Zero Burning Techniques in Oil Palm Cultivation: an Economic Perspective

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ABSTRACT

Land clearing for oil palm cultivation used to be undertaken by the clean clearing method, which included burning and re-burning of biomass. The method pollutes the air and is costly to the society. The government of Malaysia had imposed a ban on open burning in 1998. A financial and economic analysis of various zero burning techniques of land clearing for oil palm cultivation indicated that the techniques bring higher return compared to the clean burn method. The benefits of the zero burning techniques, in addition to cost saving from pollution related problems, include faster returns, and savings in fertilizer input from nutrient recycling and soil preservation. Hence, in addition to abiding with the law, zero burning technique of land clearing earns additional financial and economic benefits.

INTRODUCTION

The traditional method of establishing new oil palm plantations or replanting is the clean clearing technique. Forest or old palm stands are felled, stacked and burnt, releasing extensive amount of smoke to the environment. This method of land clearing for oil palm cultivation is no longer acceptable because it pollutes the environment. The burn method has been replaced by the no-burn technique, which is both environmentally friendly and economically superior to the burn method (Mohd Hashim *et al*., 1993). In addition, the practice of burning felled biomass has been banned by the government of Malaysia, as a direct response to the persistent haze problem, which peaked in 1997. Since early 1998, deliberate open burning can result in a maximum penalty of RM 0.5 million.

The haze problem is not a recent feature in the environment of Southeast Asian countries, but it had been more frequent in the 1990s, worsening to a peak from September to October 1997. Previous haze problems were thought to be due to volcanic eruptions, forest fires, open burning and vehicle emissions (Shahwahid and

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Jamal, 1998). Forest burning for agricultural land clearing was not a common practice in the distant past, as revealed by charcoal tracing dating back 17 500 years (Wakker, 1998). The haze problem experienced in Southeast Asia in 1997 was largely due to the forest fire disaster in Indonesia. About 50% of the major burn was attributed to agricultural/plantation sources (Economic and Environment Programme for Southeast Asia and World Wild Life Fund for Nature, 1998). The disaster was partly the result of a scramble to clear land for oil palm cultivation, where palm oil is highly demanded in the world market and promises high returns to plantation owners.

An early technical objection to the no-burn technology was the ill-founded perception that land clearing by burning costs less than no-burn methods (Wakker, 1998). Another objection to no-burn technology was that unburned plant residues had promoted the breeding of pests and diseases. In addition to the benefits of the no-burn, land clearing mentioned earlier, intangible benefits such as less soil disturbance leading to the preservation of the flora diversity can be substantial.

When computing costs, producers only consider their own cash outlay, neglecting the externality component. Damages to air quality and subsequently, the total economy are not considered because these costs are not taken into their account. Air is a public good and therefore is not traded in the market. Hence, its price is not explicitly known. However, the pollution that the production process emits has great social and economic implications in terms of reduced health and agricultural productivity. These are explained in later discussions.

Burning to clear extensive areas of land for new oil palm and replanting, as well as for other land clearing was done particularly in Indonesia, and resulted in a major haze problem affecting that country and other Southeast Asian countries in 1997. Even controlled burning of these areas have contributed to fires which went out of control, aggravated by the *El Ninó* phenomenon which induced prolonged drought conditions in 1997 (Wakker, 1998). Indonesian plantation owners were principally blamed for most of the fires although timber concessionaires who established softwood timber farms also cleared forest by burning. Land clearing for the Transmigration Programme has played a further part in the forest burning.

Smoke, comprising of suspended particles and noxious gasses crossed the Indonesian border into neighbouring Malaysia, Singapore, Brunei and to some extent Thailand. Such smoke created major and extensive haze problems in Sarawak in September 1997(Shahwahid and Jamal, 1998). Most areas of Malaysia, Singapore and Brunei were also engulfed with haze.

The total loss due to the Indonesian blaze of 1997 was US$ 4469.5 million of which US$ 3799.9 million or 85% was attributed to Indonesia and US$ 669.6 million to other countries (Economic and Environment Programme for Southeast Asia and World Wild Life Fund for Nature, 1998). The rather inexhaustive estimate of the social cost to Malaysia due to the 1997 forest fires in Indonesia was RM 800 million. The only appreciable benefit obtained from the fire and haze incident is the creation of awareness among policy makers who took preventive measures (Shahwahid and Jamal, 1998).

Malaysian authorities, especially the Department of the Environment (DOE) were quick to respond to the problem. The 1974 Air Quality Act, which had outlawed open burning, was not effectively enforced before. Since 1998, a stricter regulation carrying a hefty maximum fine of RM 0.5 million was imposed on open burning offenders. Since the imposition of this new law, land clearing for the purpose of oil palm cultivation must only be undertaken using no-burn methods. The Malaysian oil palm industry is fortunate that the foresight of oil palm scientists had already led them to develop the no-burn technology, which could accordingly be adopted in the new circumstance.

In Malaysia, the practice of land clearing in oil palm by the clean burn method has been largely replaced by the no-burn regime since 1993. The idea was initiated back in 1989, when large plantation houses of Malaysia began developing the zero burning (ZB) technology because of their own environmental concerns. They had come to realize that apart from preserving the environment, no-burn land clearing adds benefit through nutrient recycling, soil improvement, faster plantation establishment and cheaper private cost (Mohd Hashim *et al*., 1993).

The objective of this study is to evaluate the various available methods of land clearing by ZB from the economics perspective. The purpose is to recommend the most cost-effective method of ZB, and to show that the technique is superior to conventional burning from both the financial and economic perspectives. It serves to promote the ZB technology that while abiding by the law of the land, the method has financial and economic incentives. Hence, in this study, financial and economic comparison is also made on the costs and benefits involved between the traditional clean burning method and no-burn perspectives after accounting for direct and indirect costs to the private concerns and the environment.

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The basic assumption of the study is that the decision to clear forests (if not to replant) is a prior commitment. Therefore, costs due to loss of biodiversity and ecological implications are not explicitly discussed.

In this report, the technical aspects of burning are first explored, and its impacts on the Indonesian, Malaysian and neighbouring countries scrutinised. Then the ZB technique and its development are defined followed by a discussion on the methodology of research on this technique. Then, the results and discussions are presented. In the final section, findings are presented and recommendations offered on the most cost-effective method of ZB land clearing techniques in oil palm cultivation.

TECHNICAL ASPECTS

Burning of biomass in the process of land clearing is aimed at disposing the waste material so that it does not obstruct plantation management. The other objective is the elimination of pests and diseases as well as the destruction of their breeding medium. In addition, burning of unwanted biomass and other waste material is apparently the cheapest method of waste disposal.

However, related to the entropy concept in the natural sciences, total matter available in the universe is finite. Reducing the mass by burning does not destroy matter but changes its form as well as displacing its position. Burnt biomass releases moisture, gasses and suspended particles. Complete burning reduces the original mass to a negligible volume of ash, which in oil palm planting does not require disposal. The rest of matter from burning is released to the atmosphere in the form of various gasses and suspended particles.

When replanting oil palm, for example, it is estimated that there are 89 t of oil palm biomass per hectare in the old stand. Palm trunks contain 80% water, which is released to the atmosphere as steam due to the high temperature created during burning (Khalid, 1997). About 48% of all dry palm components consist of carbon. As a carbon sink, oil palm stores about 40 t of carbon per hectare. When burnt, carbon releases carbon dioxide (CO_2), carbon monoxide (CO_2) and suspended particles of unburned carbon. Excessive releases of CO_2 to the atmosphere may induce climate change and global warming. The particles are the component of burning which causes the haze problem.

Other major contents of palm biomass are nitrogen, phosphorus, sulphur, potassium, magnesium and calcium in varied quantities. The non-metallic components are released to the atmosphere as gasses while the metallic component remains as ash.

TECHNIQUES OF ZERO BURNING LAND CLEARING

When clearing land for agricultural cultivation, the resulting biomass must be disposed off in order to avoid interference with subsequent field operations. The simplest method is by burning the biomass waste, since complete burning reduces the biomass to ash of negligible volume. However, this method of biomass disposal is now regarded as unfriendly to the environment, wasteful and unlikely to contribute to development sustainability.

Alternatively, biomass may be eliminated in other ways. The biomass may still be piled up in between planting rows and left to rot. Biomass has substantial nutrient content and in decomposing, the biomass provides humus, which helps to improve the soil. The nutrient in biomass can be recycled as fertilizer input to the growing crop, reducing the need for chemical fertilizer application. Such treatment of felled biomass in land clearing operations for agricultural development without employing fire is *zero burning* or *no-burn* technique of land clearing. It is considered friendly to the environment and likely to contribute positively to a sustainable agricultural development. The technique preserves the environment because it does not pollute the atmosphere and therefore does not compromise the environment for future generations.

Other forms of recycling method, although technically suitable have not been commercially exploited. Palm trunks may be used as inputs in the manufacture of paper, boards, *etc.* Oil palm fronds may be processed into animal feed (Dahlan, 1996). However, the market for oil palm by-products for these purposes has not been fully developed.

Development of the Technique

Most oil palm plantation owners had been aware since the 1980s, of the benefits of ZB in land clearing and there were growing concerns over the effect of clean burning on the environment.

However, the constraint to the ZB approach was the perception that the rotting biomass becomes a medium for the breeding of pests and diseases, particularly rhinocerous beetles and *Ganoderma*. When the DOE banned burning in 1994, exceptions were granted to plantations clearing land in pest and disease infested areas for sanitation reasons.

In the early 1990s, there was a persistent haze problem, speculated to be the result of volcanic eruptions, vehicle emissions and open burning (Shahwahid and Jamal, 1998). But after the 1997 fires in Indonesia, a law was passed in the Parliament of Malaysia in

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1998 making open burning illegal and carrying a maximum fine of RM 0.5 million. The Department of Agriculture (DOA) gave exemptions to the burning ban in certain situations including sanitation measures against the spread of pests and diseases although this needed certification (Department of Environment, 1998). The burning operation then had to be carried out under the supervision of qualified fire fighting personnel, and between 1.00 pm and 6.00 pm in dry weather during low pollution load as indicated by an air pollution (API) of under 100.

Upon the enforcement of the environmental regulation, the agents of oil palm plantations have no recourse but to refrain from burning in their land clearing practices. The no-burn technique had indeed been developed and adopted before 1998 with the economic benefits already recognized.

Actual Approaches

Like clean clearing in oil palm cultivation, the use of the ZB technique varies according to conditions. Differences in operation occur between oil palm cultivation in logged-over forest, rubber, cocoa, coconut or the replanting of oil palm. Additional variations in clearing and planting requirements occur according to the differences in the soil and terrain of an area. For example, on peat soils, land preparation requires special attention to the drainage and water table situations because soils may be lost over time under dry conditions. Again, flat areas are easier and hence, cheaper to work on compared to undulating or hilly land condition.

In general, ZB techniques may be divided into two major categories. The first is the method that takes advantage of the felled biomass as a source of nutrient recycling. This is most frequently adopted in replanting oil palm rather than in land use conversion or new oil palm planting areas. In this method of oil palm cultivation, preserving the nutrient content of the felled biomass is considered as one of the benefits in oil palm replanting. The second method considers only the cost of land clearing while benefits due to nutrient recycling are excluded. This evaluation approach is considered since in some estates, the management is not completely convinced about the concept of nutrient recycling.

The general ZB technology is now developed drawing information from published materials, observations from field visits and discussions with some estate managers. The ZB technology that is described for pertinent sets of conditions is then employed as a basis for evaluating the ZB practice in oil palm cultivation from the financial and economic perspectives compared to the conventional burn method. Financial analysis considers only the private costs and benefits. Economic analysis on the other hand incorporates externalities as well, *i.e.* it incorporates costs and benefits beyond the oil palm estates involved.

Logged-over forest. In Malaysia, new oil palm planting from logged-over forest is becoming rare practice especially in the peninsula. In many cases, forest clearing for oil palm, encroaches into marginal land resources such as peat areas.

The technique of ZB is also influenced by the national resource endowment in Malaysia where labour is scarce relative to capital. ZB land clearing tends to involve the use of heavy machinery. The shredding of felled trees is also common in Indonesia. ZB land clearing tends to be more labour intensive and windrowing rather than shredding is commonly used.

In logged-over areas, although the more valuable timbers have been extracted (Jamaluddin *et al.*, 1999), some less valuable but marketable timbers are still available and need to be extracted for sale. This practice not only earns income for the operator, but also reduces the volume of biomass to be dealt with. The non-marketable timbers remaining may still be useful as building material for temporary bridges or for foundation in road construction.

Access to the work area is most important in the ZB technique. Hence, the construction of roads is the first activity in establishing an oil palm estate. The next priority is lining work to identify and mark the oil palm planting points so that felled biomass can be placed conveniently away from them and not obstruct planting and field maintenance.

The requirement to build roads and determine planting points before felling necessitates careful planning before work commences. Thus, the design of the estate needs to be finalized. At the London Sumatra Oil Palm Estates in Indonesia, the usual practice is division into blocks of 100 ha and sub-blocks of 25 ha with roads surrounding the sub-blocks (Zulnerlin and Fatah Ibrahim, 1999). The main and collection roads are 8 m and 6 m wide respectively. In the clean clearing method, roads and lining come after tree felling.

Once roads have been constructed, planting points are pegged before tree felling commences and mechanical land clearing is undertaken. Trees are felled in a north-south direction to facilitate stacking by the bulldozers. Two planting rows are cleared and the forest debris is stacked at every alternate avenue about 3 m from the planting points to facilitate later planting, maintenance

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and harvesting work. Where the area is sloping, lining has to follow the contours and timber placed thinly in between terraces.

After clearing and stripping, a leguminous cover crop (LCC) is established to limit damage to the land through soil erosion. Before this operation, weeds are first eliminated through herbicide spraying. The establishment of two rows of LCC on each side of future harvesting paths help hasten the decay process of the felled biomass, and the recycling of the nutrient. Holing and planting is carried out concurrent to LCC establishment.

Logged-over peat. On peat soils, burning is particularly dangerous because dry peat burns very easily. Peat fire spreads underneath the surface and is particularly difficult to extinguish. ZB method is the only safe solution to develop peat areas for oil palm cultivation. Not all peat areas are suitable for oil palm cultivation, which should exclude acid sulphate peat.

The key to oil palm development on peat is good water management. This is because dry peat will be oxidized and lost to the atmosphere. Hence, it is important that the soil remains wet at all times. On the other hand, flooding may interfere with oil palm growth. Quick drying of peat is undesirable, because there are difficulties in the later re-absorption. These requirements are balanced by maintaining a water table between 60 cm to 90 cm below the compacted surface. This is undertaken by constructing a network of drains. The drains must be constructed following the route of roads in order to avoid building bridges unnecessarily.

In the construction of drains, work should start from the main outlet. Natural rivers and streams must be cleaned to the full width, so that the water table can be maintained at the optimal level below the compacted ground surface. The main drains should run in a north-south direction, be 2 m deep and between 1.5 m to 3 m wide. Secondary drains should be 1.5 m to 2.5 m wide and 1.5 m deep, constructed on an east-west direction as far as possible. Otherwise, secondary drains should run alongside collection roads. One secondary (or subsidiary) drain is constructed between every fourth or eighth oil palm rows.

After rivers have been cleaned and drains are in place, the area is relatively dry and ready to receive further development work. At this stage, chainsaw felling of trees can commence. Leaving the felled trees to dry for nine months to a year makes double strip clearing by bulldozer much easier. The felled timbers are stacked in windrows. Two chainsaw gangs in conjunction with an excavator should cut up big timbers to between 5 to 7 m lengths.

Once clearing is completed, the planting rows have to be compacted to preserve the soil level. Before planting, noxious weeds should be removed. Planting must be done on a hole-within-a-hole technique. The hole can be constructed using specially designed tractor-mounted equipment that works in a single operation.

Table 1 summarizes the work schedule of ZB in oil palm cultivation on flatland, by different types of soil and original vegetation. It is that in ZB oil palm cultivation, planting work may be completed in four months.

Replanting on flat areas. In old oil palm estates, replanting is the main establishment activity. The reasons for replanting are multifolds. The first reason is that the trees have grown old and are much too tall to be economically harvested. The second reason is that especially in coastal and old oil palm areas, trees have thinned down due to *Ganoderma* infestation over the years. The third reason is the low yield of the present stand compared to the much higher expected productivity of modern oil palm planting material. Present day planting material is able to provide up to 20 t/FFB/ha and recording 5 t/ha to 6 t/ha in the first year of maturity.

In older estates, where replanting work is sometimes in the third generation, pests and diseases tend to be endemic. On peat, there exists a special problem of termite

TABLE 1. LIST OF ZERO BURNING PROCESS SCHEDULE FROM VARIOUS LAND USE ORIGINS

Type of farm operation	R	LOF	LOP	COP	B
1. Timber extraction	X	/	/	X	/
2. Road construction	/	/	/	/	/
3. Drain construction	/	/	/	/	/
4. Lining	/	/	/	/	/
5. Felling and stacking	/	/	/	/	/
6. Burning	X	X	X	X	/
7. Restacking and re-burning	X	X	X	X	/
8. Lining and holing	/	/	/	/	/
9. Compaction	X	X	/	X	/
10. Planting material	/	/	/	/	/
11. Planting	/	/	/	/	/

Notes: R - replanting; LOF - logged-over forest; LOP - logged-over peat; COP - cocoa to oil palm; B - burn method; š - operation done; X - operation not relevant.

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infestation, which is up to 70% in some areas. In such areas and where *Ganoderma* problem is serious, sanitation is the only policy to establish new and healthy oil palm planting. Burning is inevitable, but certain specific procedures must be strictly followed.

When there is no serious problem with pests and diseases, the normal ZB practice is used in replanting. In this method of oil palm replanting, the existing road is maintained but the drains and harvesting paths are reconstructed. In order to explain the layout of the fields, we demonstrate the concept by a schematic plan of the field as shown in *Figure 1*.

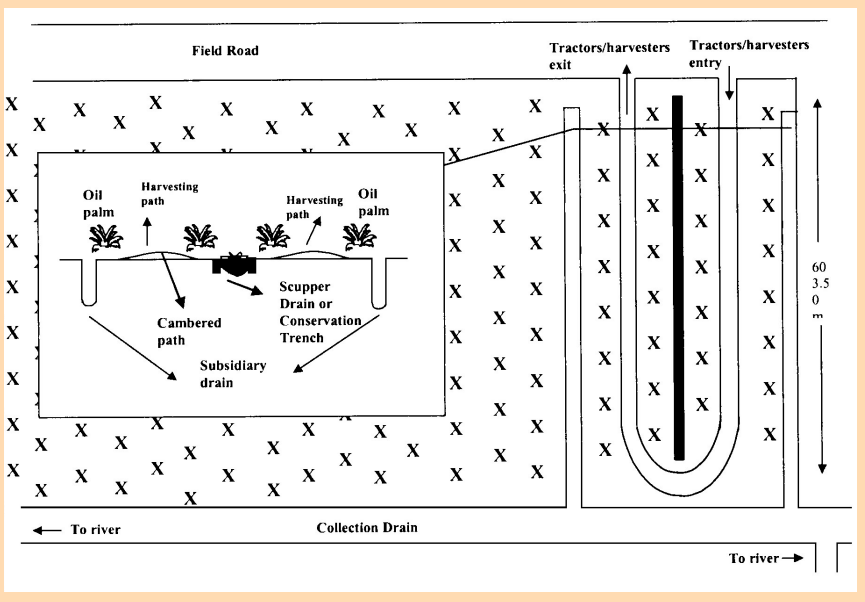

Figure 1. Field layout for flat land zero burning oil palm replanting.

METHODS OF FINANCIAL PERFORMANCE ASSESSMENT

In comparing the financial performance of the various approaches to the ZB and traditional techniques of oil palm cultivation, a market-based analysis is adopted. Although the study deals with analysing the impacts of various oil palm cultivation methods to the environment, most benefits and costs can be satisfactorily evaluated in this way. The quantification of environmental costs uses figures from past burn experiences. A classic case for the quantification of the financial and social costs concerning forest burning was calculated for the big Indonesian forest fire incidence of 1997 (Economic and Environment Programme for Southeast Asia and World Wild Life Fund for Nature, 1998) and these figures were adopted. Global warming cost was obtained from estimates by the United Nations, which was US$ 10/t of carbon burnt. Other operational costs are obtained from real operations by various studied oil palm plantations.

When analysing the various scenarios, the usual financial measures are computed to facilitate comparison. Although only the net present value (NPV) is sufficient to show profitability, other measures such as the internal rate of return (IRR), payback period and benefit-cost ratio (BCR) are also computed and discussed.

The felling of the old stand may be undertaken by two methods. The first method is the traditional, less costly but more time consuming way of tree felling by chainsaw. The resulting biomass is either The other method of oil palm felling is by the employment of the *plant eater,* a machine that pulverises the trunk while it is still upright. The trunk may also be felled before it is pulverised. The crown, which is very fibrous and may jam the *plant eater* is stacked along the windrows.

ASSUMPTIONS

A number of assumptions are required in order to enable the comparison of the financial performance of the various methods of land clearing for the establishment, maintenance and harvest of the oil palm. Firstly, the analysis is based on 1 ha of land area. This is plausible when the required capital items are considered constant. Hence, the cost of these facilities can be ignored as their effects on the analysis are mutually cancelling.

In addition, the oil palm planting material is considered similar in all situations analysed. This enables the analysis to adopt a single yield profile. In consonance with the singularity of the productivity assumption, the price of the output is also assumed constant at a long-run average of RM 200/t FFB. To enhance the comparability with the paradigm that exist in the oil palm industry, it must also be mentioned that the analysis did not include interest and general charges and income tax.

In the system of the ZB oil palm establishment, we assume that land clearing takes about three months to be completed. In the ZB approach to land clearing, there is a greater difficulty with biomass disposal compared to conventional burning. However, the biomass not disposed of is stacked in the windrows, therefore enabling young palms to be planted after three months from the start of the land clearing work. In the case where burning is done, it takes a

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longer time to plant because of the process of burning, restacking and re-burning to completely dispose the biomass usually takes about a year to complete. As a result, the areas are planted about nine months later compared to the ZB method. It follows that the area will start yielding about nine months after oil palm planted using the ZB method. The financial performance assessment methods assume that oil palm is cultivated to the full economic lifespan of 25 years. The assumed normal and adjusted yield profile to suit the ZB planting technique is shown in *Table 2*.

Various scenarios are assumed in the ZB land clearing techniques. It should be noted that the ZB technique, due to its relative infancy has a dynamic technology. New methods are being tried out to find an acceptable and cost effective way of land clearing without burning the biomass. The following broad scenarios are considered in this study:

- traditional burn method (control);
- ZB method without nutrient recycling;
- ZB method with nutrient recycling;
- ZB method with *plant eater*; and
- ZB method with windrowing and pulverising of biomass.

In the financial and economic analyses, the calculation of PVs and BCRs, assumes a 10% discount rate. This discount rate is adopted in the PV and BCR analysis.

RESULTS AND DISCUSSIONS

The various methods of no-burn land clearing techniques as well as the traditional burn method in oil palm cultivation are subjected to long-run financial analysis. For details, please see Mohd Noor (2002).

In the ZB method of oil palm cultivation, the financial returns are in general found to be superior to the traditional burn method. The sources of extra financial return are numerous. The first and most important is the greater accumulated fresh fruit bunches (FFB) obtained due to the earlier establishment and hence earlier realization of FFBs. Therefore earnings from the venture are realized much earlier.

The second advantage of the ZB land clearing technique in oil palm cultivation is the cost saving in terms of recycled nutrient from the decayed biomass. Up to 18 months of nutrient supply can be obtained from the decaying biomass. However, many estate owners are less convinced or rather reluctant to take the risk of relying on this source of nutrient for fear that it might adversely affect early growth of the oil palm. Early growth of the oil palm is considered highly critical for the future performance of the investment.

As observed in *Table 3*, all ZB oil palm cultivation show relatively high returns when compared to the burn method. After taking into account the cost to the society, *i.e.* economic costs, the return to the burn method becomes very low at only an IRR of 15%. For the no-burn method, the rate of return can rise up to an IRR of 25%. The lowest estimated return was 17%, when the relatively more expensive method of oil palm clearing using the *plant eater* was employed.

When converting the crop rubber to oil palm, it was found that the IRR could not be computed. This particular system gave benefit flows that oscillate first positive due to the sale of the rubber logs, then negative during the immature oil palm phase followed by posi-

TABLE 2. NORMAL AND ZERO BURNING YIELD PROFILE OF OIL PALM

Year	Normal yield profile	Zero burning yield profile
1	0.00	0.00
2	0.00	0.00
3	0.00	3.39
4	4.52	6.78
5	7.53	11.30
6	12.55	15.57
7	16.57	18.45
8	19.08	19.64
9	19.83	20.21
10	20.34	20.34
11	20.34	20.15
12	20.09	20.09
13	20.09	19.90
14	19.83	19.64
15	19.58	19.58
16	19.58	19.58
17	19.58	19.39
18	19.33	19.14
19	19.08	18.89
20	18.83	18.64
21	18.58	18.39
22	18.33	18.14
23	18.08	17.89
24	17.83	17.64
25	17.58	17.39

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TABLE 3. FINANCIAL RESULTS OF THE VARIOUS LAND CLEARING TECHNIQUES IN OIL PALM CULTIVATION

Land clearing methods	PV	IRR (%)	BCR
Normal ZB (felled and chipped)	7 455	24	1.48
Excavator (without cambering)	7 074	22	1.45
Excavator (with cambering)	6 501	20	1.40
Land clearing with *plant eater*	5 414	17	1.31
Replanting from rubber	11 000	n.a.	1.75
Normal ZB with nutrient recycling	7 902	25	1.53
Burn method (financial costs)	5 930	20	1.39
Burn method (economic costs)	3 899	15	1.23
Coastal areas (ZB with *Ganoderma* infestation)	7 487	24	1.49
Cocoa-coconut to oil palm	7 682	25	1.50
Cocoa-coconut to oil palm (burn, financial costs)	6 084	20	1.40
Cocoa-coconut to oil palm (burn, economic costs)	4 053	15	1.24
Logged-over forest (ZB)- Endau Rompin	7 332	23	1.47
Logged-over forest (ZB)- Sungei Lembing	7 782	25	1.51

Notes: 1. Cambering is usually a practice on coastal soils.
2. Land clearing under *Ganoderma* infestation, burning of the infested palms is necessary.
PV – present value; IRR – internal rate of return; BCR – benefit-cost ratio.
3. n.a. – Not available.

tive benefit flow at oil palm maturity. When the benefit flow exhibits this behaviour, computation of IRR yield multiple roots, thereby breaking down the technique of IRR (Gittinger, 1982).

In addition to the above advantages of the ZB technique, there are benefits from the reduced erosion due to the limited ground disturbance. The reduction in erosion preserves soil fertility and avoids costs in eventual clearing of silted field drains.

CONCLUSION

In this study, the ZB technique in oil palm cultivation was found to be financially and economically superior to the burn method. The IRR earned from oil palm plantings by employing the ZB method of land clearing ranges from 17% to 25%, well exceeding the cost of fund at 10% per annum. The return to oil palm cultivation using the burn method was only 15%. The higher return from the ZB method was due to the earlier return from earlier planting and the cost savings due to nutrient recycling. Although the burning method is banned, its adoption is no longer fashionable even from the financial and economic perspectives. Above all, preservation of the environment is the ultimate advantage of the ZB oil palm cultivation technique.

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