWF. Major furniture manufacturers like Home Depot and Loewe in the USA, or IKEA in Europe, want to improve all 'certified wood products' to increase market shares and public relations. Hence they are pressuring Indonesian wood suppliers to become certified.[18]

One criterion for obtaining a certificate is having a fire protection system, and good relationships with neighbouring farmers and stakeholders. This is probably the only direct market incentive for responsible behaviour in natural resource management in Indonesia right now. However, its effects are limited, since the number of interested companies that are eligible for certification and can afford it is small. It is difficult to evaluate the financial benefits of forest product certification.

A recent study evaluated that 60% of European consumers are ready to pay an average 6 to 10% more for certified wood products (Keogh, 2000). This is consistent with other studies on the willingness of consumers to pay for good environmental and social records. In that case, the lost benefits because of careless use of fire (usually associated with a number of other environmental and social abuses) is about 3.6 to

[18] J. Hayward, Smartwood, pers. comm.

6% of the value of the product prices. However, it may in fact be more important because being certified is not so much about selling a product with a higher price to any consumer, than it is about being able to sell the product to an upper-end market. Being certified may mean being able to sell wood products to luxury retailers from Europe instead of selling to China. Then, the price gain may reach 100 or 200%.

3.3. The cost of being responsible

As indicated above, studies on the costs of managing fire control systems are scarce. Most studies focus on training, equipment and operations needed for fire prevention and fire fighting (Nicolas and Beebe, 1999a; Nicolas *et al.,* 2001), but they do not include costing. A team of experts from the South and Central Kalimantan Production Forest Project (SCKPFP) have recently started calculating such costs (Nicolas and Pansah, 2001). It remains difficult to calculate costs per hectare since the conditions of needs and implementation in the field are very different. Using standard official prescriptions would lead to costs that are not always realistic.

Table 19 provides an example of costs of setting up a fire crew and equipment for an imaginary 30,000 ha HTI on flat land, costing nearly US$ 3 per ha. These costs do not include the construction of firebreaks and access roads, which are the main components, and which vary among locations. They also do not include operation costs in case there is a fire.

The last El Niño was five years ago, and communities, managers and company staff are becoming less and less concerned about fire dangers.

Table 19: Cost of setting up a fire crew and equipment for a 30,000 ha HTI on flat land

Cost component	US$ per unit	No. of units	Total (US$)	US$ per ha
Water tank (2,500 litre)	775	5	3,875	0.13
Lookout tower	1,290	6	7,740	0.26
Warehouse	2,700	2	5,400	0.18
Equipment for 30-men firecrew	68,000	1	68,000	2.27
Training for firecrew	860	2	1,720	0.06
Total			**86,735**	**2.90**

Source: Adapted from Nicolas and Pansah, 2001 and Nicolas, pers. comm.

The total cost of fire management is about US$ 10 per ha. This, however, depends on major factors — the type of area to be protected, and so on. Moreover, even the best fire control systems can be inadequate during extreme periods of drought. Besides, it is always easier to be lax, especially when there has been no long drought and fires for several years and as the memory of previous disaster fades away. This is the main danger faced by HTIs and the plantation sector right now: the last El Niño was five years ago, and communities, managers and company staff are becoming less and less concerned about fire dangers.

4. Who pays the bill? The economic impact of fire use

4.1. Global economic impact analysis

Several macro-level studies have been produced after the large fire events, especially the one in 1997/98, to evaluate the impact of the fires from a qualitative and quantitative perspective. Most of these studies include evaluations of the costs from a global perspective. They also provide detailed analyses of the causes of the fires, linking the fires to commercial land clearing.

The most recent and probably the most comprehensive study is a useful review and synthesis on the impacts of the fires (Barber and Schweithelm, 2000). It does not provide new economic insight, but a useful comparison of previous economic impact evaluations. The study reviews three major attempts to value the costs of the 1997/98 fires and haze event. The first one was the EEPSEA/WWF study, which covered the fires from August through October 1997 and estimated the costs to be about US$ 4.5 billion. The second one, the report of the Environmental Emergency Project of the Environment Ministry yielded a much lower figure, which was considered to underestimate the actual losses. Neither study took into account the 1998 fires in Kalimantan. Building on these works, the BAPPENAS/ADB study concluded that the total loss from the 1997/98 fires and haze was about US$ 9.3 billion for 9.8 million ha. These figures are the most comprehensive until today.

It is interesting to note that these studies are widely accepted and quoted, and have generated sufficient concern and funding for fire prevention programmes. Some Indonesian government officials tried to dismiss the figures as being too high. Their lower estimates were rejected because both the EEPSEA/WWF and the ADB/BAPPENAS studies were seen to be rather conservative in their estimates. Additionally, the ADB/BAPPENAS study excluded some indirect costs, such as the loss of biodiversity.

Despite the shortcomings, these studies are immensely valuable because they provide the only figures available to decision-makers. Still, quoting costs expressed in billions of US dollars has a stunning, numbing effect. The EEPSEA/WWF study made an effort to convert the costs to more easily understood concepts, by comparing them with the Indonesian budget and the costs of water and sanitation development projects. Such comparisons are extremely powerful and should be used systematically. However, even when converted into more palpable units, the figures remain so astounding that they seem to discourage intervention.

Indeed, most decision-makers are not necessarily interested in general costs, which would interest only international donors, scientists or inter-governmental agencies. The stakeholders who make the decisions that directly affect the use of fire for economic purposes are increasingly found at local and regional levels, such as:

- regional governments, which are increasingly more responsible for land-use policies and any other regulatory measures;

- managers of plantation and forestry companies, who decide whether and how to use fire for land clearing; and
- farmers and their organisations.

Hence, breaking down the costs is more useful: by region and by type of stakeholder or actor.

4.2. Regional impact analysis: Limited to biophysical data

4.2.1. Studies on Sumatra

The Forest Fire Prevention and Control Project (European Union and Ministry of Forestry, South Sumatra) which operated from 1995-2001 has produced a number of socio-economic studies of villages in South Sumatra, and the location and extent of the fire damage in the province. Of more than 20 studies produced, however, only one report evaluated the costs associated to fire use and fire damage in the plantation sector (especially rubber smallholders and large rubber and oil palm estates) (Gouyon, 1999a and 1999b). Biophysical quantification in the other reports can partially help to estimate the costs and benefits of fire use, for example in *sonor* cultivation (Bompard and Guizol, 1999), or the value of the damaged area.

The research institutes on estate crops located in North Sumatra (Indonesian Oil Palm Research Institute) assessed the costs and benefits of land clearing using fire and alternative methods, in addition to some biophysical impacts on the plantation sector. The Research Centre of Sembawa in South Sumatra has published many studies on the rubber smallholder economy, especially on *Imperata cylindrica* control. Only a few of these studies, however, include an economic evaluation of the costs and benefits of the various recommended methods.

ICRAF and CIFOR have published a vast volume of studies on the tree-based agro-ecosystems of South Sumatra, Jambi and Lampung, especially as part of the Alternatives to Slash-and-Burn (ASB) initiative. Some of these studies include economic figures on land clearing activities and socio-economic analyses of smallholder tree crop and agroforestry systems using fire.

The ACIAR has conducted research on the smallholder economies of Sumatra and on the management and rehabilitation of *Imperata* grasslands. Some of the publications include useful evaluations of the economic impact of using fire for land clearing. A very original and useful work is the analysis of the impact of fire risk on investment decisions by smallholders.

4.2.2. Studies on East Kalimantan

Numerous studies on the causes and impact of fire in East Kalimantan have been conducted, especially since the big fire outbreaks in 1982/83. JICA in collaboration with PUSREHUT (Center for Tropical Forest Rehabilitation), Mulawarman University, GTZ-IFFM Project and WWF have been most active. However, these studies focus mostly on socio-technical aspects.

A multiple-volume impact study for the 1982/83 fires by GTZ (see for example Mayer, 1989) is widely referenced. The GTZ's IFFM fire project has published several reports on its work in setting up a wildfire management system in East Kalimantan. Estimates of area burnt in East Kalimantan by the 1997/98 fires are also available

(Hoffmann *et al*., 1999) and estimates of economic loss from the fire incident are forthcoming.

4.2.3. Studies on eastern Indonesia

Most of the international concern about fire impact has concentrated on Sumatra and Kalimantan, where most of the fires occurred in 1997/98 and during the previous large fire events.

A workshop on *Fire and Sustainable Agriculture and Forestry Development in Eastern Indonesia and Northern Australia* was conducted by ACIAR in 1999, as part of a project on 'The use of fire in land management in Eastern Indonesia and Northern Australia' (see Russell-Smith, 2000). Most of the papers presented concentrate on East Nusa Tenggara or Northern Australia, with one paper on East Kalimantan, one on Komodo, and one on the Transfly region of Irian Jaya/West Papua New Guinea. The workshop focused on the agro-ecosystems of eastern Indonesia, especially East Nusa Tenggara, which differs from the rest of Indonesia and supports some of the poorest people. However, the results are still qualitative, without any economic data.

4.3. Stakeholder financial analysis: Costs and benefits for various parties

Stakeholder financial analysis is basically an analysis from the individual point of view. Stakeholder analysis must be conducted in two steps:

- First, identify all the different types of stakeholders who may benefit (directly or not) from the use of fire and all those who may be negatively impacted (directly or not).
- Second, evaluate the costs and benefits from the point of view of each of the stakeholder.

This is a relatively long exercise since the stakeholders are usually numerous, and the costs and benefits difficult to calculate. In most cases the costs and benefits stem from the incidence of wildfires escaping management, and from occasional local haze events.

No such studies have been conducted yet, although they would be needed to be able to determine how damaging fire use should be sanctioned.

5. Conclusion: A strategy for preventing wildfires in the next El Niño

The financial analysis of the costs and benefits of fire versus zero-burning for land clearing indicates that when applied to low-volume vegetation, zero-burning methods are not more expensive — and may actually be more cost effective in the long term — than burning. This is the case for clearing oil palm or rubber plantations for replanting, low secondary vegetation or heavily logged-over forest. Under high-volume forest conditions, burning remains less expensive because it is more difficult, time consuming and costly to dispose of high volumes of piled wood mechanically. Sound land-use policies are needed to ensure that high-volume forests are not cleared for development in Indonesia especially since abundant areas of low-volume and degraded forests are available.

While there could be a strong financial case for companies to use zero-burning in Indonesia in the future, there are some barriers and costs associated with changing practices. It is a relatively complex and technical operation requiring new skills and investment in heavy equipment. It also necessitates an attitudinal change in plantation managers who dislike the 'messy' appearance of mechanically cleared sites with their high windrows of residues.

ASEAN has identfied zero burning as an appropriate approach to reduce the incidence and intensity of transboundary haze and smoke events.

The Association of South East Asian Nations (ASEAN) has identified zero-burning as an appropriate approach to reduce the incidence and intensity of transboundary haze and smoke events. Yet the concept meets strong resistance from operation managers. Smaller companies with lower profiles have fewer incentives to adopt zero-burning and are reluctant to do so. The adoption of zero-burning is further complicated by the use of contractors who are difficult to control and lack the funds to acquire new technology after three years of the economic crisis and low-level planting activities in Indonesia.

Laws and regulations penalising irresponsible fire use are seldom enforced.

A similar case can be made for balanced forest fire management. On paper, implementing a fire management system in a forest concession or a plantation is not expensive but requires initial investments in training and acquisition of equipment, even if simple hand tools are all that are needed in most cases. Constant discipline and maintenance are crucial, both of which tend to diminish with time and absence of crisis. Faced with financial difficulties, the management tries to reduce costs and a fire management system may be a target especially after several incident-free years.

When comparing the relatively low financial costs of zero-burning and fire management with the enormous socio-economic costs when fire escapes, it is clear that there is a market and institutional failure in fire management. Laws and regulations penalising irresponsible fire use are seldom enforced. For the moment, the most significant pressure to exact a cost on irresponsible fire users is through the public image. Shareholders may lose confidence in companies with poor reputations, causing the value of their stocks to plummet. Credit standings are seriously affected, making it more difficult for the companies to secure financial backing. Some NGOs are increasingly pressurising financial institutions to stop providing finances to irresponsible companies.

This type of pressure is only effective on large companies that attract financing from international sources. Local companies are somewhat insulated from these types of problems. However, like large international companies, they are sensitive to pressures from local farmers and communities, that become increasingly vocal and demand compensation from errant companies.

Not only are there few rewards for responsible or sanctions for irresponsible fire use, there are also perverse incentives to using fire and letting it escape. Areas damaged by fires can be purchased at lower prices and easily converted to agricultural use. As long as the authorities in charge fail to regulate and enforce proper land uses effectively, this practice will continue in Indonesia.

Planting and burning operations have slowed down since 1997/98 due to a combination of factors — apprehension of negative publicity, concern about retaliation from local communities, depressed commodity prices, limited financial resources, and consequences of the Indonesian and world-wide economic crisis. Nevertheless, significant fire and haze events have occurred repeatedly even during years with no prolonged droughts. If commodity prices pick up again, as expected by some sources for 2002, and with an impending El Niño, extensive fires may break out in large planting operations. To reduce irresponsible and dangerous use of fire, the following recommendations need to be implemented.

1. For local communities and smallholders, promote responsible fire use in land clearing, organised and monitored at the community level. This requires an effective institutional arrangement in terms of local government and villager organisations. It is also necessary to clarify and guarantee the local community's and smallholders' rights over and access to land and natural resources. Furthermore, alternative income generation and/or financial and technical support, especially from the government, must be provided for the poorest villagers to reduce slash-and-burn practices.
2. For commercial plantations (mostly oil palm and HTI), promote zero-burning as a cost-effective method in the long-term, resulting in improved soil fertility and better public image for the company. Promotion of zero-burning should be conducted through a programme of field trials to develop methods adapted to the Indonesian context, accompanied by demonstrations, training, dissemination and extension. The industry leaders and their associations should be co-opted into the programme.
3. For governments, develop a system to sanction dangerous practices and reward good behaviour. Financial institutions should be lobbied to link finance with responsible fire management, targeted media and NGO monitoring campaigns, and perhaps a certification system for companies applying responsible fire management or practising zero-burning.
4. For governments, ensure that land use policies incorporate responsible fire use at all levels, particularly at regional and local levels due to the ongoing decentralisation process in Indonesia.
5. For governments, identify the key locations of potential future large fire. Currently, vulnerable areas are relatively well mapped by various international co-operation projects. However, more data on locations of

land development activities likely to use fire are needed. A study to identify these areas through interviews, and aerial and field surveys should be initiated before the advent of the next El Niño. A permanent monitoring system should also be established. These activities should involve all relevant stakeholders at various levels (companies, NGOs, communities, etc.) under the co-ordination of the national government and supported by international organisations and donors.

6. For the government, once the key danger areas are identified, set up a surveillance system to prevent irresponsible fire use at the regional and local levels in collaboration with local people. At the same time, provide training and incentives for responsible fire use, particularly at the level of companies and communities.

Several opportunities to influence decision-makers at various levels can be identified to promote a reduced and, more importantly, responsible use of fire to prevent destructive wildfires (Table 20). A summary of methods and approaches to analyse the economics of fire use, the gaps and inconsistencies found in the data and methods, and the recommendations to generate data that can be used for lobbying decision-makers is shown in Table 21.

Four focus areas to generate missing data include:

- conduct studies at provincial and district levels on the impacts of the fires to influence decision-makers;
- identify areas at risk for the next El Niño, taking into account the changes in the burning and planting behaviour of the companies since the crisis;
- develop and disseminate methods of zero-burning adapted to Indonesia's situation; and
- document the costs of conflicts and negative image due to irresponsible fire use to the companies.

Table 20: Economic data needed to influence decision-makers towards the prevention of wildfires

Decision-maker	Level	Potential impact on fire prevention	Economic data needed	Availability of these data
Inter-government agencies, donors, intern. NGOs, banks	international/ global	increased funding with better allocation increased political pressure, campaigns regulate international treaties	global impact of the fires, especially on the environment (biodiversity, carbon released)	EEPSEA/WWF and ADB/BAPPENAS studies
ASEAN governments	international/ ASEAN	increased funding with better allocation increased political pressure increased pressure on companies from their own countries active in Indonesia	impacts of the fires on neighbouring countries (Malaysia, Singapore, Brunei, etc.).	EEPSEA/WWF study, research from Malaysia and Singapore
Indonesian government, Indonesian NGOs, Indonesian banks	national, regional (districts)	improved regulations/ laws increased funding/ budget with better allocation	impacts of the fire on the Indonesian economy breakdown by category of constituents/ stakeholders costs and benefits of alternative methods areas at risk of fire	EEPSEA/WWF and ADB/BAPPENAS studies lack of stakeholder and regional disaggregated data lack of data for the Indonesian case no update taking into account the changes in the Indonesian economy and society since 1997/98
Consumers	international	reference for environmentally sound products avoidance of environmentally hostile products	global impact of the fires, especially on the environment (biodiversity, carbon released)	EEPSEA/WWF and ADB/BAPPENAS studies
Farmers, communities	stakeholder	responsible use of burning watchdog action on companies	cost of the wildfires destroying their properties or their forest land reserves	partly available, the farmers are well aware of the direct impact on themselves
Plantation and forestry companies, banks	stakeholder	reduced and responsible use of burning	data on how conflicts and bad image generated by the fires affect them	not publicly available but some companies are well aware of it

Table 21: Recommendations to generate data to influence decision-makers

Topic	Sound methods and approaches	Gaps and inconsistencies	Recommended strategies to generate data and lobbying
Impact of the wildfires	A comprehensive methodology was developed by the EEPSEA/WWF (1997) and ADB/BAPPENAS studies (1997/98)	Some government groups think that the impacts are exaggerated. Uncertainties in the methods, especially in the evaluation of health impacts (especially the long-term effects), and the valuation of lost of biodiversity. The studies used satellite pictures, without regionally disaggregated data. No updating to reflect progresses in environmental valuation methods or new information gained on fire use and impact.	Conduct updated regional economic and financial evaluations of the impacts of the fires in some key districts or provinces, using a stakeholder-disaggregated approach in co-operation with local government and stakeholders, to influence local decision-makers to limit the risk of wildfires. This could be done in co-operation with other agencies such as EEPSEA, which may be able to fund a proposal if it comes from an Indonesian institution.
Risk of fires and strategies for fire prevention	Excellent analyses are available on the causes of the fires. Local evaluations of the areas at risk are available from satellite images	There has been no general update on the areas at risk since 1997/98. The only data available are satellite images, but there is a lack of data about what is happening in the field, especially the planting and burning activities of the companies, which have changed a lot since 1997/98.	Conduct an identification and mapping of the areas at risk before the next El-Niño, combining satellite images with a survey of the planting strategies of the large companies and their planned use of fire. In co-operation with other donor projects post the map on a web site and advertise it.
Zero-burning methods for large plantations	Numerous papers have been published, especially in Malaysia, to analyse the costs and benefits of burning versus zero-burning from the point of view of the company	There is a lack of information about the actual trends of land development and use of fire or zero-burning methods by Indonesian companies. There is a lack of data on zero-burning methods in the Indonesian context.	Conduct a survey on the actual use of burning by Indonesian companies, taking into account the impact of the crisis, the 1997/98 fires and price changes. Develop a set of practical methods and prescriptions for zero-burning in Indonesia. Disseminate methods of zero-burning to plantation managers, government and contractors, especially through training. This can be done with some other organisations such as APHI, IOPRI, HPG, which are interested.
Impact of conflicts on companies' economy	Well known from a qualitative point of view	No publicly available evaluation on the costs of conflicts and bad image of companies.	Conduct case studies on how conflicts with other stakeholders, fire and other 'bad press' has affected shareholders' value, market of the company's product, and generated direct costs to the company (claims, compensations, lawsuits, etc.). This can be done in co-operation with the HPG, which is interested. Major banks should also be included.

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Appendix 1: Economics of fire use in land clearing in plantation and timber estates (HTI): Case studies in Indonesia

Dicky Simorangkir[1]

Fire is often used to clear and prepare land for plantations and timber estates in many parts of the world. In Indonesia, the area to be converted vary from bare land, grassland and bushland to secondary forest with different density of vegetation cover. Technically, areas with light dense vegetation cover are preferred for plantation and HTI development, since it is easier, quicker and cheaper to clear such areas. In practice, however, few companies in Indonesia like to convert well-stocked secondary forest, since they can cut and sell the trees. Usually, the scrub and underbrush are first cut, and trees (usually above dbh 15 cm) are felled and then chopped manually. After that, all the vegetation and timber wastes are burnt, or collected and removed by tractors. If the converted areas were grasslands or bushlands, the company simply sets fire or, in few cases, sprays herbicide to kill the vegetation cover.

Until now fire is the preferred tool to clear the land because it is quick, easy, effective and particularly cheap. Results from two case studies show the cost effectiveness of using fire in land preparation activities. Table 1-1 summarises the costs of preparing land for an *Acacia* HTI and Table 1-2 for an oil-palm plantation on on dryland in Riau.

Table 1-1: Cost structure of land preparation of a timber estate (HTI) on dryland in Riau, 1997 (thousand Rp/ha)

Cost items/allocation	Fire	Tractor
Cutting of scrub/underbrush (manual)	75	75
Cutting of trees (chainsaw)	105	105
Chopping/hacking branches, logs, end logs, etc. (manual)	40	40
Burning	45	-
Collecting and piling scrub, logs, end logs, etc. and clearing of other wastes	-	230
Total	**265**	**450**

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Table 1-2: Cost structure of land preparation of an oil palm plantation on dryland, Riau, 1997 (thousand Rp/ha)

Cost items/allocation	Fire	Tractor
Cutting of scrub/underbrush (manual)	148.5**	108.0
Cutting of trees (chainsaw)	396.0	156.0
Chopping/hacking branches, logs, end logs, etc. (manual)	148.5	117.0
Burning	33.0	-
Collecting and piling scrub, logs, end logs, etc. and clearing of other wastes	-	663.0
Total	**726.0**	**1,044.0**

** The costs for cutting of scrub/underbrush, cutting/felling of tress, and chopping shall be the same for both systems. The differences were caused since the company put these cost items under logging cost when it used tractor to clear the land.

The cost of land clearing using tractor after cutting and chopping scrub and trees in the HTI was five times higher than using fire (Rp 230,000 to 45,000 per ha). The total cost for using tractor almost doubled that of using fire (Rp 450,000 to 265,000 per ha). The difference in the oil palm plantation was even striking – using the tractor was about 20 times higher than using fire (Rp 663,000 to Rp 33,000 per ha). Furthermore, developing an oil palm plantation is more expensive than a HTI because the former needs more intensive clearing and better access.

It is clear that land preparation cost is very site specific and depends on many factors, particularly on labour cost, site condition and vegetation cover. An East Kalimantan example shows that the cost of cutting and chopping scrub/underbrush and tress for a HTI is lower than in Riau (Table 1-3) mainly because labour cost is cheaper in East Kalimantan. In addition, the company in East Kalimantan carried out all the activities itself, while a contractor was hired to do the work in Riau. However, the operational cost of a tractor to collect and remove wastes was more in East Kalimantan (80% of the total cost compared to 50% in Riau).

Table 1-3: Cost structure of land preparation of a timber estate (HTI) on dryland in East Kalimantan, 1997 (thousand Rp/ha)

Cost items/allocation	Total Cost
Cutting of scrub/underbrush (manual)	44.80
Cutting of trees (chainsaw)	90.00
Chopping/hacking branches, logs, end logs, etc. (manual)	25.90
Collecting and piling scrub, logs, end logs, etc. and clearing of other wastes	735.75
Total	**896.45**

Usually the cost for land preparation in a peat swamp is much higher than on dryland, as shown by the experience of a HTI company in West Kalimantan (Table1-4). A logged-over area — originally a peat swamp forest with a very heavy logging history that left a secondary forest with a lot of scrub/underbrush and timber wastes — was cleared for planting rubber trees. The company had to burn the area twice, once after the scrub/underbrush and trees were cut and hacked, and then again after the rest of the first burning were collected and piled.

Table 1-4: Cost structure of land preparation of timber estate (HTI) in West Kalimantan, 1997 (thousand Rp/ha)

Cost items/allocation	Peat soil	
	Fire	Tractor
Cutting of scrub/underbrush (manual) and trees (chainsaw) Chopping/hacking branches, logs, end logs, etc. (manual)	248.5	248.5
Burning I	251.0 * (inc. cost of burning of Rp 50,000) *	–
Collecting and piling scrub, logs, end logs, etc. and clearing of other wastes		2,400.0
Burning II		–
Total	**499.5**	**2,648.5**

* Fire can clear a 7.4 ha plot in 4 days with satisfactory results. On the other hand, productivity of a tractor is 10-14 hours per ha.

The cost for using fire in this area almost doubled that of Riau's (Rp 499,500 to Rp 265,000 per ha) and amounted to almost 6 times if tractor is used (Rp 2,648,500 to 450,000 per ha). Obviously, the harsher the condition of the area to be cleared (peat soil and dense vegetation), the greater the cost difference between manual (fire) and mechanic (tractor) system will be.

Other cost comparisons between dryland and peat soil land clearing are shown in Table 1-5. In this case, relatively light logged-over areas in Central Sumatra — one on dryland and the other on peat soil — have been cleared and converted to oil palm-plantations by one of the biggest plantation company groups in Indonesia. The cost for land preparation on peat soil was almost doubled that on dryland (Rp 1,247,000 to 767,000 per ha). Furthermore, while the cost of burning in the examples above amounted to Rp 40,000 per ha on average, it costs the company in Central Sumatra 14 times more on dryland and 30 times more on peat soil to collect and clear the wastes (Rp 767,000 and 1,247,000 respectively).

Table 1-5: Cost structure of land and plant development of oil palm plantation in 1999 (thousand Rp/ha)

Cost items/allocations	Dryland	Peat soil
Land Preparation		
Cutting of scrub/underbrush (manual)	97.5	97.5
Cutting of trees (chainsaw), inc. chopping and hacking	138.0	138.0
Collecting and piling scrub, logs, end logs, etc. and clearing of other wastes	531.5	1,011.0
Sub-total land preparation	767.0	1,247.0
Planting		
Marking/staking (manual)	10.0	10.0
Making seedling holes (manual)	49.0	49.0
Planting *legume/*cover crops (manual)	19.5	19.5
Caring *legume* (manual)	234.5	234.5
Fertilising *legume* (manual)	15.0	15.0
Fertilising seedling holes (manual)	15.0	15.0
Planting seedlings (manual)	58.5	58.5
Clearing seedling plateau (manual)	98.0	98.0
Fertilising the seedlings (manual)	19.0	19,.5
Spraying alang-alang (manual)	108.0	108.0
Clearing alang-alang (manual)	10.5	10.5
Others		
Marking materials	3.0	3.0
Transporting of seedlings	50.0	50.0
Sub-total planting	690.5	690.5
Seedlings	600.0	600.0
Land utilisation right	100.0	100.0
Crop caring for 3 years at Rp 1,500,000/year *(60- 70% of this item is allocated to fertilisers)*	4,500.0	4,500.0
Total cost	**6,657.5**	**7,137.5**

Many studies (e.g. Chandler *et al*., 1983; Xiang *et al*., 1990) have proven that forest fire will change soil chemical characteristics and increase soil fertility by the increasing of pH, CEC (Cation Exchange Capacity), organic matter, as well as N, P, Ca and Mg contents. While some researches showed that the increased nutrient content would last for at least five years (Pritchett and Fisher, 1987), many other studies (e.g. Ruhiyat, 1989; Mackensen, 1999) concluded that huge nutrient deficiencies would result after several years in the burnt area. Fire will also increase bulk density and decrease soil porosity as a result of the very fine textured ash filling the soil macropores (Kusumandari, 1999). The nutrients are not replenished from the biomass above the ground and atmosphere (through rainfall). This is very common in Kalimantan and Sumatra, where the soils are seriously weathered and of poor quality.

Table 1-5 shows that in an oil-palm plantation established without using fire, fertilisation will account for at least 60 to 70% of nurturing cost, or 40 to 47% and 38 to 44% of the total costs of land and plant development in dryland and peat soil respectively. This is obviously one of the main reasons for HTI companies to use fire in land clearing. Additionally, most of HTI companies are geared towards short-term gains because the concession contract in Indonesia is limited to only 2-3 felling periods without any guarantee that the permit can be extended.

One other advantage of using fire is the speed and effectiveness of clearing all the wastes during the dry season. As noted in the HTI development in West Kalimantan (Table 1-4), fire can ‘clear’ 7.5 ha forest in less than four days with a satisfactory result while a tractor needs in average 10-14 hours to clear one hectare of land.

Appendix 2: Effect of fire and biomass removal on the monetary value of nutrient stocks contained in standing biomass

Thomas Fairhurst[2]

Impact of clearing rainforests on soil fertility

The natural land cover in much of South East Asia is rainforest. However, over the past 50 years the population of the region has grown from approximately 180 million to over 500 million inhabitants. Large areas of land have been cleared to meet the increased demand for food (e.g. rice, sweet potato, maize) and traded agricultural commodities (e.g. coffee, cocoa, sugar, palm oil).

Nutrient cycling in forest systems

The paradox of luxuriant vegetation growing on infertile soils is very striking and has sometimes led to the misconception that soils under tropical rainforest are very fertile. In fact, the rainforest can grow on very nutrient poor soils because it has a closed nutrient cycle. Natural forests are not affected by large nutrient losses through processes such as biomass removal, leaching, or erosion that occur in agricultural systems. When rainforest plants take up nutrients from the soil (or obtain them from the atmosphere), they are returned to the soil through leaf wash, plant death, root death, or when leaves, twigs and trees fall to the forest floor and decompose. Only small amounts of nutrients are lost through erosion because the soil is protected by the forest canopy and leaching losses are small because of efficient nutrient recycling.

The litter layer on the forest floor protects the soil surface and is itself protected from the sun and rain by the forest canopy cover. The forest floor environment favours biological activity, resulting in the rapid decomposition and release of nutrients from dead vegetative matter. Nutrients are readily re-absorbed by the large number of tree roots that grow in the fertile litter layer beneath the forest floor.

Once the rainforest has been removed, the delicately balanced cycle of nutrients between soil and above ground vegetation as well as the processes that prevent nutrient losses are disturbed. Table 2-1 shows the permanent changes to the soil if the forest is cleared. Most acid upland soils cannot support agricultural cropping systems without the implementation of soil conservation practices and the addition of fertiliser nutrient inputs. Some of the *temporary* changes that result from forest clearing are listed below:

- Single, large addition of nutrients to the soil surface when the biomass is burnt.
- A temporary increase in pH and base saturation of the topsoil.
- Very irregular distribution of nutrients across the soil surface as a result of clearing and burning practices.
- Poor soil tilth following the irreversible dehydration of soil particles because of high temperatures during burning.

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- Short-term decrease in microbial activity, followed by a sudden large increase.
- Loss of protective forest canopy, which affects temperature and water balances.
- Loss of protective mulch layer on the forest floor.
- Reduced organic inputs to replenish soil organic matter (SOM).

Table 2-1: Permanent changes to the soil following land clearing and burning

Factor	Before clearing	After clearing
Soil surface temperature	Uniform, 24-28°C	Wide variation, 23-52°C
Soil surface moisture	Uniformly moist	Extreme variation
Leaching	Minimal	Substantial
Surface erosion	Minimal	Substantial
Soil structure	Stable	Variable
Nutrient cycle	Closed	Open
Organic matter cycle	Closed	Open
Organic matter content	Constant	Decreasing
CO_2 production and release	High and uniform	Low and irregular

Nutrient cycling in agricultural systems

In many food crop agricultural systems, soil losses due to erosion, leaching, and volatilisation (losses to the atmosphere) are large because of the lack of soil cover. In contrast to the forest floor, the soil surface in most agricultural systems is periodically exposed and subjected to extremes of heat and moisture. This reduces biological activity and makes it difficult for plant roots to grow near the soil surface where most of the nutrients are located.

Unlike undisturbed forests, agricultural systems sustain large nutrient losses due to nutrient removal in crop products, crop residues and harvested biomass. In addition, nutrient inputs added in agricultural systems can exceed the capacity of the soil to retain nutrients and may result in large leaching and/or volatilisation losses.

The effect of fire on the economic value of nutrients contained in standing biomass

In the short term, fire is often the least costly method of land clearing and is an efficient means to convert nutrients contained in the standing biomass into nutrients available to crop plants. These are the reasons why fire is sometimes the preferred land clearing method of small-scale farmers and plantation developers in the outer islands of Indonesia.

A 'climax' vegetation results when land is left undisturbed for long periods of time. In the humid tropics, the climax vegetation is tropical forest and most cleared land will revert to some form of forest cover if left undisturbed. *Imperata cylindrica* grassland or 'alang-alang' is the predominant climax vegetation when land is cleared and subject to recurrent episodes of fire. (Galleries of vegetation dominated by alang-alang sometimes developed within predominantly forest systems, however, even without human intervention, and were one of the reasons why indigenous populations of cattle were larger in prehistoric times in parts of Java compared with Sumatra). Other man-made climax vegetation types include tree crop plantations. For this discussion five types of above ground biomass are considered:

- oil palm plantations;
- rubber plantations;
- primary forest;
- secondary forest; and
- *Imperata cylindrica* grasslands.

Economic value of nutrients

An economic value can be attributed to the nutrients contained in the standing biomass when they are taken up by crop plants and contribute to the production of crop products. The economic value of the nutrients contained in the standing biomass is a function of:

- amount of standing biomass, affected by the vegetation type (e.g. *Imperata cylindrica*, tree crops, primary forest, secondary forest) and the length of time the above ground biomass has been allowed to accumulate;
- concentration of nutrients in the biomass (a function of the vegetation type);
- effect of indigenous soil fertility and applied nutrients (e.g. fertilisers) on the amount and nutrient concentration of the standing biomass;
- amount of biomass containing nutrients that are *removed* from the field (for sale, e.g. timber, or on-farm use, e.g. animal fodder);
- effect of fire on nutrient availability (e.g. losses of N due to volatilisation, losses of P and Mg due to surface run-off and erosion following burning, losses of K due to leaching in the absence of crop plants); and
- presence of crop plants to take up nutrients made available after land clearing and burning.

Thus, burning or the use of fire can be assessed in terms of its quantitative and qualitative effects on the nutrient capital contained in the standing biomass. For this purpose, a simple model is constructed to compare the effect of biomass removal and fire on the value of nutrients contained in standing biomass. The cost of nutrients is based on their equivalent in mineral fertiliser (N=urea, P=TSP, K=KCl, Mg=kieserite and Ca=agrilime) (Table 2-2). For each of the five vegetation types, the effect of biomass removal and burning on the economic value of the nutrients contained in the biomass are examined (Tables 2-3 to 2-6).

Table 2-2: Cost of nutrients based on fertiliser equivalents

Nutrient	Fertiliser	US$/kg	% oxide	% element	US$/kg of element
N	Urea	0.126	46	46	0.274
P	TSP	0.197	46	20	0.973
K	KCL	0.180	60	50	0.361
Ca	Lime	0.027	30	21	0.127
Mg	Kieserite	0.160	27	16	0.988

Larger amounts of biomass are contained in primary forest, oil palm and rubber plantations compared with *Imperata cylindrica* grasslands where the standing biomass is small (Table 2-3). The amount of biomass contained in secondary forest varies widely, depending on the amount of timber removed during logging. Forest, rubber and oil palm standing biomass contain large amounts of N, P, K, Ca and Mg compared with *Imperata cylindrica* grassland. For all vegetative types, the amount and nutrient concentration in the standing biomass is strongly influenced by soil fertility and management practices.

Table 2-3: Nutrient contents in standing biomass

Dry matter	Standing biomass (t/ha)	Nutrient content in biomass									
		N		P		K		Ca		Mg	
		kg/t	kg/ha*	kg/t	kg/ha	kg/t	kg/ha	kg/t	kg/ha	kg/t	kg/ha
Imperata	7	1.7	11.9	3.3	23	5.6	39	3.5	25	2.8	20
Oil palm	90	5	450	0.45	41	6	540	2	180	1	90
Rubber	200	9	1,800	1.4	280	6	1,200	10	2,000	2	400
Secondary or logged forest	150	4.2	630	0.26	39	2.67	401	2.81	422	0.95	630
Unlogged prim. forest	300	4.2	1,260	0.26	78	2.67	801	2.81	843	0.95	285

* kg/ha = standing biomass (t/ha) x kg/t.

Based on the figures in Table 2-2 and 2-3 the economic value of nutrients contained in the biomass is computed (Table 2-4). It ranges from US$ 1,800 (rubber) to US$ 60 (*Imperata cylindrica*). The value of nutrients contained in the standing biomass increases in the order *Imperata cylindrica*<oil palm<belukar< unlogged forest<rubber. The proportion of each nutrient differs substantially for each vegetation type. The value of N ranges from about 5% (*Imperata cylindrica*) to 31% (forest vegetation). In contrast, *Imperata cylindrica* contains 36% of P but forest vegetation has only only 7% of the nutrient.

Table 2-4: Value of nutrients in standing biomass

Value (US$/ha)						
	N	P	K	Ca	Mg	Total
Imperata	3	22	14	3	19	62
Oil palm	123	39	195	23	89	470
Rubber	493	273	434	254	395	1,848
Sec. or logged forest	173	38	145	53	141	549
Unlogged forest	345	76	290	107	281	1,099
Percentages of each element in the total value						
	N	P	K	Ca	Mg	Total
Imperata	5	36	23	5	31	100
Oil palm	26	8	42	5	19	100
Rubber	27	15	23	14	21	100
Sec. or logged forest	31	7	26	10	26	100
Unlogged forest	31	7	26	10	26	100

Nutrients are lost from the system irrespective of the method of land clearing due to the effect of fire, erosion, leaching and surface run-off on nutrients released from biomass following burning or decomposition (Table 2-5). Losses after burning are amplified by the lack of soil cover, which results in greater rates of erosion and surface run-off. In the model, losses are assumed to be greater following burning because:

- almost all the N contained in the biomass is lost due to volatilisation;
- the amount of nutrients released after burning is too great to be stored in the soil;
- crop plants are unable to absorb the large amount of nutrients released after burning (e.g. oil palm requires much less nutrients during its immature growth period than is released from burning unlogged forest vegetation); and
- large amounts of nutrients are likely to be washed away by surface run off and erosion.

Table 2-5: Percentage of nutrients available after burning versus zero-burning

	Nutrient available (%)				
	N	P	K	Ca	Mg
Burning	10	50	50	60	60
Zero-burning	70	80	80	80	80

Thus, the value of nutrient stocks decreases following land clearing. The value of nutrients contained in *Imperata cylindrica* is reduced from US$ 62 before burning to US$ 50 after land clearing and to US$ 16 when half the biomass is removed and the remainder is burnt. The value of nutrients contained in rubber is reduced from US$ 1,848 before burning to US$ 1,429 after land clearing and to US$ 396 when half the biomass is removed and the remainder is burnt (Table 2-6).

Table 2-6: Value of nutrients available after burning versus zero-burning (US$/ha)

Vegetation type	Quantity of biomass removed (half/none)		N	P	K	Ca	Mg	Total
Imperata	Half	Burning	0	6	4	1	6	16
		Zero-burning	1	9	6	1	8	25
	None	Burning	0	11	7	2	12	32
		Zero-burning	2	18	11	2	15	50
Oil palm	Half	Burning	6	10	49	7	27	98
		Zero-burning	43	16	78	9	36	182
	None	Burning	12	20	98	14	53	197
		Zero-burning	86	32	156	18	71	363
Sec or logged forest	Half	Burning	9	9	36	16	42	113
		Zero-burning	60	15	58	21	56	211
	None	Burning	17	19	72	32	84	225
		Zero-burning	121	30	116	43	113	422
Rubber	Half	Burning	25	68	108	76	119	396
		Zero-burning	173	109	173	101	158	715
	None	Burning	49	136	217	152	237	792
		Zero-burning	345	218	347	203	316	1429
Unlogged forest	Half	Burning	17	19	72	32	84	225
		Zero-burning	121	30	116	43	113	422
	None	Burning	35	38	145	64	169	450
		Zero-burning	242	61	232	85	225	845

These estimates underline the importance of taking into account the effect of biomass utilisation and burning on the value of nutrient stocks. No attempt has been made to quantify the effects of returning organic residues to the soil in terms of their contribution to soil organic matter replenishment and thus soil fertility.

The nutrients released from the biomass following land clearing or burning are not utilised in one year. Some assumptions are made about the effect of burning on the availability of nutrient stocks over a five-year period following burning. Clearly, the benefit stream from nutrient stocks contained in the standing biomass is greater when the biomass is allowed to decompose compared with the effect of burning (Table 2-7).

Table 2-7: Percentage of the nutrients available each year

	Year					Total
	1	2	3	4	5	
Burning	80	20	0	0	0	100
Zero-burning	40	30	15	10	5	100

Conclusions

When assessing fire as a management tool, a key aspect is its effect on nutrient stocks and thus the economic potential of the land. The utility of fire as a land-clearing tool must be offset against the large losses of nutrients that occur when the biomass is transformed into 'fertiliser'. Where burning is practised, great care should be exercised to ensure the maximum retention of nutrients released from the standing biomass by:

- installing soil conservation measures (bunds, hedgerows), and
- establishing actively growing crop plants that take up nutrients (e.g. legume cover plants in oil palm and rubber plantations).

If the value of the biomass is greater than its equivalent in terms of mineral fertilisers, it may be more prudent to sell the biomass and buy mineral fertilisers.

Appendix 3: Industrial timber plantation and its fertilisation aspect

Rainforest conversion implies a disturbance of the nutrient cycle and nutrient loss through biomass export, burning and leaching. Similar repeated disturbances are characteristic for plantation forestry in the tropics and endanger its sustainability. Many researches on soil fertility in the tropics and its relation to industrial timber plantation management have been conducted. Most of them focused on specific aspects of soil fertility and only few concentrated on the impact of fire use on soil fertility that can be differentiated through forest (or other land-use form) conversion into plantation, and during rotational plantation disturbance.

Two of the most comprehensive studies on the impact of plantation management's fire use on soil fertility are summarised here. The first series was conducted by the Study of Human Impact on Forests and Floodplains in the Tropics (SHIFT), a German-Brazilian co-operative research project) in Belem-Para, Brazil to analyse the impact of forest conversion using fire on the soil fertility. The details of the studies can be found in Klinge *et al*., (2001). The second study was carried out in East Kalimantan, Indonesia to investigate the sustainability of nutrient supply in fast growing tree plantations (Mackensen, 1998; Mackensen, 1999; Mackensen and Foelster. 1999; Simorangkir and Mackensen, 2000).

Nutrient loss through forest conversion into plantation

During 15 months' research in in Belem-Para, Brazil, 3 plots of 0.25 ha each were established in a tropical lowland rainforest, which was partially exploited more than 40 years ago, on poor and deeply weathered *ferralsols*. Two plots (A and B) were clear-cut and stem biomass was removed manually with the least disturbance, while a third plot remained under forest as a control (C). A residual biomass (leaves, twigs, branches) of 33 t/ha (A) and 92 t/ha (B) were left to dry and burnt two months after the clear cutting. Three months later, three-month old *Eucalyptus urophylla* seedlings were planted in both plots. The plots were frequently weeded for six months but only once afterwards.

The comparison on element stores of the 3 plots before (Table 3-1) and after (Table 3-2) the experimental phase of 15 months shows that the clear cutting, and the following removal of stem biomass and burning of the residual biomass did not have any significant positive impact on soil fertility:

- Negative changes were found in C and N of plots A and B in all depth zones. As 94-98% of above ground C and N were lost to the atmosphere during the fire, replenishment to the soil could not be expected.
- An increase of 20-28% of P in 0-10 cm depth of A and B could at least partly be explained by leaching from the residual biomass before burning.
- The 'ash effect' on the pH was still apparent 12 months after the burn. However, the deeper the soil, the weaker the increasing of pH was. It was found only in the upper 5 cm and in 5-10 cm depth (in B only).
- Ca stores in the soil increased considerably, mainly in the 0-10 cm depth zone. Mg and K were still visible in B though K had been leached and

was concentrated in the soil below 30 cm. Na was presumably leached beyond 110 cm and showed no increase after one year.

- Ca concentrations reacted strongly to clear cutting and burning. In 25 cm depth, the peak subsided several months after clear cutting and burning. The peaks at the depths of 40, 60 and 110 cm decreased over time and the concentrations hardly exceeded the control's. NO_3, Mg, Cl, and Na concentrations showed almost identical patterns. All these elements reacted very strongly to clear cutting, partly reflecting the leaching from the above ground residual phytomass and the dead fine roots. However, the fast and strong reaction of NO_3 showed that mineralisation and nitrification of the dead roots started immediately after cutting. Furthermore, the pattern of K concentrations was basically similar to that of Ca but the reaction was retarded. Only several months after clear cutting and burning, the concentration in A fell almost to the level of the control. In B, the concentrations fluctuated between 3 and 10 mg/l but without a vertical order of depth zones. This was also observed in the case of Na. The retarded reaction of K was not yet well understood as K is normally released very fast from organic debris. The pattern may possibly result from a complex interaction with Ca.

In total, the conversion of forest into plantation using fire resulted in a negative balance of element stores and element as shown in Table 3-3.

Table 3-1: Element stores, pH, and effective exchange capacity of the soils before the experiment (means of plots A, B and C)

Depth (cm)	pH_{CaCl2}	C	N	P	H	Na	K	Ca	Mg	Fe	CECe (mmol/kg)
		(kg/ha)									
0- 5	3.5	13,464	904	30.1	3.32	31.8	21.1	132.3	17.7	13.2	2.65
5-10	3.6	9,129	644	27.8	1.51	29.7	13.2	38.7	8.1	12.6	2.19
10-20	3.8	14,040	994	53.1	0.21	62.4	17.4	58.4	12.0	15.4	1.86
20-30	4.0	11,556	790	47.9	0.00	61.5	15.0	43.3	9.8	8.5	1.68
30-50	4.1	19,187	1,405	116.3	0.00	120.7	20.8	61.0	14.8	10.5	1.53
50-80	4.1	21,518	1,634	155.8	0.00	188.1	29.0	85.6	20.4	11.6	1.31
80-100	4.1	6,960	584	66.8	0.00	84.2	14.0	37.3	9.6	1.6	1.11
0-100		**95,855**	**6,955**	**497.7**	**5.05**	**578.4**	**130.5**	**456.6**	**92.3**	**73.5**	

Table 3-2: Difference between element stores of plots A, B and C (control) before and at the end of the experiment, in kg/ha and in % of original stores*

Plot	Depth	C (%)	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	Fe (%)	Al (%)
A	0-10	-6,534 (-25)	-340 (-20)	9 (20)	-16 (-50)	215 (104)	7 (27)	-23 (-81)	-62 (-54)
	10-30	-4,237 (-16)	-341 (-20)	-2 (-2)	-11 (-41)	-0 (-1)	-2 (-13)	8 (43)	16 (5)
	30-100	-3,670 (-10)	-803 (-26)	-160 (-40)	-7 (-8)	45 (33)	-3 (-7)	24 (101)	182 (18)
	0-100	-14,442 (-15)	-1,483 -23)	-153 (-29)	-34 (-30)	260 (64)	2 (3)	9 (11)	136 (10)
B	0-10	-1,398 (-5)	-214 (-12)	18 (28)	-10 (-19)	1, 085 (439)	38 (139)	-19 (-88)	-127 (-80)
	10-30	-1,204 (-5)	-394 (-21)	-4 (-4)	11 (34)	80 (54)	10 (32)	4 (22)	-22 (-6)
	30-100	-4867 (-13)	-1244 (-33)	18 (4)	112 (194)	47 (30)	-4 (-7)	13 (43)	81 (7)
	0-100	-7,470 (-8)	-1,852 (-24)	32 (8)	113 (82)	1,213 (221)	43 (43)	-3 (-5)	-68 (-4)
C	0-10	-2,458 (-13)	-179 (-13)	-18 (-27)	-6 (-22)	-35 (-26)	-6 (-22)	-8 (-30)	-0 (-1)
	10-30	-2, 589 (-11)	-222 (-14)	-22 (-20)	-10 (-32)	-26 (-28)	-4 (-22)	-5 (-21)	36 (11)
	30-100	-2,306 (-6)	-667 (-19)	-168 (-44)	-32 (-44)	6 (4)	-8 (-17)	-0 (-8)	167 (21)
	0-100	-7,353 (-8)	-1,068 (-16)	-208 (-37)	-49 (-35)	-55 (-13)	-18 (-19)	-14 (-18)	202 (16)

* negative figures indicate apparent loss .

Table 3-3: Balance of element stores and element fluxes during conversion of rain forest on plots A and B (in kg/ha)

	Bio-mass (t/ha	C	N	P	Na	K	Ca	Mg	S
Plot A									
Element loss by wood export	(279)	140	1,397	46	116	688	1397	175	206
Element loss by fire		15	325	2	3	7	44	7	26
Element loss by leaching			166	2	107	66	77	31	8
Total flux loss by conversion		155	1,889	49	226	761	1517	212	240
Element input by rain			8	3	26	4	9	2	6
flux balance		-155	-1,880	-46	-200	-756	-1,508	-210	-234
Plot B									
Element loss by wood export	(223)	112	828	22	65	330	712	96	160
Element loss by fire		42	804	7	10	87	189	40	70
Element loss by leaching			211	2	166	165	102	29	20
Total flux loss by conversion		154	1843	31	241	583	1,004	165	220
Element input by rain			8	3	26	4	9	2	6
flux balance		-154	-1,835	-28	-215	-579	-995	-162	-214

The elements contained in the residual phytomass after clear cutting and the amount lost by burning and leaching are of special importance for plantation forestry. The loss expressed as percentage of the residual store indicates the extent the released elements can be stored in the soil. High losses reflect strong volatilisation during the burn (C, S), additional decomposition of below ground biomass (Nt) and/or a high leaching rate (Na) (Table 3-4). When applying the results to plantation rotations, one should keep in mind that the quantity of root mass is probably smaller, and less NO_3 will be released. Ruhiyat (1989) had suggested that the nutrient content of the residual phytomass might correspond to the loss by burning and leaching. This assumption is applicable in the sense that the loss is related to the nutrient store in the residual phytomass but has to be corrected by an element-specific factor.

Table 3-4: Comparison of element stores in the residual phytomass and element losses by burning and leaching on plot A and B (in kg/ha)

	C (t/ha)	N	P	Na	K	Ca	Mg	S
Plot A								
Element store in residue	16	343	9	18	109	330	37	42
Element loss by burning and leaching	15	491	3	110	73	120	37	34
Loss in % of residual store	94	143	38	595	67	36	100	81
Plot B								
Element store in residue	46	854	29	59	392	848	100	113
Element loss by burning and leaching	42	1015	8	176	253	292	69	90
Loss in % of residual store	91	119	29	298	65	34	69	80

It can be concluded that the clearing the forest for conversion to plantation, where the stem biomass were removed and the residual phytomass were burnt (slash-and-burn technique), did not improve the soil fertility significantly. It even resulted in negative balance of element stores in the soil. Except a slight increase of pH value through the 'ash-effect' for several years, almost all vital nutrients decreased after a certain period. In long term it seems that the ecological and economic sustainability of plantation can only be guaranteed if the removal of biomass is kept minimum and the use of fire is avoided. This aspect is very critical given the rapid speed of plantation development in Indonesia. Until now 3.5 million ha of HTI has been established and the target is to extend it 10.5 million ha by the year of 2030. Over 90% of the land used for these plantations have highly weathered soils with a moderate to poor supply of nutrients (*alfisols, acrisols, ferralsols* and *arenosols*).

Nutrient loss during rotational plantation disturbance

Plantation management can change soil nutrient storage and therefore soil fertility and productivity of stands. Successive and intensively managed plantation crops can be expected to deplete the soil nutrient storage depending on the management in short cycles. A series of study about plantation management, including the nutrient management and fertilisation, have been conducted for many years in the concession area of PT. IHM in East Kalimantan, Indonesia (see Mackensen, 1999). Researches were conducted in *Acacia mangium* and a *Eucalyptus deglupta* stands, on standard soil types (*alisols* and *acrisols*) with an assumed standard harvest volume of 200 m^3/ha. Table 3-5 shows that the total nutrient losses in amount approximately to 690 kg N, 13 kg P, 280 kg K, 250 kg Ca and 45 kg Mg per ha in *Acacia mangium* stands, and to 430 kg N, 12 kg P, 370 kg K, 180 kg Ca and 60 kg Mg per ha in *Eucalyptus deglupta* stands.

Table 3-5: Absolute and relative values for nutrient losses*

	N		P		K		Ca		Mg	
	kg/ha	%	kg/ha	%	kg/ha	%	kg/ha	%	kg/ha	%
Acacia mangium										
Harvesting losses	202	*29*	2.6	*21*	73	*26*	161	*64*	10	*22*
Atmospheric losses	329	*48*	2.5	*20*	113	*41*	63	*25*	20	*45*
Extra leaching	84	*12*	0.1	*1*	86	*31*	8	*3*	10	*22*
Erosion losses	77	*11*	7.4	*59*	4	*2*	20	*8*	5	*10*
Sum	692	*100*	12.6	*100*	276	*100*	252	*100*	45	*100*
Eucalyptus deglupta										
Harvesting losses	75	*18*	3.7	*30*	206	*56*	85	*48*	21	*37*
Atmospheric losses	219	*51*	1.1	*9*	91	*25*	64	*36*	21	*37*
Extra leaching	56	*13*	0.1	*0*	69	*19*	9	*5*	10	*18*
Erosion losses	77	*18*	7.4	*60*	4	*1*	20	*11*	5	*8*
Sum	427	*100*	12.3	*100*	370	*100*	178	*100*	57	*100*

* based on harvesting volume of 200 m^3/ha

In both plantation stands, almost all nutrient losses through harvesting were smaller then the sum of losses caused by clearing the land (slash) and burning of residual biomass (atmospheric, leaching and erosion losses). An exception was found only for K under *Eucalyptus deglupta* stand, where wood harvest caused 56% of the nutrient losses. Atmospheric losses (burning) were responsible for the largest N and Mg losses under both species and the largest K losses under *Acacia mangium*, while erosion caused the largest P losses for stands of both species.

Such high rates of nutrient depletion will determine the sustainability of plantations. Further research of the same plantation sites showed that after only a few rotations of successive land clearing, wood export and burning residual biomass, the nutrient losses would deplete the total storage of exchangeable soil nutrients. Table 3-6 showed that while the storage of P and Mg on average plantation sites in East Kalimantan (*alisols, acrisols*) were sufficient for more than five rotations, the storage of N, K, and Ca would be depleted within a few rotations, assuming constant conditions. However, this is just an indication of the extent of management-dependent nutrient losses on sites with low nutrient supplies but not the absolute number of possible rotations. Constant conditions as assumed for the calculation of the site nutrition potential are, however, unlikely. It can be expected that the stand productivity will decrease continuously on intensively managed sites. A reduction in site productivity is a common feature for second and third rotation stands on low fertile soils.

Table 3-6: Site nutrient potential for selected sites at PT. IHM, East-Kalimantan, based on storage of plant-available nutrients*

	N	P	K	Ca	Mg
Acacia mangium					
Average ali-/acrisol (ultisol)		>10	3-4	5	>10
Average ferralsol (oxisol)		6	1-2	3	6
Calcisol		>10	2-3	infinite	10
Eucalyptus deglupta					
Average ali-/acrisol (ultisol)	3	>10	3	6	10
Average ferralsol (oxisol)	2	6	1-2	4	5
Calcisol	2-3	>10	2-3	infinite	10

* Numbers represent the theoretical number of rotations possible per element.

To maintain site productivity despite nutrient losses, it is necessary to replenish the soil with mineral fertilisers. However, in industrial plantation, fertilisation is still considered uneconomical. This view is based on concepts developed for temperate forests, where nutrient depletion generally is negligible over the course of long rotation periods and nutrient supply is maintained by inputs via rainfall or weathering. Fertilisation is also costly because applications were usually needed at early stages of site establishment the first return to investments are seen.

It is necessary to consider the timing and location of fertiliser application, as well as the fertiliser's effectiveness. It is assumed that the magnitude of nutrient losses is comparable for a wide range of sites and that nutrient depletion is faster on poorer sites. On poorer sites (*ferralsols* and poorer *acrisols*), fertilisation is to be applied earlier and in shorter intervals. On relatively fertile soils, such as *alisols* on lower slopes, fertilisation may be necessary in much smaller amounts or might become relevant only during later rotations. Furthermore, the fertiliser applied will not be absorbed entirely by the plants. A certain percentage will be lost through leaching, volatilisation or immobilisation. The proportion of fertiliser used by the plant represents the fertiliser efficiency. The efficiency rate depends mainly on the type of fertiliser, soil and climate conditions and the application management.

Based on the extent of nutrient losses, different fertiliser types available on the market and efficiency rates, the fertiliser doses necessary to compensate for N, P and K losses was estimated (Table 3-7). It is assumed that *Acacia mangium* does not need N fertilisation because of its nitrogen-fixing ability.

Table 3-7: Quantity of N, P and K fertiliser necessary to compensate management-dependent nutrient losses in industrial plantations*

Element/species	Loss kg/ha	Type of fertiliser (element concentration) *Assumed fertiliser efficiency*							
N		**NPK** (13%N)		**Urea** (46% N)		**NH_4NO_3** (35%N)		**Nitrate** (16%N)	
Eucalyptus deglupta		***50***	***70***	***50***	***70***	***50***	***70***	***50***	***70***
harvesting losses	75	1,155	825	323	233	428	308	938	668
atmospheric losses	219	3,373	2,409	942	679	1,248	898	2,738	1949
extra leachIng losses	56	862	616	241	174	319	230	700	498
erosion losses	77	1,186	847	331	239	439	316	963	685
sum	**427**	**6,576**	**4,697**	**1,836**	**1,324**	**2,434**	**1,751**	**5,338**	**3,800**
		NPK (5.7%P)		**TSP** (22%P)		**CIRP** (15.8%P)		**SP** (8%P)	
Acacia mangium		***10***	***40***	***10***	***40***	***10***	***40***	***10***	***40***
harvesting losses	2.6	466	116	118	30	165	41	325	81
atmospheric losses	2.5	448	112	114	29	158	40	313	78
extra leachIng losses	0.1	18	4	5	1	6	2	13	3
erosion losses	7.4	1,326	332	337	84	468	117	925	232
sum	**12.6**	**2,258**	**564**	**573**	**144**	**798**	**199**	**1,575**	**394**
Eucalyptus deglupta									
harvesting losses	3.7	663	166	168	42	234	58	463	116
atmospheric losses	1.1	197	49	50	13	70	17	138	34
extra leachIng losses	0.05	9	2	2	1	3	1	6	2
erosion losses	7.4	1,326	332	337	84	468	117	925	232
sum	**12.25**	**2,195**	**549**	**557**	**140**	**775**	**194**	**1.531**	**383**
		NPK (17.4%K)		**KCL** (50%K)		**KCl** (40%K)		**K_2SO_4** (33%K)	
Acacia mangium		***50***	***70***	***50***	***70***	***50***	***70***	***50***	***70***
harvesting losses	73	840	599	292	212	350	248	445	314
atmospheric losses	113	1300	927	452	328	542	384	689	486
extra leachIng losses	86	989	705	344	249	413	292	525	370
erosion losses	4	49	35	17	12	21	15	26	18
sum	**276**	**3.177**	**2266**	**1.105**	**801**	**1.326**	**939**	**1.685**	**1.188**
Eucalyptus deglupta									
harvesting losses	206	2.369	1.689	824	597	989	700	1.257	886
atmospheric losses	91	1.047	746	364	264	437	309	555	391
extra leachIng losses	69	794	566	276	200	331	235	421	297
erosion losses	4	49	35	17	12	21	15	26	18
sum	**370**	**4,258**	**3,036**	**1,481**	**1,074**	**1,777**	**1,259**	**2,259**	**1592**

* Calculation of losses refers to standard site management including slash burning and average harvest of 200 m^3/ha.

The lowest fertiliser doses are needed if urea, TSP and KCL are used. The amounts applied are also a question of costs and availability. To compensate for all occurring N losses in *Eucalyptus deglupta* stands, between 4-6 kg NKP or 1.2-1.65 kg urea per tree are needed. That is several times the amount normally used for growth enhancement. To compensate for the N losses resulting from harvesting of stems at least 0.2 kg urea per tree is needed. The amounts of P and K are equally large. To compensate for total P losses up to 0.5 kg of TSP per tree are required. To compensate for the harvesting losses up to 0.15 kg of TSP per tree must be applied. To compensate total K losses with high concentrated KCL, 0.72-1.4 kg per tree would be needed, while 0.19-0.74 kg per tree need to be applied to compensate for K losses resulting from harvesting.

It is concluded that the replenishment of nutrients will require immense amounts of fertilisers per site. Economically, this is a huge cost for plantation estates; especially if such calculations were not incorporated in the investment plans. Table 3-8 shows the costs for different variants of fertiliser that are necessary to replace the nutrient losses. The percentage values are based on a standard fertiliser application using 100 g NPK, 40 g TSP and 840 g dolomitic limestone per tree, with a stand density of 800 trees per ha. Such an appliation amounted to US$ 88 (Rp 193,680) per ha in 1996/97. If the same fertiliser combination were to be applied to replace the total management nutrient losses (Min_{200}), the expenditure on fertilisers would increase by 2,229% for *Acacia mangium* or 1,256% for *Eucalyptus deglupta*. Even by the most optimal fertiliser combination and very low nutrient losses, the costs to replace the total losses are 281% (for *Acacia mangium*) or 434% (for *Eucalyptus deglupta*) higher if compared with the company's current expenditure for fertilisers. It is important to see that by avoiding slash burning (Alt_{200}), the cost of fertilisers can be reduced from US$ 800 (standard fertiliser) to US$ 65 per ha (optimal fertiliser combination) or from US$ 545 to US$ 117 per ha for *Acacia mangium* and *Eucalyptus deglupta* stands respectively.

Table 3-8: Costs of fertilisation in case of compensation of total nutrient losses for the management variants Min_{200} and Alt_{200}

Variant	*Acacia mangium*				*Eucalyptus deglupta*			
	Min_{200} [a]		Alt_{200} [b]		Min_{200} [a]		Alt_{200} [b]	
	US$/ha	%	US$/ha	%	US$/ha	%	US$/ha	%
Standard (NPK, TSP, dolomit)	1,962.55	**2,229**	1,164.37	**1,323**	1,105.30	**1.256**	560.43	**637**
Standard (NPK, TSP, dolomit), without NPK-N	865.76	**983**	544.34	**618**				
Alternative fertilisers (urea, TSP, potash, dolomit)	530.33	**602**	368.19	**418**	499.81	**568**	382.34	**434**
Alternative fertilisers (TSP, potash, dolomit), no N fertilisers	311.46	**354**	246.94	**281**				

* All costs related to 1996/97 (US$ 1 = Rp 2,200).

[a] harvest volume: 200 m^3, minimal losses by leaching, burning and erosion.

[b] harvest volume: 200 m^3, no burning, minimal losses by reduced leaching and erosion.

[c] related to the costs of standard fertilisation application (US$ 88 per ha).

In summary, replacing nutrients in intensively managed timber plantations constitutes a major operating cost. While standard fertiliser applications account for an average of 4% of the plantation's total costs, the costs necessary to replace the expected nutrient losses range from 9 to 40% of the plantation's total costs depending on the species, site management and fertiliser. Besides, it is likely that the increase in costs is even higher since additional costs (e.g. for planning, infrastructure, research or training) are not considered in this estimation.

Such high costs for mineral fertilisers make alternatives to fertilisers a an attractive option for industrial plantation management. Soil and nutrient maintenance is generally used to keep management-dependent nutrient losses small. Major aspects to consider include selection of appropriate sites, discontinuation of slash-burning, use of low-impact harvesting techniques and restricted area access of machinery, minimising erosion, cover crop and undergrowth management, species matching and species change. Two other activities can be added: N fertilisation through use of N-fixing tree species or the combination of species (e.g. *Eucalyptus spp.*) with N-fixing trees (e.g. *Acacia spp.*), and the use of bark residues in the form of mulch or ash. The planting of N-fixing species or mixing of those species with non N-fixing trees is especially promising on N deficient soils (such as the poor sites in the Kalimantan study). N-fixing species are known to fix any amount of up to 500 kg N/ha/a and thus enrich soil N storage through higher inputs via mineralisation.

Finally, stopping slash burning is the single most important factor to improve nutrient management. Slash burning results in atmospheric nutrient losses and triggers further leaching and erosion losses. Arguments for slash burning often rely on the need to clean the site prior to planting, to facilitate access and allow for better planting rates and prevent bushfires. However, many of these arguments are based on traditional management concepts. The use of slash cutting machines or the establishment of planting lines might be economically comparable to slash burning if manpower and nutrient replacements are reduced. Many trials with *Acacia mangium* proved a higher productivity on unburnt sites compared to burnt sites.