Sustainable Oil Palm Development on Degraded Land in Kalimantan

T Fairhurst, Tropical Crop Consultants Limited, 26 Oxenturn Road, Wye ,Kent TN25 5BE, United Kingdom.
D McLaughlin, World Wildlife Fund, 1250 24th St, NW, Washington, D.C.

Oil palm is expected to make a significant contribution to the predicted two-fold increase in demand for vegetable oils over the next forty years. Given the current expansion of the oil palm, there is much debate on the sustainability of oil palm due to deforestation and habitat destruction that is occurring in Indonesia, raising serious concerns regarding the sustainability of this cultivation. Many have called for expansion on “degraded lands” as well as increasing yields on existing cultivations. Production can be increased by a combination of area expansion and yield intensification.

Yield improvements on existing cultivations alone could potentially avoid the need to expand on 1.6 million hectares. Further planting on peat land and forested land should be avoided at all costs as there is a large amount of degraded forest land and anthropogenic grassland that can be converted into productive oil palm plantations. Four land types were assessed in terms of yield potential and economic returns on investment. Return on investment increased in the order Spodosols < 2nd forest (hilly) < 2nd forest (flat) < alang-alang. The palm oil industry in Indonesia can meet the growing world demand for edible oils by focusing on improving yields in existing plantations and expanding the area planted on alang-alang grasslands and degraded forest land provided this is carried out within a framework of good governance. In addition, the impacts to biodiversity and carbon emissions due land use change are evaluated for the alang-alang alternativetitSuch a course of action will enable the industry to tackle financial hurdles, minimize impact on biodiversity, and meet climate change criteria in terms of carbon payback without further deforestation.

The demand for edible vegetable oils is expected to double from present consumption of around 120 to 240 M t yr-1 by 2050, based on projected per capita consumption and population growth (Corley, 2009). Amongst the major vegetable oils, palm oil has the lowest production costs, and is therefore expected to make a large contribution to growth in demand for edible vegetable oil with an increase in the planted area of up to 12 M ha (or about 300,000 ha yr-1) over the next 40 years(Corley, 2009).

If all expansion takes place in Indonesia and Malaysia this would result in a 140% increase in the area under harvest from 8.4 M ha (2007) to 20.4 M ha (2050) (FAO, 2008). If palm oil is used for biofuel as well as a food, however, the increase in demand could be much greater but this will depend upon mandates and incentives for inclusion of vegetable oil in biodiesel based on comparative assessments of vegetable oil crop sustainability.

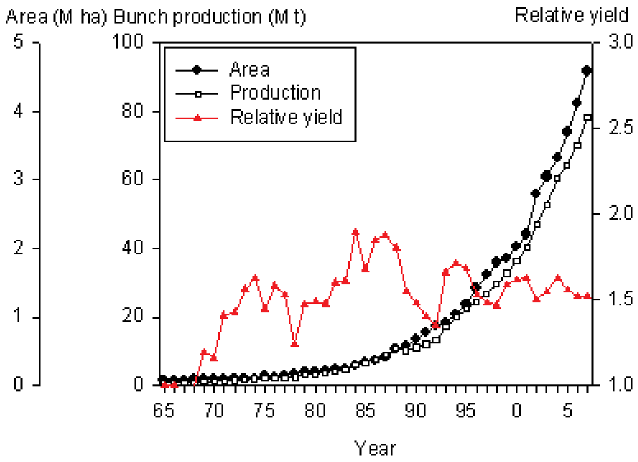

Figure 1: Area planted, bunch production and relative yield of oil palm in Indonesia from 1965-2007 (FAO, 2008). Relative yield set at 1 for 1965 (11.2 t ha-1 fruit bunches).

The increase in the planted area required to meet future demand depends greatly on yield and improvements in yield through improved crop management can be an important driver in reducing the amount of land required for vegetable oil production. Over the past forty years, while the area of oil palm planted and in production in Indonesia has expanded almost exponentially from about 80,000 ha in 1965 to 4.6 M ha in 2007, yields have stagnated since the 1970s at about 17 t ha-1 fruit bunches, equivalent to 3.8 t ha-1 crude palm oil (CPO) (Figure 1).

During the past twenty years relative yield has actually declined, despite improvements in the yield potential of commercially available planting materials (Corley and Tinker, 2003). This decrease may be explained partly by recent expansion into areas with less fertile soils, climatic constraints, and therefore lower yield potential but we estimate that for sites located on mineral soils (excluding very coarse textured soils) with adequate rainfall (i.e., three months or less with rainfall below 100 mm), the average commercially achievable yield potential over a production cycle of 25 years is at least 23 t ha-1 or >5 t ha-1 CPO. The production gap across Indonesia is therefore approximately 28 M t fruit bunches, (or 6.5 M t CPO), equivalent to a potential increase in productivity or current yield gap of 35%, which is equivalent to about 1.6 M ha of new plantings at current yields.

While this yield gap in current production is very substantial there is ample evidence from commercial plantations and smallholders that such yields are achievable. As we shall see, while there are important technical and agronomic aspects to yield intensification, the overriding change required is in approaches to field management.

Yield improvement alone will not provide sufficient palm oil to meet growing world demand over the next thirty years, however, and area expansion will almost certainly be required. Recent reports have highlighted the potential to focus future area expansion on so-called degraded land carrying small carbon stocks and low species diversity (Casson et al., 2008; Gallagher, 2008; Rötheli, 2008; Smith et al., 2007) but there has been little critical assessment of the economics and agronomy aspects of degraded land development.

Methods:

Seven plantation companies were visited in West and Central Kalimantan, as well as numerous smallholders to evaluate actual practices of establishing oil palm plantations under four different planting scenarios: alang-alang grasslands, heavily degraded secondary forests on flat land, heavily degraded secondary forests on hilly land, and heathlands (kerangas).

A financial model was developed and reviewed by both plantation management and finance staff. In addition, current operating practices and results were reviewed, and where possible, tied to previous land use. Soils in the four locations visited were sampled and analyzed.

Results:

Yield intensification

Several studies have shown that management is often more important than soil type in determining yield potential of oil palm at a given site (Goh et al., 1994; Goh et al., 2000).

Practical experience in the oil palm estate Harapan Sawit Lestari (HSL) in West Kalimantan showed that when best management practices (BMP) were applied and using standard fertilizer application rates, yields were greater in mature palms (≥3 years after planting) compared with palms under standard estate practice irrespective of previous land use, suggesting that management is a more important determinant of yield than previous land use (Figure 2 and 3). Similar results were reported by other plantations visited during the study.

This implies that the, contrary to popular belief, production potential of land for oil palm is not strongly affected by degradation of the vegetation cover. Furthermore, there do not appear to be significant differences in key soil fertility parameters (e.g., soil organic carbon, exchangeable K and available P) between soils sampled from grasslands and from secondary forest.

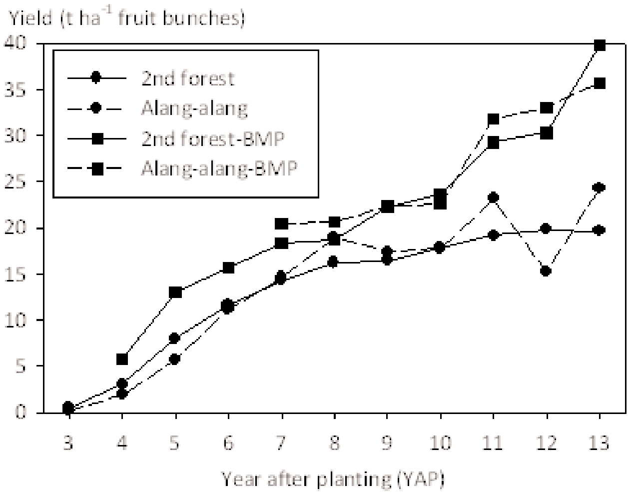

Figure 2: Comparison of yield from palms planted on land cleared from secondary forest and from grassland under standard and best field management practice in Harapan Sawit Lestari (HSL).

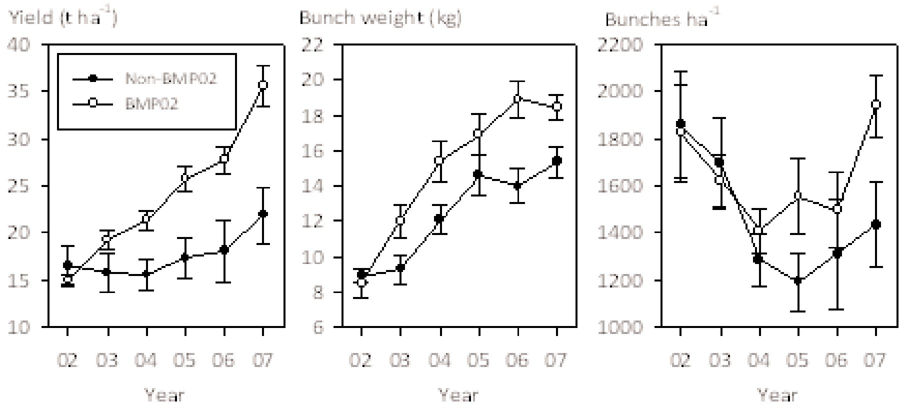

Figure 3: Bunch yield, bunch weight and bunch number in BMP (BMP02) and non BMP blocks in HSL (1995 and 1996 plantings).

The BMP project implemented in HSL illustrates the potential for yield improvement in oil palm. This approach includes ten main elements:

- Complete crop recovery by strict control of harvesting to eliminate crop loss in the field.
- Seven day harvest intervals.
- Proper access for harvesting (infield paths, foot bridges, road access).
- Continuous maintenance of correct canopy conditions by removing fronds at harvest and pruning twice each year.
- Ground cover management to provide adequate soil cover but provide harvesters and other field workers with unimpeded access.
- Adequate in-field drainage and outlets.
- Recapitalization of soil phosphorus with a one-time application of 1 t ha-1RRP (if there is evidence that soil and palm phosphorus status is very low).
- Timely application of standard fertilizer rates (no additional fertilizer was applied in BMP blocks).
- Application of empty fruit bunch mulch (40 t ha-1 once every five years).
- Strong commitment of all plantation management staff (including field workers) to maximize yield by eliminating field constraints.

Soil texture class varied widely between four sites developed from degraded land that were visited during this field study (Figure 4). Yields in mature oil palm plantations, between 10-20 years after planting in Sanggau on soils with suitable clay loam soil texture were only 13 t ha-1 due to poor standards of management and insufficient application of mineral fertilizers. By contrast, yields on well managed mature palms >7 years after planting averaged >21 t ha-1 and BMP blocks averaged >35 t ha-1 on soils on soils with a wide range of texture (sandy clay loam, sandy loam and clay loam) in the area around Ketapang (Figure 4).

Well managed mature plantations >7 years after planting located mainly on Ultisols with sandy loam, clay loam and clay texture in Kotawaringin mature plantings produced average yields of almost 30 t ha-1 (Figure 4). This clearly demonstrates that proper agronomic management, including use of crop residues and adequate mineral fertilizer, can overcome the constraints presented by coarse soil texture.

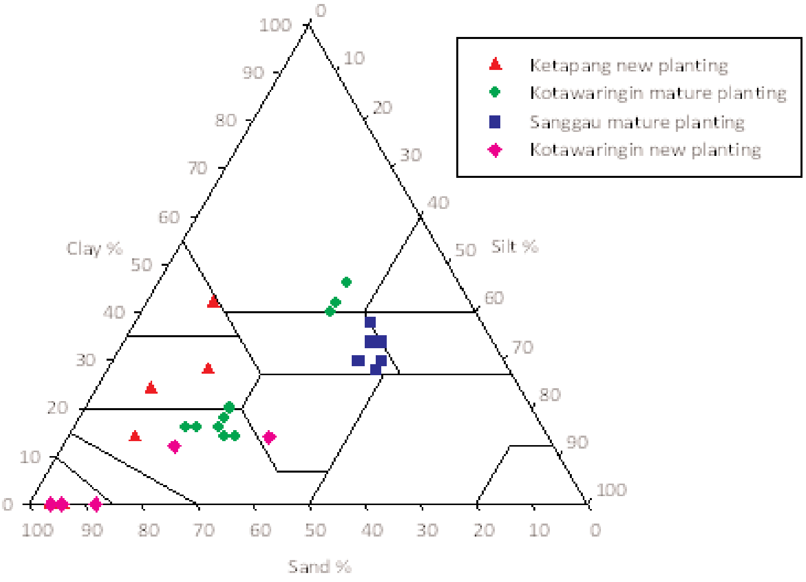

Figure 4: Wide range of soil textures encountered in top soil (0-20 cm depth) in four sites visited.

The fine textured fractions in the soil bind soil organic matter and reduce the rate of decomposition (Six et al., 2002). Not surprisingly, there was a strong relationship between soil texture (clay plus silt content) and soil organic carbon content in the soil samples collected in degraded land in West and Central Kalimantan (Figure 5), and the organic carbon content of soils containing <20% clay plus silt will likely not increase substantially even with very large inputs of crop residues over several years. Some of the soils sampled in new plantings in Kotawaringin contained quite large amounts of organic matter probably because of accumulation under long-term waterlogged conditions (Figure 9).

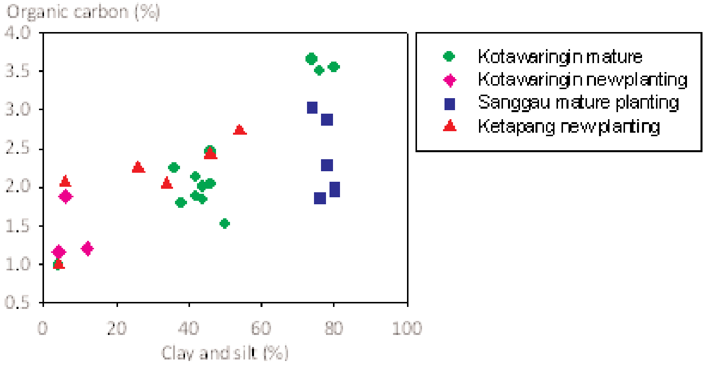

Figure 5: Relationship between soil texture and organic carbon in top soil (0-20 cm depth) in four sites visited

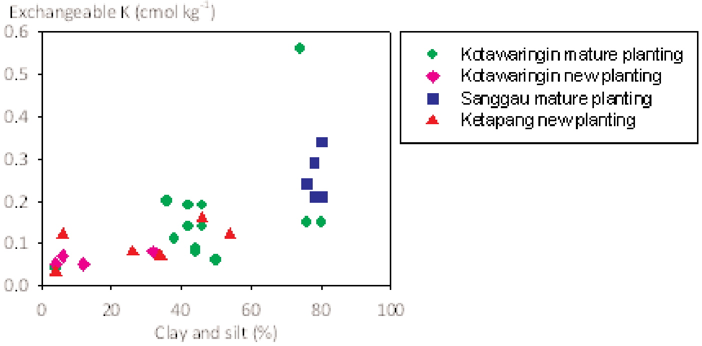

Figure 6: Soil exchangeable K in top soil (0-20 cm depth) in four sites visited

Soil exchangeable K content was greater in the finer textured soils in Sanggau compared with coarse textured soils in Ketapang (Figure 6). Yields were lower in Sanggau, where little fertilizer was applied compared with Ketapang, where commercial rates of K fertilizer were applied.

Most soils sampled in degraded land prior to plantation development were deficient in phosphorus (<15 mg kg-1 available P), potassium (<0.2 cmol kg-1 exchangeable K) and magnesium (<0.4 cmol kg-1 Mg) (Figure 7) and large inputs of P fertilizer will be required for successful establishment of LCP. Cation exchange capacity was generally very low and the soils were sufficiently acid that reactive rock phosphate (RRP) can be used to correct phosphorus deficiency (Figure 10).

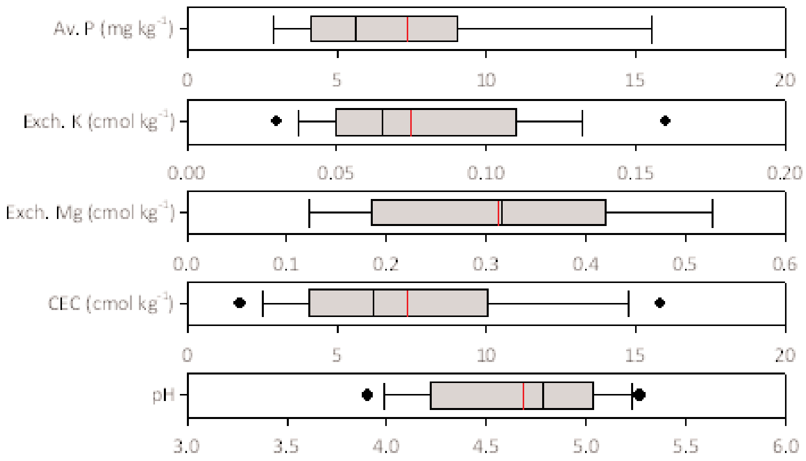

Figure 7: Available P, and exchangeable K and Mg, CEC and soil pH in 16 top soils sampled in degraded land in West and Central Kalimantan. Red vertical bars represent means.

Expansion on degraded lands

We will now consider the requirements for soil improvement in degraded land and then review some of the characteristics of four major vegetation types as candidate areas for oil palm development:
- Grasslands (on Ultisols)
- Flat land secondary forest (on Ultisols)
- Sloping land secondary forest (on Ultisols)
- Kerangas heathland (on Spodosols)

Grasslands

Imperata cylindrica (alang-alang in Indonesia and lalang in Malaysia) has long been recognized as a problem weed (Rudin, 1935) and is an extremely competitive perennial species that can reproduce vegetatively, by underground rhizomes, and generatively by seed. It is particularly competitive where an area is subject to periodic burning and where soil fertility status is poor. Alang-alang is often found in association with other species such as Straits rhododendron (Melastoma malabathricum) and tropical bracken (Dicranopteris linearis). Siam weed (Chromolaena odorata) may also be present, particularly where soils are a little more fertile.

Early attempts at alang-alang control focused on mechanical methods (digging out rhizomes) and physiological methods involving repeated cutting to starve the rhizome (van Wijk, 1936). Various chemicals were evaluated (van Alphen de Veer and Vink, 1952) but it was not until the release of glyphosate in the 1970s that effective chemical control was possible. Why is alang-alang viewed as a difficult weed to control? Part of the problem lies with attempts to promote either mechanical, or chemical or biological methods of control (Friday et al., 1999; Indonesian Rubber Research Institute and Natural Resources Institute, 1996) rather than developing strategies that integrate the different techniques.

Many oil palm plantation companies have become expert at alang-alang control in new oil palm developments and the key components are:
- control fire in the area to be developed (Friday et al., 1999);
- slash or roll and then spray several times with glyphosate to kill the alang-alang (Terry et al., 1997; Zaini and Lamid, 1993);
- recapitalize soil phosphorus with 1 t ha-1 RRP (Adiningsih and Mulyadi, 1993; Sri Adiningsih and Fairhurst, 1996); and
- plant LCP (Rankine and Fairhurst, 1999)

When supplied with adequate P, LCP can out-compete the alang-alang but it is important to time each step correctly. LCP must be sown as soon as the second round of spraying has been completed and P fertilizer must be applied on time so that the LCP can grow rapidly and compete effectively with any residual alang-alang that has not been controlled by spraying. The first step is to flatten the alang-alang vegetation using a tractor drawn roller (Photo 1). After 15 days the vegetation is sprayed with glyphosate (2 L ha-1) using a tractor-mounted boom sprayer or knapsack sprayers.

A second application of glyphosate (1 L ha-1) is applied using knapsack sprayers 15 days after the first round. LCP are sown immediately after the second application of glyphosate to maximize the period for cover plant establishment whilst alang-alang growth is suppressed by glyphosate.

A third spot spray application of glyphosate (0.5 L ha-1) is made 3-4 weeks after LCP planting and a final spot spray round (0.25 L ha-1) is applied to eradicate remaining patches of alang-alang after a further 3-4 weeks. By 70-90 days after rolling, alang-alang should be completely eradicated with LCP dominating the vegetation. The total cost of establishing palm oil on alang-alang lands is estimated at US$ 3,680 ha-1 which compares favourably with the secondary forest or heathland alternatives at US$ 3,950 ha-1 and US$ 4,640 ha-1 respectively.

Photo 1: Rolling' the alang-lalang is the first step in the conversion process. After the roller has pressed ther alang-alang flat, chemical control using glyphosate is much easier and cost effective. The roller was manufactured by a local workshop.

Secondary forest – flat land

Land covered with secondary forest is usually preferred to grassland by planters because of the perceived beneficial effect on soil fertility of the large input of organic matter and nutrients contained in the felled vegetation that is returned to the soil after land clearing. Because the concentration of nutrients (potassium, phosphorus and nitrogen) and soil organic carbon decrease exponentially with increasing soil depth it is imperative to preserve soil organic matter and the soil 'A' horizon by careful land clearing (von Uexküll et al., 1984).

Failure to husband the soil nutrient stocks at land clearing results in greater fertilizer costs during the immature growth phase and possibly a permanent reduction in site yield potential. Thus, while significant amounts of nutrients are recycled to the soil when degraded secondary forest vegetation is felled, there may be little benefit to the oil palms planted subsequently if:

- top soil is scrapped from the soil surface and piled in windrows when bulldozers are used to clear planting avenues (von Uexkull, 1987) and palms are then planted in soil from which the top soil has been removed;
- residues are burned after land clearing, resulting in the loss of nitrogen and sulphur; and
- the phosphorus, potassium, magnesium and calcium contained in the above ground biomass is concentrated in soil beneath the windrowed log piles.

Perhaps the most significant factor in top soil destruction is the use of flat blades to fell and then clear the felled vegetation into windrows (Ataga et al., 1986; Martin, 1986).

Secondary forest - sloping land

Similar considerations apply when planning secondary forest on sloping land for oil palm production but it is also important to consider palm access, soil conservation requirements as well as infrastructure layout (i.e., main and harvest collection roads) in relation to slope.

Soil conservation measures (bunds, platforms and terraces) must be installed on sloping land to provide adequate access for field workers and harvesters and to reduce soil erosion and surface run-off. Conservation bunds should be formed along the contour at 20 m intervals and silt traps (about 500 m ha-1) should be installed on gently sloping land (<5o or <9%) (Caliman and de Kochko, 1987; Gillbanks, 2003).

Individual palm platforms are adequate on land with slopes 5-10o (9-18%) but terraces are required where the slope exceeds 10o (18%) and some planters insist on full terracing where the slope exceeds 5o (9%). RSPO has already set an upper limit of 20o (36%) slopes for oil palm development and all companies should make a careful assessment of slopes prior to development so that areas with slopes greater than 20o (36%) are allowed to regenerate into full forest cover. Several examples were observed during the field work for this study where land much steeper than 20o was being cleared for oil palm.

Kerangas heathland

A number of companies are now developing oil palm on Spodosols and Entisols (Quartzipsamments and Tropopsamments) found in kerangas heathland. Spodosols feature a hardpan (15-20 cm thick) at roughly 1.2 m below the soil surface and Psamments show very little if any profile development. They occur where rainfall is high (>2,000 mm) but poorly distributed and are therefore either drought prone in the dry season or water logged in the wet season.

Spodosols and Psamments are very coarse textured (only 2-5% clay) and very poor in nutrients (the term kerangas means 'land which cannot grow rice' in the Iban language) (Burnham and Whitmore, 1984; Paramananthan, 2007). As mentioned above, quite large amounts of soil organic matter may accumulate in these soils because waterlogged ground conditions inhibit organic matter decomposition.

They are usually covered in characteristic heathland vegetation (Whitmore, 1984) and are rightly referred to as problem soils (Paramananthan and Eswaran, 1984).Establishment costs are high on kerangas heathland because:

- it is costly but essential to break up the hard pan to allow adequate drainage and palm root development;
- drainage is required every second palm row;
- fertilizer requirements are greater than in Ultisols; and
- achievable yield is lower than Ultisols.

Because of the requirement to apply large quantities of organic material (35-60 t ha-1 yr-1 empty bunches) for the first five years after planting to improve soil fertility, development of Spodosols is only feasible for plantations that already have areas in production and a supply of crop residues to ameliorate soils in new plantations on sandy soils (Paramananthan, 2007).

Financial analysis

Cash flow models were developed for the four different planting scenarios using a CPO price of US$ 500 t-1 which is close to present prices and the long-term discounted price. Planting and operating costs were estimated after interviews and reviews with financial and management staff in the seven estates visited in Kalimantan. We noted wide variability in the cost of inputs, particularly of fertilizers, the largest plantation variable cost, due to differences in procurement strategy.

For example, some estates had long term fixed price contracts for fertilizers, whilst others purchased according to need. At the time of the visit, there were large day-to-day fluctuations in fertilizer prices, particularly for potash (KCl) but fertilizers nevertheless represented the largest plantation input cost (Appendix III). In this financial model, harvest and transport, factory processing, as well as all committed overhead costs (farm, factory, and general) were taken directly from one of the estates visited.

When compared with alang-alang, land clearing costs for flat land covered by secondary forest are higher but operating costs and productivity assumptions were similar (Table 1). Cost of establishment was much greater in hilly land covered by secondary forest due to the requirement for terracing which also leads to greater road establishment costs.

Yields in hilly land covered by secondary forest are slightly less, and fertilizer applications are slightly greater (Table 1). This resulted in a significantly smaller net present value (NPV) for the hilly land covered by secondary forest option due to the combined impact of lower yields and greater establishment and operating costs. Returns were poorest for palm development on heathland where projected yields are smaller and development costs are much greater.

At current prices, oil palm development on alang-alang and flat land covered by secondary forest generates an economic return whilst developments on hilly land after forest with terracing, and on Spodosols are not economic.

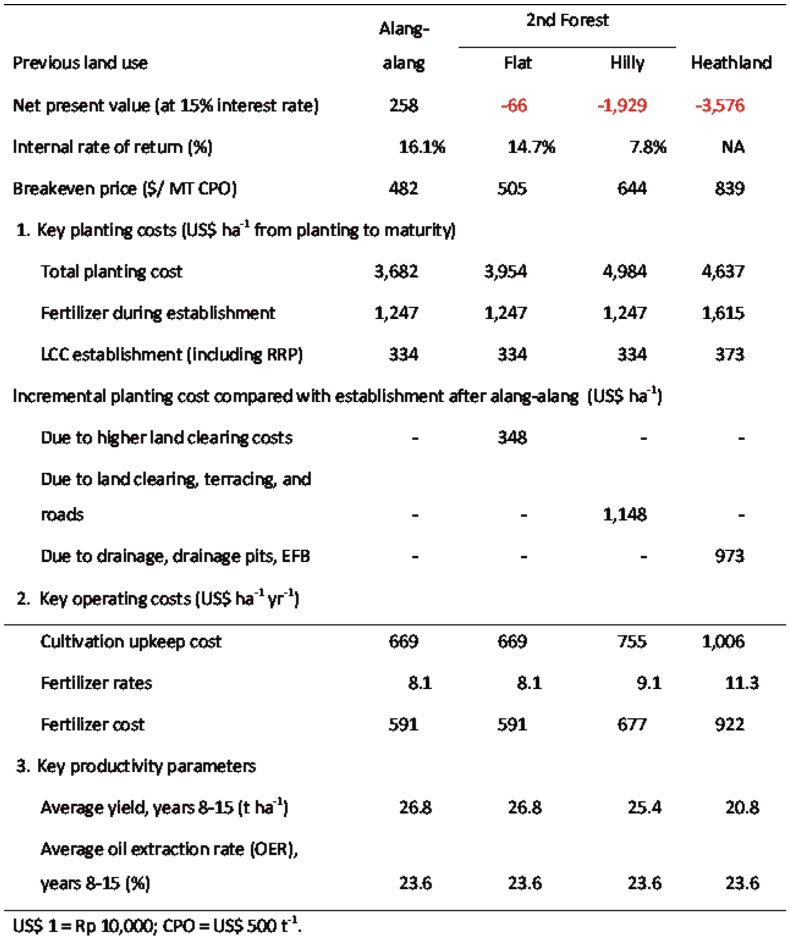

Table 1 Key costs in the financial analysis of oil palm establishment on four land types.

Previous land use	Alang-alang	2nd Forest Flat	2nd Forest Hilly	Heathland
Net present value (at 15% interest rate)	258	-66	-1,929	-3,576
Internal rate of return (%)	16.1%	14.7%	7.8%	NA
Breakeven price ($/ MT CPO)	482	505	644	839
1. Key planting costs (US$ ha^{-1} from planting to maturity)				
Total planting cost	3,682	3,954	4,984	4,637
Fertilizer during establishment	1,247	1,247	1,247	1,615
LCC establishment (including RRP)	334	334	334	373
Incremental planting cost compared with establishment after alang-alang (US$ ha^{-1})				
Due to higher land clearing costs	-	348	-	-
Due to land clearing, terracing, and roads	-	-	1,148	-
Due to drainage, drainage pits, EFB	-	-	-	973
2. Key operating costs (US$ ha^{-1} yr^{-1})				
Cultivation upkeep cost	669	669	755	1,006
Fertilizer rates	8.1	8.1	9.1	11.3
Fertilizer cost	591	591	677	922
3. Key productivity parameters				
Average yield, years 8-15 (t ha^{-1})	26.8	26.8	25.4	20.8
Average oil extraction rate (OER), years 8-15 (%)	23.6	23.6	23.6	23.6

US$ 1 = Rp 10,000; CPO = US$ 500 t^{-1}.

Discussion

Many recent studies have shown that palm oil production is a net emitter of greenhouse gasses due to land use change when the crop is established. Fargione et al. (2008) calculated an ecosystem carbon payback time (ECPT) of 423 years for tropical peat land, and 86 years for lowland tropical rainforest whilst Danielsen et al. (2008) estimated an ECPT of 692 years for tropical peat, 93 years for tropical forest, and 10 years for degraded grassland.

Gibbs et al. (2008) calculated an ECPT of about 918 years for tropical peat, 90 years for forest, 30 years for degraded forest, eight years for woody savanna (similar to severely degraded forest) and <10 years for grassland and cropped lands. Danielsen et al. (2008) assumed a standing biomass of 39 t ha-1 for grassland, based on measurements carried out by Murdiyarso et al. (2002), and biomass production by oil palm of 40 t ha-1 by ten years after planting, based on data of Niklas and Enquist (2002).

By contrast, Syahrinudin (2005) estimated the total carbon stocks in Imperata cylindrica grassland at only 5.9-7.6 t ha-1 and Corley et al. (1971) gives total dry matter production for palms at 5-17.5 years after planting at 29.8 t ha-1 yr-1, equivalent to about 13 t ha-1 yr-1 carbon. Oil palm may therefore provide a valuable carbon sink soon after planting when established on grassland and degraded forest land (Tomich et al., 1996).

By pursuing a strategy of yield intensification and planting on degraded lands, especially alang-alang grasslands, the palm oil industry would effectively be addressing many of the issues that it currently confronts, such as deforestation, carbon emissions due land use change, habitat destruction, human-wildlife conflict, just to name a few.

In addition, from a purely financial standpoint, the yield intensification strategy is a low cost strategy that provides enormous financial return, with little investment. Finally, we think that more investment in training facilities in Indonesia will be required to prepare the next generation of planters with the necessary skills in people, land and crop management.

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