



The impacts and opportunities of oil palm in Southeast Asia

What do we know and what do we need to know?

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Abstract

The ongoing expansion of oil palm plantations in the humid tropics, especially in Southeast Asia, is generating considerable concern and debate. Amid industry and environmental campaigners' claims, it can be hard to perceive reality. Is oil palm a valuable route to sustainable development or a costly road to environmental ruin? Inevitably, any answer depends on many choices. But do decision makers have the information they require to avoid pitfalls and make the best decisions?

This review examines what we know and what we don't know about oil palm developments. Our sources include academic publications and 'grey' literature, along with expert consultations. Some facts are indisputable: among these are that oil palm is highly productive and commercially profitable at large scales, and that palm oil demand is rising.

Implementing oil palm developments involves many tradeoffs. Oil

palm's considerable profitability offers wealth and development where wealth and development are needed—but also threatens traditional livelihoods. It offers a route out of poverty, while also making people vulnerable to exploitation, misinformation and market instabilities. It threatens rich biological diversity—while also offering the finance needed to protect forest. It offers a renewable source of fuel, but also threatens to increase global carbon emissions.

We remain uncertain of the full implications of current choices. How can local, regional and international benefits be increased while costs are minimised? While much important information is available, it is often open to question or hard to generalise. We conclude this review with a list of pressing questions requiring further investigation. Credible, unbiased research on these issues will move the discussion and practice forward.

1

Introduction and background

Few developments generate as much controversy as the rapid expansion of oil palm into forest-rich developing countries such as Indonesia (Koh and Wilcove 2007; Stone 2007). Oil palm expansion can contribute to deforestation, peat degradation, biodiversity loss, forest fires and a range of social issues. But oil palm is also a major driver of economic growth and a source of alternative fuel.

Since the early 1980s, the total area of land allocated to mature oil palm has more than tripled globally, reaching nearly 14 million hectares in 2007 (Figure 1). Most of this expansion has occurred in Indonesia, where the total land area of oil palm plantations increased by over 2100 per cent (more than 22 times greater) over the same period, growing to 4.6 million hectares (FAOSTAT 2008). The total area of land officially designated to oil palm in Indonesia is estimated to be around 6.2 million hectares¹ (which is less than 4 per cent of Indonesia's land area, but up to 15 per cent in some provinces of Sumatra) and all of these plantations are planned to become productive by 2010 (IPOC 2006).

Concerns over global warming and worldwide energy use have escalated the controversy over oil palm.² Greenhouse

gases and high prices for fossil fuel have spurred interest in biofuels³ and other alternative sources of energy. Currently, 77 per cent of palm oil is used for food (USDA 2008a). However, the interest in biodiesel from palm oil (palm oil methyl ester) is currently a leader among biofuel options, and major investments are already planned to convert millions of hectares of tropical forests and other land types to oil palm plantations.

Biofuels may have major positive or negative effects on natural forests, forest dwellers and owners. On the one hand, biofuel from oil palm plantations could increase the value that can be derived from previously forested land and help to promote economic prosperity and alleviate poverty—leading to a higher standard of living with fewer people depending on the remaining forests for subsistence. On the other hand, demand for biofuels could increase competition for land, threaten food production and exacerbate inequality between rich and poor (Astyk 2006).

In 2005, Indonesia stated its intention to develop biodiesel and bioethanol industries to meet 2 per cent of the country's fuel needs by 2010 (Wakker 2006). In early 2006, the government revealed a plan to establish 3 million

hectares of new oil palm plantations to meet these targets. This triggered an outcry from the environmental sector. Much of the controversy is about clearing natural forests and peatlands to make way for oil palm plantations, which has generated widespread negative publicity. Producers are afraid that environmental concerns will turn consumers against biodiesel, and even palm oil (Murphy 2007).

Today, biodiesel investors are rethinking their decisions not just for environmental reasons but also because of cost concerns. In mid 2008, the price of crude palm oil was higher than the selling price of petroleum-derived diesel. Given that it costs, on average, about 10 US cents per litre to convert crude palm

oil into biodiesel, unsubsidised biodiesel manufacturers would lose money. Prices for crude palm oil (CPO) were predicted to rise because demand for vegetable oil for human consumption is strong in India and China, but it dropped in early 2009 when the global financial crisis took hold.

This study reviews oil palm cultivation and the oil palm sector in Southeast Asia; examines the reasons for rising demand for CPO and the effects of large plantations on local communities and the environment; and identifies questions for further research. Credible (objective) research is needed to answer these questions, so that the discussion and practice of oil palm production can be carried forward.

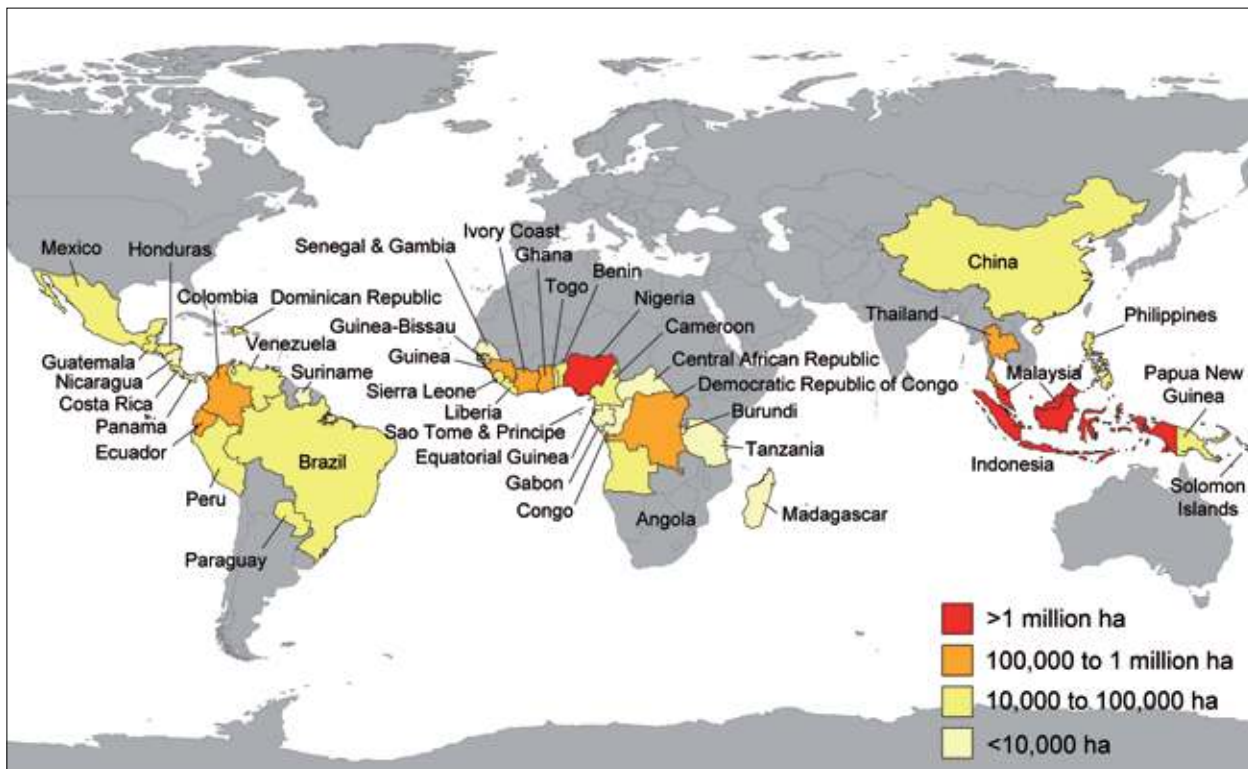


Figure 1. The extent of oil palm cultivation in 43 oil palm-producing countries in 2006.
(Source: Koh and Wilcove 2008a)

2

oil palm basics

Oil palm and palm oil

Elaeis guineensis is a tropical forest palm native to West and Central Africa. Grown in plantations it produces 3–8 times more oil from a given area than any other tropical or temperate oil crop. Oil (triacylglycerols) can be extracted from both the fruit and the seed, crude palm oil (CPO) from the outer mesocarp and palm-kernel oil from the endosperm (Figure 2). Most crude palm oil is used in foods. In contrast, most palm-kernel oil is used in various non-edible products, such as detergents, cosmetics, plastics, surfactants, herbicides, as well as a broad range of other industrial and agricultural chemicals (Wahid *et al.* 2005).

One debate we shall not explore in detail concerns the nutritional qualities and

health effects of eating different types of palm oil products. Considerable research is already being conducted on these issues (see Colon-Ramos *et al.* 2007; Karsulinova *et al.* 2007; Ladeia *et al.* 2008; van Rooyen *et al.* 2008).

Historical summary

African oil palm originated in Africa, along the coastal strip (200–300 km wide) between Liberia and Angola, from whence it spread north, south and east to Senegal, the Indian Ocean, Zanzibar (Tanzania) and Madagascar (NewCROP 1996).⁴ It retains many traditional uses in Africa (Maley and Chepstow-Lusty 2001). Since its domestication, oil palm has been introduced and cultivated throughout the humid tropics (16°N to 16°S) (NewCROP 1996).

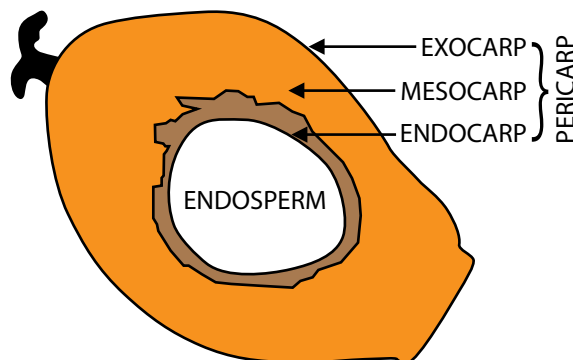


Figure 2. Cross section of an oil palm fruit. The fruit comprises outer oily flesh or pericarp (made up of exo-, meso- and endocarp) and an oil-rich seed or kernel (endosperm).

James Welsh first took 32 barrels of palm oil to England in 1590. By the early 19th century, it was being used to make soap and candles, then later, for heating and cooking, and in many other products from dynamite to tinplating (as used in the food canning industry) to margarine (Henderson and Osborne 2000; Poku 2002). By 1930, oil palm had become important enough to justify the merger of *Margarine Unie*, a Dutch producer of margarine, and *Lever Brothers*, a British soap maker, into *Unilever*—now the world’s second largest consumer goods company with annual sales of more than US\$ 75 thousand million. Both businesses shared a key ingredient, palm oil: growing it in overseas plantations and importing it would benefit from economies of scale (Anonymous 2008a).

It has been suggested that the first oil palms to be introduced to Asia came from the Americas (where African oil

palm had been introduced some time between the 14th and 17th centuries) (Poku 2002); however, other sources suggest that they came via Mauritius (RMRDC 2004). Wherever they might have originated, the four original trees planted in Java in 1848 were the seed source for all Southeast Asian plantations developed over the following century (Henderson and Osborne 2000). The first plantations were established in Peninsular Malaysia (see Figure 3 for a regional map of Malaysia and Indonesia) in 1917. The native pollinator of African oil palm (the weevil *Elaeidobius kamerunicus*) does not occur naturally in Southeast Asia—when it was introduced to Asia from Africa, fruit production increased and the cost of artificial pollination was saved (Southworth 1985). Indonesia and Malaysia began to dominate world trade in palm oil in 1966, taking over from Nigeria and Zaire (now DR Congo) (Poku 2002).



Figure 3. Key oil palm areas in Malaysia and Indonesia.

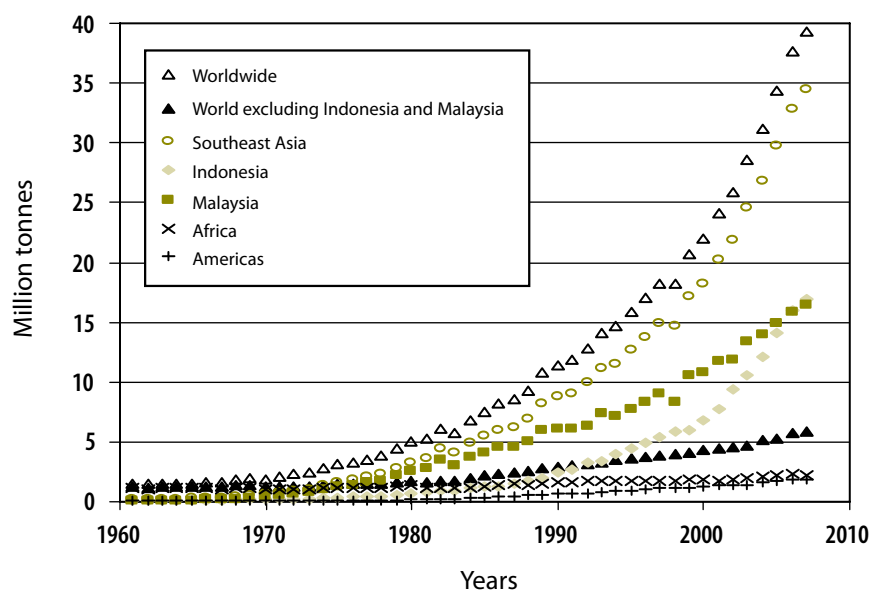


Figure 4. Palm oil production in selected areas, 1961–2007. Increase in world production is driven by increases in Indonesia and Malaysia. (Source: based on data from FAOSTAT)

By 1998, palm oil contributed over 5 per cent of Malaysia's gross domestic product (Yusoff 2006). Production in Indonesia rose from 168 000 tonnes grown on 105 808 hectares in 1967, to roughly 16.4 million tonnes grown on 6.2 million hectares in 2006 (Indonesian Ministry of Agriculture) (annual yields rose from 1.58 t/ha to 2.6 t/ha) (BisInfocus 2006; IPOC 2006). Some experts estimate recent expansion in Asia at 0.4 million hectares a year (Corley 2005). Most of this expansion has occurred in Indonesia, where an average of 350 000 hectares of new oil palm plantations was planted each year between 2000 and 2006 (IPOC 2006).

Since 2005, Indonesia has been the world's largest and most rapidly growing producer. Its wet tropical climate provides ideal growing conditions for oil palm (see below). Land is abundant and labour is cheap. About 10 per cent of Indonesia's palm oil production comes from government plantations, 40 per cent from smallholders and 50 per cent from private plantations (IPOC 2006). Most production comes from Sumatra,

but is expanding rapidly in Kalimantan and spreading further east to Papua.

Malaysia is the world's second largest palm oil producer, producing 15.8 million tonnes of CPO from 4.3 million hectares in 2007 (Malaysian Palm Oil Board 2008). Together, Indonesia and Malaysia account for about 90 per cent of the *ca* 36 million tonnes of CPO produced globally per annum (USDA 2008a; see Figure 4).

Palm oil biology, products and productivity⁵

The native habitat of oil palm is tropical rainforest with 1780–2280 mm annual rainfall and a temperature range of 24–30°C (minimum and maximum); seedlings do not grow below 15°C (NewCROP 1996). The palm thrives in disturbed forest and near rivers; it does not grow well under closed canopies (Corley and Tinker 2003). Oil palm is tolerant of a wide range of soil types, as long as it is well watered (NewCROP 1996). The African oil palm



A 12-year-old palm tree at harvest. Trees can reach up to 20 metres in 25 years. (Photo: Patrice Levang)

is now among the best studied tropical rainforest plants.

Typically, oil palm plantations are planted at a 9 m by 7.5 m spacing and the resulting 148 palms per ha produce one new frond every 3 weeks; each new leaf adds 4.5 cm to the trunk height (80 cm per year, 20 m in 25 years) and goes on to form one flower bunch (either male or female); typically, under well-managed conditions, 10–15 bunches can be harvested per palm per year, weighing 15–20 kg each; total yields are thus 15–30 tonnes of fresh fruit bunches per hectare per year.

The sex determination of flower bunches depends on the level of resources in the

plant and levels of water and nutrient conditions. Under ‘good’ conditions, the majority of bunches are female and can lead to high fruit yields. Drought stress increases the proportion of male flowers. Once the female flowers are pollinated, the plum-shaped fruits develop in clusters of 200–300 on short stems (pedicels) close to the trunk. Each fruit is about 3.5 cm long and 2 cm wide, and weighs about 3.5 g. The fruit comprises outer oily flesh or pericarp (made up of exo-, meso- and endocarp) and an oil-rich seed or kernel (endosperm; see Figure 2).

Oil palm has the highest yield of any oil seed crop, averaging 3–4 tonnes of mesocarp oil per ha per year in the major palm oil producing countries (Wahid 2005). The fresh fruit bunches (FFB) typically are 52 per cent dry weight and have an extractable oil content of 15–25 per cent, depending on ripeness at harvesting time. Processing the fruit bunches begins with separating the stalks and empty fruit bunches (EFB, about 8 per cent of FFB dry weight) and then pressing the resulting mass, leading to ‘press liquor’ that still needs to be separated into crude palm oil (CPO) and palm oil mill effluent (POME). The ‘press cake’ yields fibre and shell (dry weight equivalent to 8 and 5.5 per cent of FFB, respectively) and kernels (dry weight about 5 per cent of FFB, of which 45 per cent is kernel oil). Empty fruit bunches can be used as mulch and organic fertiliser, POME can be used as cattle feed or liquid fertiliser, and it contains enough methane to be a viable source of biogas. The fibre and shell can be used as fuel, source of pulp and paper or organic fertiliser (Weng 1999; Henson 1999).

Oil palm cultivation

Oil palm is grown commercially in at least 43 countries and accounts for almost 10 per cent of the world’s permanent crop land (*ca* 14 million ha; world permanent

cropland: *ca* 138 million ha, FAOSTAT; see Figure 1). Oil palm needs humid equatorial conditions to thrive, and conditions in Southeast Asia are ideal. Seasonal droughts at higher tropical latitudes greatly reduce yields (Basiron 2007)—water-stressed palms produce fewer female flowers and abort (drop) unripe fruit. Palm productivity benefits from direct sunshine: the lower incidence of cloud cover over much of Southeast Asia is thought to be one reason why oil palm yields are higher there than in West Africa (Dufrene *et al.* 1990).

Oil palm seedlings are typically raised in a nursery for one year before planting out. Planting densities range from 110 to 150 stems per hectare. Ground cover crops are used to reduce weed growth and prevent soil erosion (Basiron 2007). Fruit production responds well to soil nutrients and trees produce more fruit when fertilised. Mulching also boosts yields; for example, empty fruit bunches used as a mulch can reduce the need for fertilisers by over 50 per cent in immature stands and by 5 per cent in mature stands (Tailliez 1998).

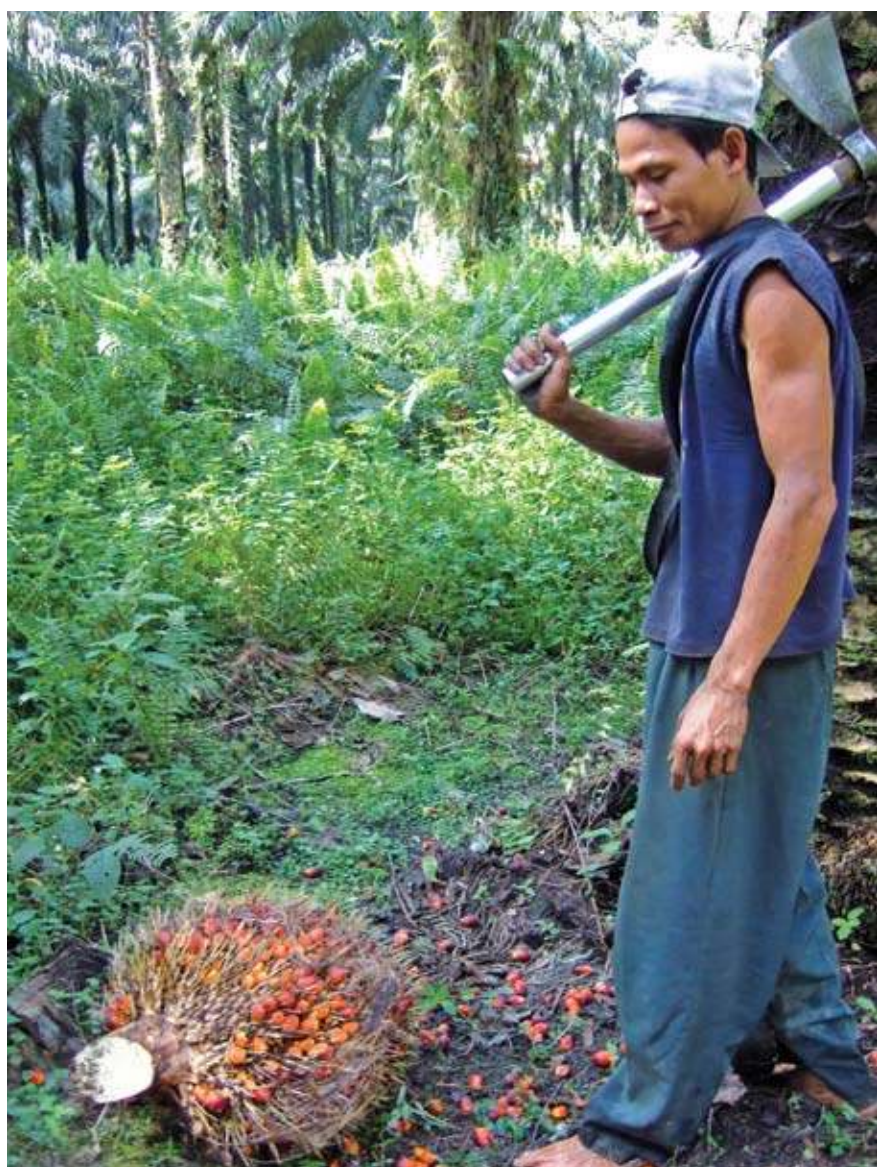
With appropriate management, plantations can be productive on a wide range of soils, including ‘problem soils’ such as acid sulphate soils, deep peat and acidic high aluminium soils, where few other crops are successful (Auxtero and Shamshuddin 1991). Yields often vary with landscape terrain, but patterns are inconsistent: sometimes the highest yields are from higher ground and sometimes from valleys (Balasundram *et al.* 2006). Plantation developers avoid steep slopes because of access and erosion problems. There are also laws prohibiting conversion of forests on slopes.⁶

Palms mature rapidly and fruit can be harvested as soon as 2–3 years after planting (Basiron 2007), although trees aged 9–15 years are the most productive

(BisInfocus 2006). After 25–30 years, trees become too tall to harvest⁷ and are replaced. Some long-established plantations in Malaysia have already been replanted for the third time (Basiron 2007).

Yield and its improvement

A typical mature palm plantation in Indonesia now yields 2–4 tonnes per ha per year. In the early 2000s, yields stagnated in both Indonesia and Malaysia, possibly as a result of expansion into less fertile areas, and the high proportion of immature



Worker harvesting palm oil fruits in a plantation in Riau, Indonesia. (Photo: Joanne Gaskell)

plantations (Fairhurst and Härdter 2003). Low yields are also attributable to labour shortages, limited mechanisation, low-grade planting material, palms that are too old or too tall, poor crop management, changes in oil prices, inadequate fertiliser use, economic instability, increased production costs, pests and serious droughts, such as occurred in 1998 (Casson 2000). It is also true that reported yields can be unreliable because of conflict with local communities, corruption, pilfering and fraud (Lord and Clay nd).

Africa has a wider range of oil palm varieties than other regions. Most modern varieties are from the *Tenera* group, with thin shell and thick mesocarp, which was developed by crossing the wild-type *Dura* (thick shell, thin mesocarp) and shell-less *Pisifera*. *Tenera* varieties have high oil content, are easier to process than wild oil palm (Poku 2002) and are widely cultivated in Asia (Wahid *et al.* 2005).

Pest and disease control, and harvesting, transport, storage and processing methods, make a big difference to yields. In some areas, specific diseases are known to reduce yields. The most notable is the bracket fungus *Ganoderma*, which commonly causes basal stem rot in Asian plantations (Paterson 2007; Rees *et al.* 2007; Anonymous 2008b). There is no cure and infection is lethal to oil palm trees. Spread of the fungus and disease is enhanced when old trunks are left to rot within the plantation. Infected palms gradually stop producing fruit, and finally collapse. The fungus can remain 'hidden' in wood or soil-borne debris, so the disease can reappear in a plantation during its second or third planting. The disease is a major and increasing threat in Malaysia. Differences in the susceptibility of varieties have been detected in Indonesia—suggesting that disease-resistant varieties could eventually be bred (Anonymous 2008b). Since the no-burning policy was

instituted in Malaysia in the 1990s, the rhinoceros beetle (*Oryctes rhinoceros*) has become a problem. To combat these and other pests, most producer countries are pursuing biocontrol strategies such as beetle pathogens, namely *Metarhizium anisopliae* fungus and Oryctes virus (Murphy 2007). In Malaysia, trials are underway to study the extent to which birds in oil palm plantations control pest species and reduce crop losses (Koh 2008a).

In recent decades, the main improvements in yields and disease resistance have come from plant selection and breeding⁸ (Durand-Gasselin *et al.* 2000). Selected varieties of oil palm already produce 2–3 times more than unimproved varieties. Substantial improvements are still possible as there has been little attempt to match cultivars to specific soil types or conditions. Intensively managed selected cultivars already produce over 10 tonnes per ha per year⁹ and further gains are anticipated (Murphy 2007), some suggesting up to 18.5 tonnes per ha per year (Corley 1998) or even an incredible 50 tonnes per ha per year (Murphy 2007). It remains to be demonstrated what yield improvement can be achieved in practice and how much is commercial hype (Breure 2003). Yield improvements due to better management and varieties could reduce pressure for expansion (Murphy 2007), as even a 50 per cent increase in yield would produce 18 million tonnes more oil.

As well as increasing the amount of oil, breeding can also improve the types of oil produced by the palms¹⁰ and boost nutritional values (increasing the levels of carotenoids, vitamin E and iodine) (Wahid *et al.* 2005). There is ongoing intense genetic research (Anonymous 2007), which could shorten the 19-year cycle currently required for one round of selection (Wong and Bernardo 2008).

Various genetically modified plants are being developed, such as shorter palms that can produce fruits for longer than 25 years, but commercial plantings are unlikely before 2020 (Parveez *et al.* 2000). By May 2008, the first phase of sequencing the oil palm genome was complete, which may provide significant future improvements in both quality and production (Crowley 2008).

Large companies naturally seek maximum yields and, therefore, plant high-yielding varieties. Most smallholders, however, do not have the cash to buy high-yielding seedlings or are unable to differentiate between good and bad seedlings sold by unscrupulous traders (Zen *et al.* 2006). This is exacerbated by limited supply, which raises costs and limits access. In Indonesia, while the government supports and promotes the benefits of high-yielding seeds for oil palm, local production is insufficient to meet national demand. The Ministry of

Agriculture estimated that 220 million tonnes of seeds were required for 2008, but approximately 60 million tonnes needed to be imported (Syafriel 2008).

Industry commentators often imply that, if yields rise and oil palm production becomes increasingly profitable, pressure on land will be reduced (Murphy 2007). There is, however, the counterargument that there will be more incentive to establish new plantations. The issues that will ultimately decide whether more or less land is turned over to oil palm are complex, though the relatively unusual conditions under which the ‘intensification hypothesis’—that is the claim that intensive systems save land—is true are relatively well understood (Kaimowitz and Angelsen 1998; Angelsen and Kaimowitz 2001; Tomich *et al.* 2001). Land, labour, access to capital, good planting material and associated know-how can all limit oil palm expansion under certain conditions.



3

Palm oil production and global trends

Palm oil production

Once harvested, fruit deteriorates rapidly and must be processed within 48 hours, so access to a mill is a major factor in determining where palms can be commercially established (Vermeulen and Goad 2006). The development of small-scale or even portable mills would allow communities and companies to plant and process oil palm fruit in remote areas. At present, large mills processing at least 30 tonnes of fruit per hour are more profitable and require less energy per unit of oil produced than the current generation of small mills (Jekayinfa and Bamgboye 2007). Thus, small mills are not considered viable and centralisation (*de facto* local monopolies) means that buyers control fruit prices.

Compared to other major oil crops, palm oil has lower production costs and produces more oil from less land (Yusoff and Hansen 2007; see Table 1). Returns on land, capital and labour produce substantial revenues both for companies and for countries. Oil palm plantations employ cheap labour and, unlike annual crops, provide work throughout the year.¹¹ Oil palm can be an attractive crop for smallholders. If they can make the necessary initial investments and survive the 2–3 unprofitable years before their first harvest, smallholders can get good

returns on very limited labour and low inputs of fertiliser, suggesting possible benefits from oil palm in less intensive and in mixed production systems.¹²

Table 1. Oil production of palm and other major oil crops

Oil type	Oil yield (kg/ha)
Palm†	4000–5000
Rapeseed†	1000
Groundnut†	890
Sunflower†	800
Soya bean†	375
Coconut‡	395
Cotton seed‡	173
Sesame seed‡	159

Sources: (†) Journey to Forever; (‡) Mielke (1991, cited in Fairhurst and Mutert 1999).

Crude palm oil is refined to remove impurities.¹³ Refined oil is then separated into solid and liquid fractions—it is the liquid that is commonly used for cooking oil. Palm-kernel oil is extracted as a separate process, involving grinding, heating and the use of an ‘oilseed expeller’ or solvent (Poku 2002).

In Indonesia, current planting materials are believed capable of achieving a productivity of 32 tonnes of fresh fruit bunches per hectare per year, yielding 6–7 tonnes of oil. But in reality, typical

Box 1. Potential oil palm byproducts may increase profits and reduce waste

Oil palm byproducts include empty fruit bunches, mill effluent, steriliser condensate, palm fibre and palm kernel shell. The first two are widely used as mulch and soil improvers in palm plantations, and fibre and shell are increasingly used as fuels in the oil mills (Yusoff 2006). Ash can be mixed with concrete (Tangchirapat *et al.* 2007) and shells to surface plantation roads (Yusoff 2006), while methane from mill effluent fermentation can also provide energy for mills (Yacob *et al.* 2006). Treated palm trunks can be made into furniture (Darnoko 2002 cited in Simorangkir 2007). Other experimental items made from byproducts include paper (Wanrosli *et al.* 2007), fibre board and fillers (Wahid *et al.* 2005), activated carbon (Ahmad *et al.* 2007), fish food (Bahurmiz and Ng 2007), compost for growing mushrooms, and enzymes, vitamins and antibiotics (Ramachandran *et al.* 2007). Palm fibre is already used in the composite body of Malaysia’s national car. Commercial research goes on: for example, vanilla flavouring can be generated from empty fruit bunches (Ibrahim *et al.* 2008), while fibre is being proposed as a means to filter heavy metal pollutants from other industrial processes (Isa *et al.* 2008). Even the pests may find commercial use: for example, the *Oryctes rhinoceros* beetles caught in pheromone traps in oil palm plantations are used in a nutritional supplement for ornamental fish feed (Kamarudin *et al.* 2007). The use of byproducts can increase the financial viability of oil palm and reduces waste. Uptake in Malaysia is in advance of that in Indonesia and varies from company to company.

yields are only 50–60 per cent of this potential (Goenadi 2008). In official Indonesian statistics, the mean yield of smallholders (2.5 t CPO/ha per year) is half that of large-scale producers (4–6 t CPO/ha per year) (Goenadi 2008). Reasons for this disparity probably include access to good planting stock and fertiliser, and low intensity maintenance. There are cases where smallholders achieve yields that surpass large-scale producers (van Noordwijk personal observation).

The multiple uses of ‘byproducts’ can increase profits and reduce waste—there has been considerable research on these opportunities (Box 1; Figure 5). With a combination of reuse, recycling, using solid and liquid wastes, and appropriate energy management, the CPO industry can achieve almost zero pollution discharge, making it an environmentally friendly industry (Chavalparit *et al.* 2006). (See also ‘Mills and water quality’ in Chapter 6.)

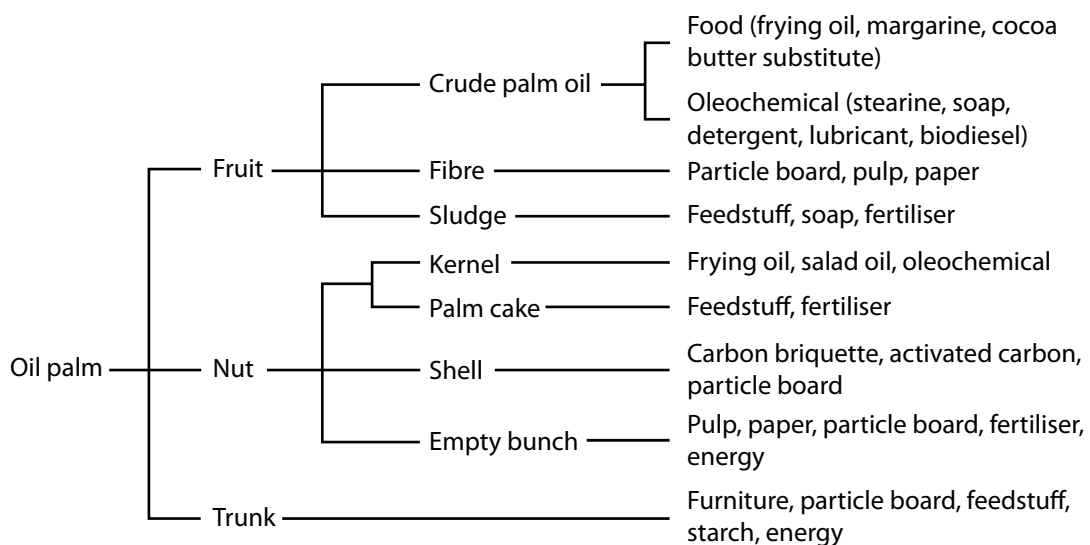


Figure 5. Uses of oil palm byproducts and biomass in food and manufacturing industries. (Source: Fairhurst and Mutert 1999)

Biofuel development, demand and expansion

Ten years from now the rapid expansion of biofuel production may look foolish, or worse—unethical, if it leads to environmental degradation, high food prices, and increases the number of undernourished people. While we are optimistic that this scenario can be avoided, it would require both an increase and redirection of the global research, development, and extension portfolio because the magnitude of the scientific challenge has been grossly underestimated and critical research areas are currently neglected (Cassman and Liska 2007).

Global energy consumption is predicted to increase by 50 per cent (over 2007 levels) by 2030.¹⁴ Approximately 95 per cent of global energy comes from fossil fuels. The development of alternative fuels is thus driven by two factors: first, the necessity to identify cheaper sources of energy and, second, the need to reduce greenhouse gas emissions (Lin *et al.* 2006). Sovereignty and control over supplies, as well as enhancing rural development are also clear motivations (Wakker 2006; Koh and Ghazoul 2008).

It is unclear to what extent biofuels can address fuel needs. According to UN estimates (UNEP and Cleveland 2008), biofuel crops covered about 1 per cent of the world's arable land in 2007. There are predictions that this figure will reach 4 per cent by 2030 (with 92 million tonnes of oil equivalent production). Without major productivity increases, this is inadequate to compensate more than a fraction of global hydrocarbon use. In any case, many observers are increasingly questioning the various other impacts of expanding biofuel production (Scharlemann and Laurance 2008). Biofuels have the potential to be

carbon neutral, because the carbon that combustion releases is the same carbon that the crop previously sequestered from the atmosphere during photosynthesis (Somerville 2007). There is a range of biofuels, including biodiesels, fuel oils and alcohols (Demirbas 2007a). Biodiesel produces fewer harmful emissions than fossil fuels (Lin *et al.* 2006). It can be used in conventional diesel engines if mixed with conventional fuels and, if spilt, breaks down more rapidly than fossil fuels (Lutz *et al.* 2006). (In virtually all current and planned large-scale use, biofuel is mixed with fossil fuels.)

Because biodiesel production (Box 2) from raw lipids is relatively efficient, the net energy from biodiesel is more than that, for example, from maize ethanol. Volume for volume, ethanol produces about 67 per cent of the energy of petrol/gasoline, while biodiesel produces about 86 per cent of the petrol/gasoline energy. Compared with ethanol, biodiesel releases just 1.0 per cent, 8.3 per cent and 13 per cent of the agricultural nitrogen, phosphorus and pesticide pollutants, respectively, per net energy gain. The production and combustion of ethanol produces 12 per cent less greenhouse gas emissions than fossil fuels, whereas biodiesel reduces emissions by 41 per cent. Biodiesel also releases less air pollutants per net energy gain than ethanol. The conversion of palm oil into fuel is more efficient than for

Box 2. Palm oil to biodiesel

Biodiesels are fuels developed from mixtures of fatty acid methyl esters (produced by transesterification of triacylglycerols) and minor additives (antioxidants, etc.), and are often blended with traditional liquid fuels to improve physical properties (although various other additives can also be used, they are typically more costly) (Nikiema and Heitz 2008). A variety of processes are being explored that allow palm oil to be made into biodiesel (Al-Zuhair *et al.* 2007; Demirbas 2007c; Ooi and Bhatia 2007; Tamunaidu and Bhatia 2007; Talukder *et al.* 2008).

ethanol (Hill *et al.* 2006). However, these factors, and the choices involved, have not yet been extensively evaluated by the oil palm industry.

Up to 2007, palm oil had contributed less than 5 per cent to global biodiesel production (Rupilius and Ahmad 2007), but the industry is swiftly expanding. In Malaysia, palm biodiesel already fuels buses and cars (Reijnders and Huijbregts 2008), and most major automotive and oil companies are researching biofuel (Herrera 2006).

Comparing biofuels is difficult as each has specific advantages and costs (Scharlemann and Laurance 2008). Zah *et al.* (2007) evaluated 26 biofuels, including palm biodiesel (along with petrol, diesel and natural gas), using two established criteria: greenhouse gas

emissions and overall environmental costs (Figure 6). Using a defined comparison protocol, the greenhouse gas emissions of 21 biofuels are 30 per cent less than those of petrol or even less. But nearly half (12) of the biofuels, including palm diesel, have markedly higher aggregate environmental costs than fossil fuels. The biofuels that offer the most benefits are those derived from biowaste and other byproducts (Zah *et al.* 2007; Scharlemann and Laurance 2008).

In Indonesia, the government has pledged to reduce dependency on fossil fuels by 25 per cent and to produce up to 22.26 thousand million litres of biofuel by 2025. It has also formed a National Team for Biofuel Development, which has recommended a mandatory biodiesel blending requirement of 10 per cent and drawn up plans for the expansion of

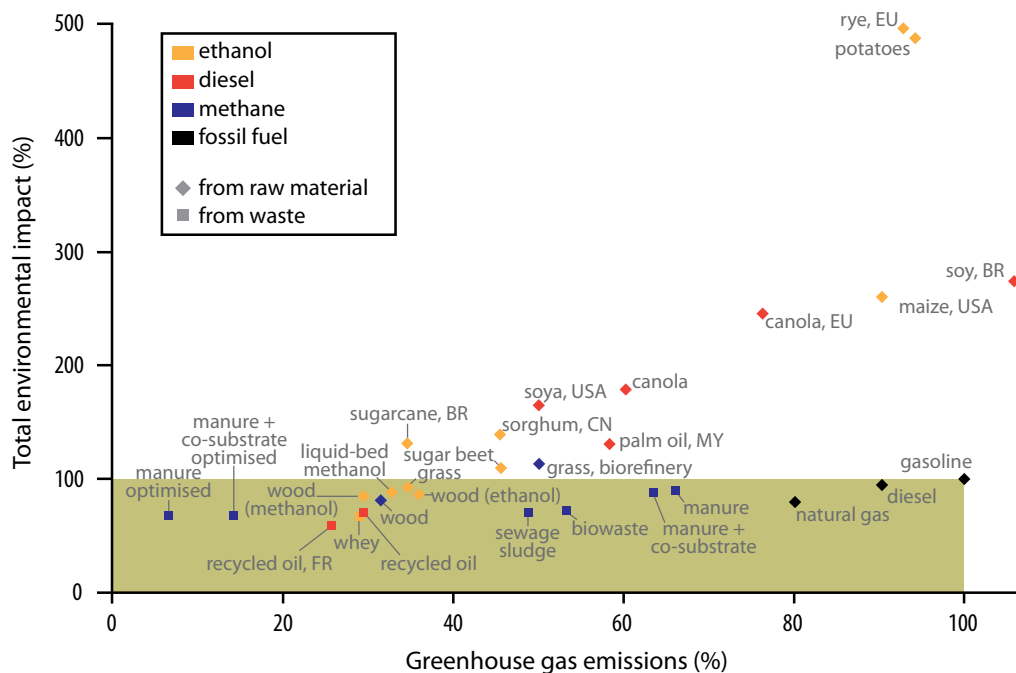


Figure 6. Greenhouse gas emissions of 29 transport fuels plotted against overall environmental impacts, scaled relative to petrol/gasoline. Origin of the tested biofuels is Switzerland, except where otherwise indicated by country codes: Brazil (BR), China (CN), European Union (EU), France (FR), Malaysia (MY) and the USA (USA). Fuels in the shaded area are considered advantageous in both their overall environmental impacts and greenhouse gas emissions. (Source: adapted from Zah *et al.* 2007 by Scharlemann and Laurance 2008)

biofuel crops, such as oil palm, *jatropha*, sugar cane and cassava. The Indonesian Government has provided a number of incentives to support its biofuel development programme, including tax incentives and interest rate subsidies. Several companies are taking advantage of these incentives to expand plantations and invest in biodiesel plants (Casson *et al.* 2007).

According to data from the Institute for Agriculture Bogor (IPB, Indonesia), oil palm can produce 5830 litres of biodiesel per hectare, *jatropha* 600 litres per hectare, and algae 58 700–136 900 litres per hectare. Research continues on all three feedstocks.

Europe and the USA aim to use biodiesel for both transport and electricity (Reijnders and Huijbregts 2008). The USA is expected to become the world's largest consumer of biodiesel by 2010 (Demirbas 2007b). In Europe, most palm oil used as a fuel has until recently been used as a fuel oil (without conversion to biodiesel) in small-scale electricity generation (500 000 tonnes in 2005; Rupilius and Ahmad 2007).

Countries vary widely in their biodiesel blending mandates, from 1 per cent in The Philippines to 10 per cent by 2020 in the European Union (Table 2). While some mandates have been passed into law, others (for example, in Indonesia) are still just recommendations.

Assuming a biofuel yield level of 5200 litres per hectare (Naylor *et al.* 2007), conservative estimates of the additional land area needed to meet these targets (not including the USA, which does not have a specific blending mandate) are 3.5 and 6.3 million hectares by 2010 and 2020, respectively (Figures 7 and 8).

Global biodiesel infrastructure has a current production capacity that roughly matches the volume of biodiesel required to meet proposed blending targets. However, an additional 4 million hectares of palms would be required to actually produce this maximum volume (Figure 9). This is two-fifths of the current combined area of oil palm in Indonesia (6.1 million hectares) and Malaysia (4.2 million hectares) (Direktorat Jenderal Perkebunan 2006; MPOB 2007).

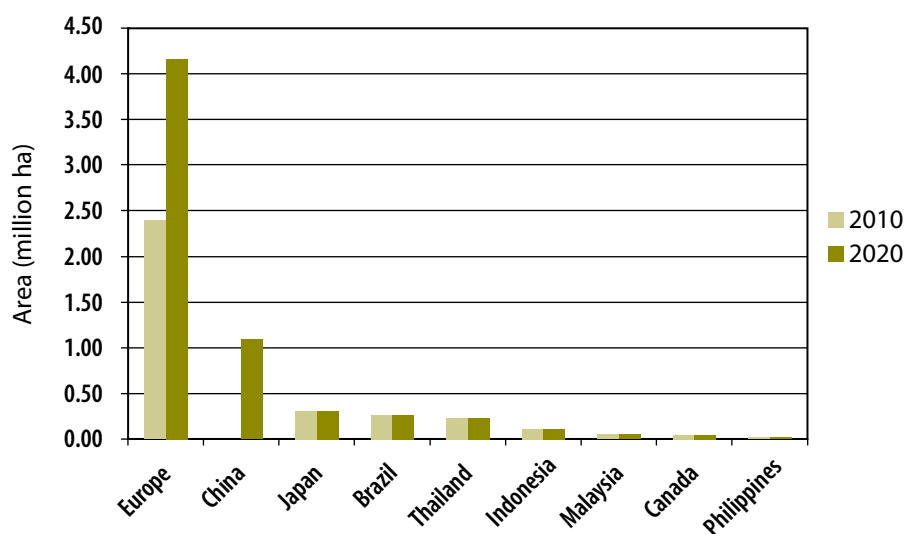


Figure 7. Additional area of oil palm plantations required to meet country-specific biodiesel targets. (Source: authors' calculations based on IEA 2006, Naylor *et al.* 2007)

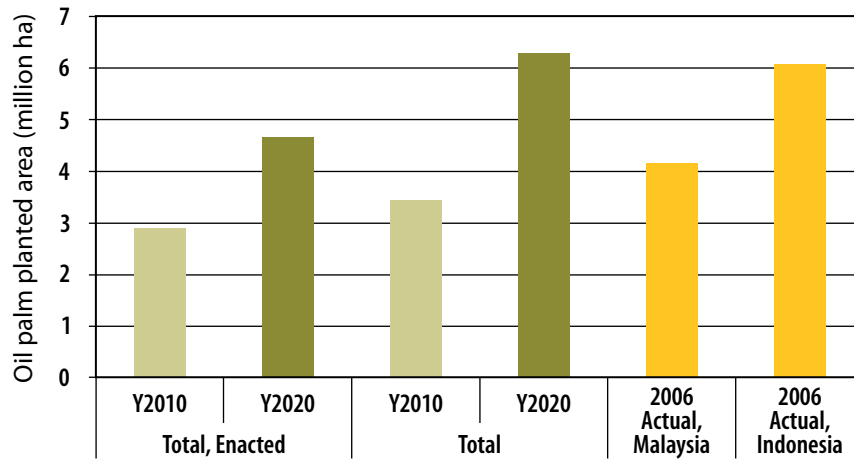


Figure 8. Additional areas of oil palm potentially required for all biodiesel blending targets compared to current oil palm plantation area. (Source: authors' calculations based on IEA 2006, Naylor *et al.* 2007)

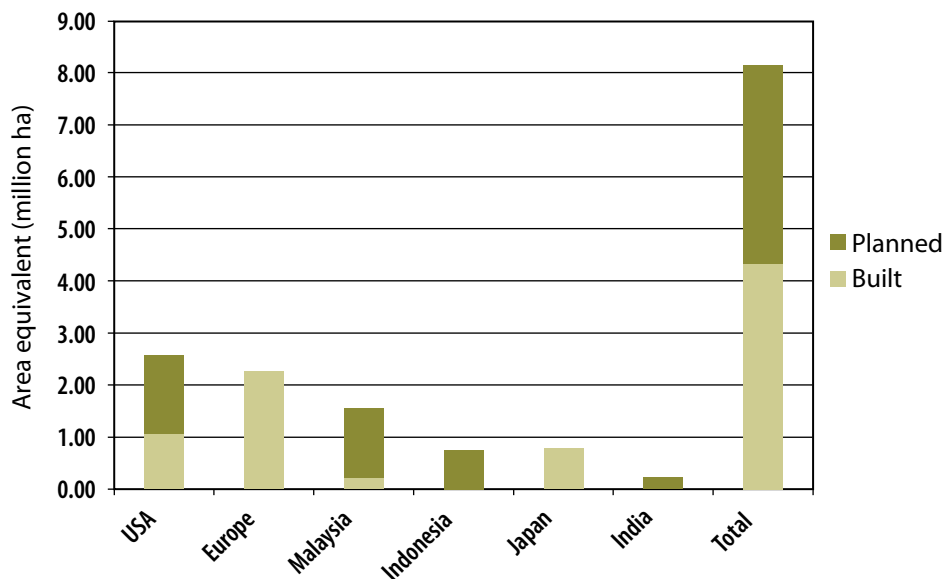


Figure 9. Land requirements estimated from existing and planned biofuel processing capacity. Global biodiesel production capacity roughly matches the volume of biodiesel required to meet proposed blending targets, but an additional 4 million ha of oil palms would be required to run existing processing plants at full capacity. (Sources: authors' calculations based on Naylor *et al.* 2007, International Palm Oil Congress 2007, European Biodiesel Board 2008)

Table 2. Projected global biofuel targets and potential feedstocks for biodiesel production

Country/ Region	Target†	Tentative or implemented?	Mandate or subsidy/tax?	Veg oil trade status	Crude mineral oil trade status
Brazil	Mandatory B2 in 2008 to B5 by 2013	Implemented	Strong tax incentives, mandate	Exporter of soya	Importer
Canada	B2 by 2012	Indicative	None	Exporter of rapeseed	Exporter
China	15% biofuels by 2020	No concrete policy	Tax support proposed	Importer of soya and palm	Importer
EU	B2 to B5.75 by 2010; Mandatory B10 by 2020	Implemented	Subsidies and tax incentives evolutionary mandate‡	Importer of soya	Importer
India		Preparing legislation; Jatropha focus		Importer of palm	Importer
Indonesia	B2 to mandatory B5 by 2010	Tentative		Exporter of palm	Importer
Japan	B5 in 2009	Preparing legislation		Importer of soya, rapeseed and palm	Importer
Korea	Mandatory B5	Implemented	Mandate	Importer of soya and palm	Importer
Malaysia	B5	Tentative		Exporter of palm	Exporter
The Philippines	Mandatory B1 in 2007 to B2 by 2009			Exporter of coconut, importer of palm	Importer
Thailand	Indicative B5 Mandatory B10 by 2012	Implemented	Tax waiver, future mandate	Importer of soya, exporter of palm	Importer
USA	28.4 thousand million litres by 2012 (not fuel specific) General support for larger mandates	Implemented: Energy Act of 2005	Tax credits; mandatory in some states	Exporter of soya	Importer

† B2 = 2% of biodiesel mix, B5 = 5%, etc.

Source: IPOC (2007)

With renewed interest in liquid biofuels, particularly for transportation, new initiatives are underway. For example, the USA has installed 65 biodiesel production facilities and aims to meet 30 per cent of its needs for transportation fuels from biomass by 2030 (Somerville 2007). In Europe and the USA, biofuel production based on rapeseed and soya bean is heavily subsidised and has been developed to support local agriculture (Rupilius and Ahmad 2007).

Opportunities for palm biodiesel producers are, nevertheless, closing in Europe. A 2008 directive issued by the European Parliament on biofuels and renewable energy sources has proposed three criteria for acceptable biofuels: (a) land with high carbon stocks should not be converted for biofuel production; (b) land with high biodiversity should not be converted for biofuel production; and (c) biofuels should achieve a minimum level (35 per cent) of greenhouse gas savings.¹⁵ The European Commission ranked other oil crops (such as rapeseed and sunflower) as having greater greenhouse gas savings than oil palm (European Commission 2008). The future for palm biodiesel is therefore likely to lie within Indonesia and Malaysia themselves, and perhaps in other key consumer countries outside the European Union (i.e., China and India).

Without subsidies, the costs of biofuels from crops are typically higher than those of fossil fuels (Peters and Thielmann 2008), although this can change with changing oil prices. Many researchers are seeking biodiesel alternatives, such as algae and *jatropha*, which might be cheaper and less likely to compete with food crops (Chisti 2008). As Farrell and Gopal (2008) note, 'the overall research challenge for

bioenergy is to develop the technologies to produce useful products at low costs while minimizing the use of scarce resources such as arable land and water'. It remains to be seen what role oil palm will play a role in meeting this challenge.

Palm oil prices

The economic viability of palm biodiesel depends on the price of crude palm oil. Global palm oil prices rose from US\$ 390 per tonne (\$0.33/litre) in November 2006 to over \$900 in November 2007 (Leow 2007), and continued to climb, peaking at \$1146 in March 2008 and falling again to \$791 in August of the same year. Even at \$700 per tonne in 2007, CPO was more expensive than petroleum diesel (Figure 10), even before the additional \$100 per tonne that it costs to convert CPO into biodiesel. The volatility of palm oil and petro-diesel prices underlines the uncertain role of palm oil in the biofuel market. While comparatively low palm oil prices make it more reasonable to use in biofuel, there must be a balance between prices being low enough for biofuel production while remaining high enough for oil palm plantations to be profitable. Currently, unless it is subsidised, converting palm oil into biodiesel is economically a marginal activity at best. Producers who signed forward contracts to deliver biodiesel to European or US buyers are scrambling to secure vegetable oil inputs at a reasonable price and, for the most part, are meeting contracts at a loss. Biodiesel producers who are the best off are those with a well-integrated supply chain who also own large plantations (e.g. Wilmar Holdings, which is currently establishing a large biodiesel plant in Riau) (Casson *et al.* 2007).

High CPO prices also impact upon local people who regularly use palm oil in food. In Indonesia, palm oil producers

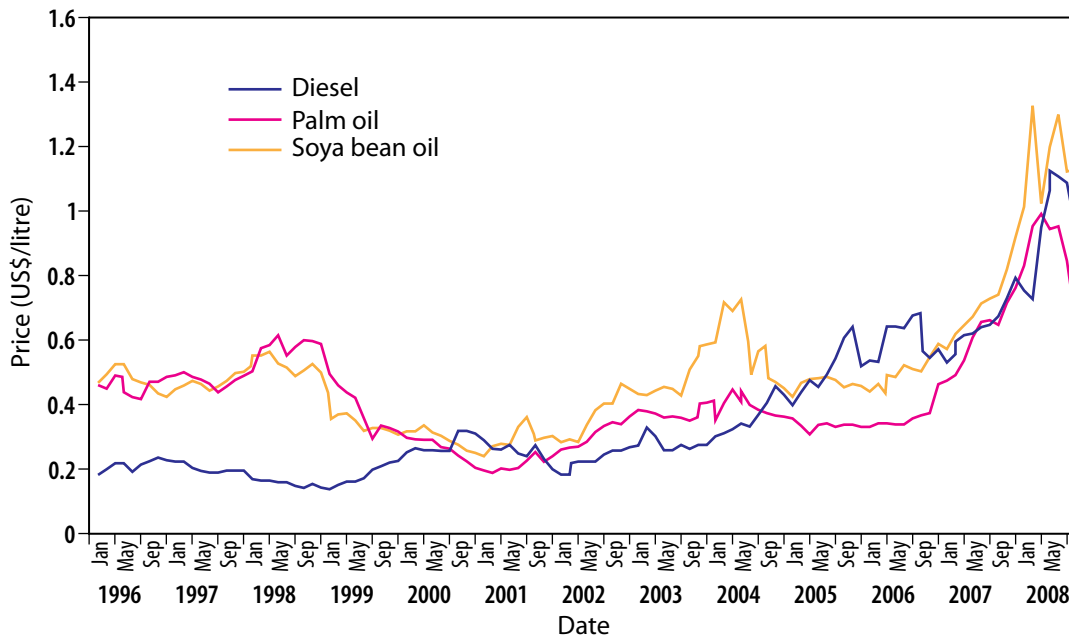


Figure 10. Prices of diesel, palm oil and soya bean oil, 1996–2008. (Source: Vegetable oil data from Global Financial Data 2008 [<https://www.globalfinancialdata.com/>], petro-diesel data from International Energy Association 2008 [<http://www.iea.org/>])

tend to increase exports when prices increase and this causes a shortfall for domestic users. Such a shortfall sparked protests and riots in 1999 (Casson 2000). The Indonesian Government has increased export taxes to keep domestic cooking oil prices down.¹⁶ Nevertheless, the price of cooking oil has doubled in recent years and many Indonesian consumers, half of whom live on less than \$2 per day, are suffering. Demand from China and India, the world's largest palm oil importers, has pushed up palm oil prices over the past few years, but the 2009 financial crisis has caused prices to plummet to US\$400 a tonne.

It should also be noted that the growth in the biofuels market may also be partly responsible for the palm oil price growth prior to 2009, and quantifying how and to what extent biofuel developments influence commodity prices is a critical research question. There are several plausible links to examine: (1) higher maize production for ethanol in the

USA may displace soya bean production and raise global vegetable oil prices; (2) biodiesel production within the EU (e.g., from rapeseed) may lead to higher vegetable oil imports; or (3) palm biodiesel production in Southeast Asia may contribute directly to higher palm oil prices in the future.

The boom continues

In most developing nations, vegetable oil consumption per capita rose considerably in the 1990s—for example, by 65 per cent in Indonesia and 94 per cent in India—because incomes rose and people consumed more oil (Murphy 2007). In 2004–2005, China and India accounted for 29 per cent of global consumption (USDA 2008b). Demand for palm oil, whether for human consumption or because of the 'biodiesel effect', continues to grow rapidly and is affecting the prices of vegetable oils in general (Murphy 2007).

In 2005, palm oil overtook soya as the world's main vegetable oil, and in 2007/2008, production topped 41 million tonnes (USDA 2008b). Indonesia and Malaysia are now the leading exporters¹⁷ and both also have large domestic markets. The main palm oil importers are China, India and the European Union (BisInfocus 2006; USDA 2008a). China is investing heavily in processing and has several joint ventures with Indonesian and Malaysian palm oil producers (Rupilius and Ahmad 2007). Moreover, there are changes in the market in response to environmental concerns. For example, in response to pressure, Unilever has committed to using only palm oil from

certified 'sustainable' sources within 2008, and all the palm oil used by the company in Europe will be certified as 'fully traceable' by 2012 (Unilever 2008).

Virtually all growth in basic oleochemical processing, aside from biodiesel, is now in Southeast Asia and is supplied by palm oil and palm kernel oil (Rupilius and Ahmad 2007). Palm oil is increasingly used because European consumers prefer it to traditional animal 'tallow' for personal care products, in part due to health concerns including the risks of bovine spongiform encephalopathy, commonly known as 'mad cow disease' (Rupilius and Ahmad 2007).

4

A driver of deforestation?

There is a direct relationship between the growth of oil palm estates and deforestation in Malaysia and Indonesia (Clay 2004, pp. 218–219).

An evaluation of FAO (2005) land cover data suggests that between 1990 and 2005, some 55–59 per cent¹⁸ of oil palm expansion in Malaysia (that is 834 000–1 109 000 ha of a total of 1 874 000 ha), and over 56 per cent of that in Indonesia (1 313 000–1 707 000 ha of a total of 3 017 000 ha) occurred at the expense of natural forest cover¹⁹ (Koh and Wilcove 2008a).²⁰

Palm oil producers in Malaysia state categorically that primary forest is no longer converted into plantations—expansion only occurs on land already used for cultivation (e.g., rubber and agriculture). Nonetheless, there is continuing debate over conversion of ‘degraded and secondary forests’ (Koh and Wilcove 2008b in press).²¹

Although some claim that much destruction of forests is attributable to previous impacts and uses such as logging and plantations, oil palm continues to be widely associated with loss of natural forests (Yusoff and Hansen 2007). In Indonesia especially, palm plantations are believed to be the major cause of fragmentation and loss of forest habitats

(Buckland 2005; Koh and Wilcove 2008a). The area of forest lost is greater than the area of plantations that replace them. This is because of the knock-on effects of infrastructure, displaced people, plantation failures, bankruptcies and timber-theft land-clearance frauds. At the same time, many in the Indonesian biofuel industry and even many in government deny any links between oil palm and forest loss (Mita Valina Liem 2008). In part, this reflects a semantic debate on what constitutes ‘forest’ and ‘deforestation’. For many pro-oil palm commentators, oil palm plantations are forests.

The burning issue

Forest and other fires are an annual occurrence in Indonesia. In one month in 2007, some 5108 fire ‘hotspots’ were recorded in Kalimantan. South Sumatra reported 366 fires in one week alone (Sulaiman and Saleh 2007). Between 2000 and 2006 the average carbon emissions due to fires in Indonesia, Malaysia and Papua New Guinea were comparable to the total volume of fossil fuel emissions in the region (van der Werf *et al.* 2008).

In Indonesia, large-scale burning dramatically increased during the 1990s and, in 1997, the government banned the use of fire in relation to the clearance of land (The Environment Management

Act no. 23). In spite of this, Indonesia experienced the worst fires worldwide in 1997 and 1998, a third of them lit specifically to prepare land for plantations (World Bank 2001). This period was also the major El Niño–Southern Oscillation event which certainly contributed to the severity of the fires (van der Werf *et al.* 2008). The impacts on human life and livelihoods, health, biodiversity and habitat were extensive, and the fires potentially contributed to global warming (Simorangkir 2007). The fires burnt 11.6 million hectares of land, releasing 0.73 parts per million volume CO₂ into the atmosphere (Murdiyarto and Adiningsih 2006). The economic costs of forest loss, degradation and smoke haze pollution were estimated at \$2.3–3.5 thousand million, with an additional \$2.8 thousand million in carbon release (Tacconi 2003).

Fires require dry fuel and a source of ignition. Intact rainforests are generally too wet to burn—fires only occur following severe droughts. But forest degradation, including logging, roads and fragmentation, increases the likelihood that a forest will dry out sufficiently even in a short drought (Laurance 2003). Once a forest has burned it is likely to be dry enough to burn again in subsequent years. Secondary forests are more flammable than primary forests. Developments like oil palm plantations often increase both the degradation of surrounding forests, and the types of human activities that might lead to both intentional and unintentional ignition—thus many fires that occur in the vicinity of oil palm developments are likely attributable (directly or indirectly) to the plantation. In addition, there is a strong relationship between climate change and fires: During the moderate 2006 El Niño–Southern Oscillation event, carbon emissions from fires were 30 times greater in Borneo than they were during

the 2000 La Niña, with the incidence of fire increasing exponentially with drought (van der Werf *et al.* 2008).

Burning is still widely regarded as the quickest and cheapest method to clear land for plantations (Guyon and Simorangkir 2002). While this is true for ‘high volume’ forest and forests on peat soils, where the costs of removing wood with heavy machinery are high,²² for existing large-scale plantations, secondary vegetation or heavily logged forest, zero burning is more cost effective (Simorangkir 2007).

In Malaysia, oil palm development has similarly been preceded by large-scale forest clearance and fragmentation of the larger forest landscape (Hansen 2005; Abdullah and Nakagoshi 2007), but without the smoke and haze problems associated with Indonesian oil palm. Malaysia established a strict no-burning policy for land clearance in the 1990s. The country’s success in reducing fires may be related to the fact that most plantations were already established and replanting did not require the same degree of clearing. In contrast, many plantations in Indonesia are just being established (Simorangkir 2007) and fire is the simplest and cheapest way to clear the land.

Oil palm companies are often suspected of setting fires to degrade forest intentionally to gain land use permits (Casson 2003). Underlying causes of fires within the boundary of oil palm concessions are, however, disputed and likely complex, and the blame for such fires does not always lie with concession management (Dennis *et al.* 2005).

The clearance of land by fire is part of traditional land management practices throughout the tropics. Changing fire use will not be straightforward. The sheer number of smallholders alone involved is a formidable challenge as they cannot



usually afford to pay up front for heavy land-clearing machinery (Casson *et al.* 2007). Large estates, although easier to target, will only comply if the authorities implement the law strictly and issue penalties.

Abandoned land and logging

Forest loss and degradation in Southeast Asia is more rapid than in other tropical regions (Sodhi *et al.* 2004). Between the mid 1980s and late 1990s, logging, plantations, human migration and infrastructure reduced forests in Sumatra by 61 per cent (Nellemann *et al.* 2007). There is illegal logging, often with forest clearance, in 37 of the 41 national parks in Indonesia (Ministry of Forestry 2006 cited in Nellemann *et al.* 2007). Annual forest loss in Kalimantan is estimated at 2 per cent (Fuller *et al.* 2004) and, from 1985 to 2001, Kalimantan's 'protected' lowland forests were reduced by over 56 per cent (Curran *et al.* 2004).

Ministry of Forestry statistics indicate that close to 70 per cent of the oil palm plantations located in Indonesia were planted on land that formally fell within

Indonesia's forest estate between 1982 and 1999. This totalled close to 2.5 million hectares of forest land, most of which was within the provinces of Riau, Jambi, Aceh, West Sumatra, Central Kalimantan and South Kalimantan (Casson 2000). If we assume that this trend has continued, it is possible that up to 4 million hectares of forest has been converted to oil palm to date (2008). Oil palm is, nevertheless, increasingly being planted on already cleared lands in part because most of the lowland forests located in Kalimantan and Sumatra have already been lost. In Kalimantan, for instance, spatial analysis indicates that permits have already been granted to establish oil palm on 5.5 million hectares of land, of which only 25 per cent (1.7 million ha) is forested (Figure 11; Casson *et al.* 2007).

Didiek Hadjar Goenadi, the Executive director of the Indonesian Palm Oil Association, said on 12 May 2008 that in the future palm oil companies would focus on developing 'idle land' (notably including former forest concessions). He estimated that about 7 million hectares of such uncultivated land was available in Indonesia (Simamora 2008).

Oil palm settlement in Sumatra. Between the mid 1980s and late 1990s, logging, plantations, human migration and infrastructure reduced forests in Sumatra by 61%. (Photo: Patrice Levang)

Nevertheless, oil palm expansion is still considered to be a major driver of deforestation in Indonesia. This is because it can be easier to obtain a land clearing permit than a logging permit, and some investors use oil palm as a means to gain access to timber. This explains why location permits covering 5.3 million hectares of land for oil palm developments have been issued in West Kalimantan, while less than 1 million hectares of land have actually been planted with oil palm (Casson *et al.* 2007). Many oil palm companies are closely associated with logging companies (Casson 2000). The gains from selling the timber can offset the costs of establishing the plantation which otherwise requires several years to repay (Casson 2003). As timber fetches \$1024–2100 per hectare (various references, see Venter *et al.* 2009), it is extremely lucrative to set up a ‘bogus’ plantation, harvest the timber then abandon the area, particularly as there is no accountability. In 2003,

although 12.5 million hectares of degraded land was available, most oil palm plantations were established in forested areas (Casson 2003).

To our knowledge, not a single company in Indonesia has been prosecuted for clearing land but failing to develop viable plantings. Notably, however, the former Governor of East Kalimantan was indicted by Indonesia’s Anti-Corruption Court in November 2006 for issuing forest exploitation permits (IPK) without first seeking central government approval—the forest was cleared but oil palm was not planted (Casson *et al.* 2007). Laws presently allow the government to revoke location permits and land use licenses allocated to oil palm companies if they fail to plant within 2 years; however, such revocation rarely occurs and the damage will already have been done though the land would be available for plantation if investors are willing to cover the establishment costs.

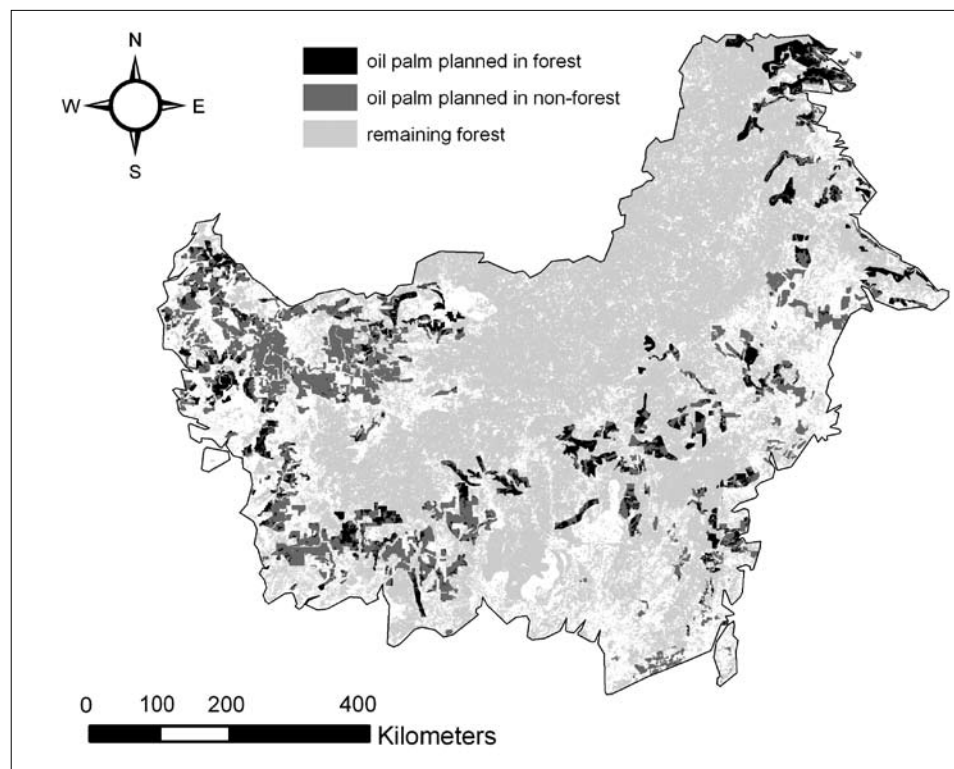


Figure 11. The extent of forest and planned oil palm plantations within forest habitat and in non-forest in Kalimantan, Indonesia. (Venter *et al.* 2009)

5

Greenhouse gas emissions

Tropical deforestation contributes around a quarter of anthropogenically released greenhouse gases (FAO 2005). Environmental changes, whether for timber extraction or plantations, the destruction of forests by fire and the degradation of peatlands, mean that Indonesia is the fourth largest contributor to the overall greenhouse gases causing global warming in the world (World Resources Institute 2009).

Carbon emissions and carbon benefits

To offer benefits, alternatives to fossil fuels need to:

- have more environmental benefits than the fuel they replace
- be economically competitive
- be produced in sufficient quantities to make a meaningful impact on energy demands
- show a net energy gain (Hill *et al.* 2006).

With palm oil production, carbon is lost when forest is converted and when fossil fuels are used in management, processing or transport. Net carbon savings can

still result if the total amount of carbon emitted from palm oil production is less than that emitted from burning an equivalent amount of fossil fuels. As any review of the literature soon shows, there are many different ways that the carbon emissions balance can be assessed—these allow those for or against oil palm to find calculations to ‘show’ the benefits or the costs.

Each tonne of petroleum diesel releases around 3.57 tonnes CO₂ into the atmosphere (Fronzel and Peters 2007). The numbers for palm biodiesel are harder to estimate and will vary considerably with context. For example, a typical hectare of undisturbed rainforest contains approximately 250 tonnes of aboveground carbon (Tomich *et al.* 2002). Replacing primary rainforest with oil palm therefore reduces this carbon by around 250 tonnes per hectare (850 tonnes of CO₂). However, this figure may be reduced to 160 tonnes per hectare (544 tonnes of CO₂) when oil palm trees reach maturity, as oil palm trees contain around 90 tonnes of carbon per hectare (Tomich *et al.* 2002; Casson *et al.* 2007; Yusoff and Hansen 2007). Venter *et*

al. (2009) use a compilation of data to estimate that each hectare of (dryland) Southeast Asian tropical forest cleared for oil palm releases an average of 698 (\pm SD 162) tonnes of CO₂ in the 30 years following development. But not all forests are equal and there is considerable variation across locations. In addition, the belowground carbon pools (and changes in these) can be substantial, but are even less well characterised. Living belowground forest biomass is generally higher where soil fertility is lower—if soil carbon pools maintained by and dependent upon the forest cover are factored in, forests are generally responsible for sequestering considerably more carbon than accounted for in most current ‘aboveground’ estimates. This becomes especially crucial in the case of peat soils discussed below.

Many commentators believe that producing and using palm biodiesel from converted forest land causes greater greenhouse gas emissions, at least in the short term, than refining and using an energy-equivalent amount of petroleum diesel (Figure 12; Fargione *et al.* 2008). In contrast, planting open areas (Hartemink 2005) or degraded areas (Gibbs *et al.* 2008) with oil palm can result in net carbon gains. Moreover, of the most common biofuel crops, oil palm has the highest potential for carbon offsets (Gibbs 2008). Overall, oil palm plantations are considered to contribute to global warming in the short term, if they replace vegetation with higher carbon content, such as primary forest.

Reijnders and Huijbregts (2008) suggest that as much as 75 per cent of the energy required for biodiesel production from palm oil comes from fossil fuel though there is considerable variation. Making various assumptions, they find that one tonne of palm oil can be linked to between 2.6 and 18.2 tonnes of CO₂.

Note that the first figure is below that of petroleum diesel (3.57 tonnes) and the second far surpasses it. Most data and trends remain contentious: while fossil fuels do tend to be used in generating the chemicals (fertilisers and pesticides) used on plantations and in transportation, these inputs could themselves be replaced in time by biofuels.

Emissions can be reduced by converting waste products into energy, halting deforestation, utilising degraded lands and by allowing secondary forest to regenerate on exhausted plantation land (Yusoff and Hansen 2007; Reijnders and Huijbregts 2008; de Vries *in press*). Many palm oil processing plants already make use of waste biomass (shell and fibre) to fuel processing, thus saving fossil fuels (de Vries *in press*). As de Vries (*in press*) notes, observers are having difficulty keeping up with all these developments: ‘A comprehensive update on palm oil energy balance and environmental emissions would be a great asset. And it is likely that recent knowledge of people from the sector would be more valuable in making such an update than that of scientists working thousands of miles away from the nearest plantation.’

Time to reach positive carbon benefits

Biofuels can release less C per unit of energy released than fossil fuels and still cause net carbon emissions in the short to medium term. This is because so much carbon is lost in the original land use conversion. Long-term benefits in the future may not be worth short-term losses, especially if they are meant to address the Intergovernmental Panel on Climate Change’s call to reverse the increase of greenhouse gas emissions by 2020 so as to avoid disaster (IPCC 2007).

Estimates of the time required for oil palm to make a positive carbon contribution vary between 71 and 93 years for oil palm planted following forest conversion and more than 600 years on peat swamp (Danielsen *et al.* 2008, Gibbs *et al.* 2008). In contrast, planting oil palm on degraded sites might lead to positive gains in only 10 years (Danielsen *et al.* 2008) or in some cases, immediately (Gibbs *et al.* 2008). Fargione *et al.* (2008) also found similar figures; estimating 86 years to become carbon positive in normal forests cleared by burning and *ca* 420–840 years for peat forest—the estimate assumes oil palm can contribute to CO₂ savings equivalent to 7.1 tonnes of CO₂ repaid per hectare per year.

Peatlands and greenhouse gas emissions

Tropical peatlands are one of the world's largest near-surface reserves of terrestrial organic carbon (Page *et al.* 2002). Many are active sinks absorbing carbon at 100 kg/ha per year (Weiss *et al.* 2002). Logging, draining²³ or clearing peatlands allows drying, allows surface peat to become flammable²⁴ or to decay, and releases large amounts of CO₂ (Wosten 1997 cited in Hartemink 2005). Even a partially drained peatland can release over 4 tonnes of carbon per hectare per year (Hirano *et al.* 2007). A well-drained peatland is more likely to release around 16 tonnes of carbon per hectare per year (55 tonnes of CO₂/ha per year) (Fargione *et al.* 2008).

One recent study estimated that about one-quarter of existing Indonesian oil palm concessions (about 1.4 million ha) are located on peat (Hooijer *et al.* 2006). A study undertaken in 2007 for the Indonesian Forest Climate Alliance revealed that around 17 per cent of the land use permits²⁵ issued to oil palm concessions lay on peatlands in

Kalimantan. Another 646 234 hectares of peatlands have been allocated to planned oil palm developments in Kalimantan. In Riau, Sumatra, about 13 per cent of the land use permits allocated for oil palm developments lie on peatlands; however, 50 per cent of the location permits²⁶ issued for planned oil palm developments (which total 711 815 ha) have been issued for peatlands (Casson *et al.* 2007). The Indonesian government temporarily stopped allocating peatlands to oil palm plantations in 2007 in response to growing concern about climate change and GHG emissions arising from peat degradation, however, it revoked this decision in February 2009.

Oil palm is increasingly being planted on peatlands because most mineral soil areas in the lowlands within Sumatra and Kalimantan are already taken. Peatlands also tend to have low population densities and oil palm is the most financially attractive development option. This makes it easier to seek and gain ownership, and investors are less likely to become embroiled in social conflicts (Casson *et al.* 2007).

The conversion of these peatlands to oil palm, which invariably involves draining, will result in significant CO₂ emissions and will counter any carbon benefits that palm-based biofuel may offer. In fact, as mentioned earlier, Fargione *et al.* (2008) estimate that it could take *ca* 420–840 years to recover the 'carbon debt' of converting peat forest to oil palm from biofuel production and use.

Based on a compilation of published figures, Venter *et al.* (2009) estimate that each hectare of peat swamp forest drained and converted to oil palm may contribute 3304 (±SD 402) tonnes of CO₂ over 30 years. If the approximately 1 million hectares of oil palm planned

for Kalimantan are developed, perhaps 1245 (\pm SD 155) million tonnes of CO₂ will be released into the atmosphere over the following 30 years. This is 65 per cent of the reductions required to bring the USA into line with Kyoto requirements for 2008 (Venter *et al.* 2009).

Other greenhouse gases

Methane (CH₄) has been excluded from most environmental assessments of oil palm development, but it is 21 times more potent as a greenhouse gas than CO₂ (Wuebbles and Hayhoe 2002). Tropical forests appear to be major global methane sinks (Eggleton *et al.* 1999; MacDonald *et al.* 1999) and absorbance usually declines when forests are cleared.

Peatlands emit some methane after long periods of flooding (Hooijer *et al.* 2006). The effect of drainage ditches and fertiliser in peatlands may also be significant—for example, urea applied to peat probably increases methane emissions (Melling *et al.* 2006). Fermentation of mill effluent also produces methane (Yacob *et al.* 2006).

Emissions of volatile organic compounds also have a significant but as yet poorly understood influence on atmospheric chemistry and climate (Wilkinson *et al.* 2006). These emissions vary by over four orders of magnitude across tropical plant taxa, making vegetation emissions sensitive to overall composition (Lerdau and Slobodkin 2002). Oil palm is a major isoprene emitter and the local and global consequences of such emission from large oil palm plantations remain to be examined.

Isoprene is known to react with the (natural) hydroxyl radicals that help cleanse the atmosphere of various trace (greenhouse) gases (e.g., methane, ozone and nitrogen oxides), which would otherwise accumulate (Guenther

2008). Recent research indicates that, in otherwise clean air, isoprene does not simply mop up hydroxyl radicals as was previously believed, but can also regenerate them (Guenther 2008; Lelieveld *et al.* 2008), while in a polluted environment this recycling is inhibited and is replaced by a process which promotes smog (Lelieveld *et al.* 2008). Thus, we can predict that oil palm plantations near to industrial and urban areas are likely to exacerbate photochemical air pollution with wider consequences for people and the environment.

Fertilisation of plantations may contribute to greenhouse gas emissions. The most significant fertilisers, from a greenhouse gas perspective, are nitrogen based, such as ammonium nitrate, ammonium sulphate and urea. According to the Intergovernmental Panel on Climate Change, one kilogram of nitrous oxide has an equivalent impact to approximately 310 kilograms of CO₂. Nitrous oxide (N₂O) is responsible for 7.5 per cent of the calculated greenhouse effect caused by human activity and the concentration in the atmosphere is increasing at a rate of about 0.2 per cent per year (IPCC 2007). When examining the greenhouse gas emissions of land use types in Jambi, Murdiyarso *et al.* (2002) found that oil palm plantations released large quantities of N₂O into the atmosphere (55 $\mu\text{g N m}^{-2} \text{h}^{-1}$) probably linked to nitrogen fertiliser use. In contrast, fast-growing pulp trees and intensive annual cropping systems emitted only 1.04 and 1.90 $\mu\text{g N m}^{-2} \text{h}^{-1}$, respectively, while natural forests were found to emit just 0.71 $\mu\text{g N m}^{-2} \text{h}^{-1}$. This is an area requiring further research.

Other relevant questions include how plantation emissions of nitrogen oxides (from natural sources as well as from the fertiliser just discussed), ozone,

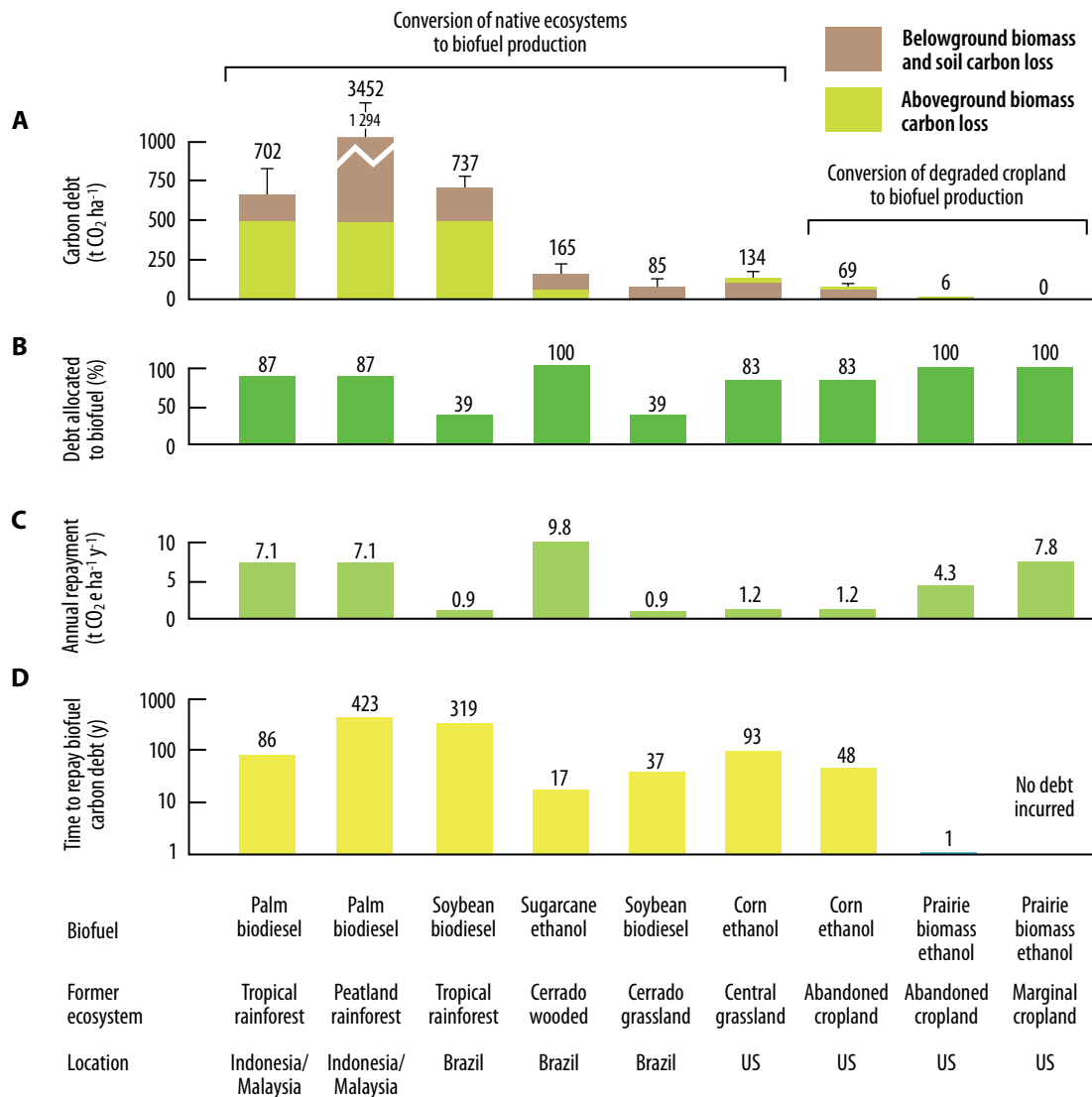


Figure 12. Carbon debt, biofuel carbon debt allocation, annual carbon repayment rate, and years to repay biofuel carbon debt for nine scenarios of biofuel production. Means and standard deviations are from Monte Carlo analyses of literature-based estimates of carbon pools and fluxes. (A) Carbon debt, including CO₂ emissions from soils and aboveground and belowground biomass due to habitat conversion. (B) Proportion of total carbon debt allocated to biofuel production. (C) Annual lifecycle greenhouse gas reduction from biofuels, including displaced fossil fuels and soil carbon storage. (D) Number of years after conversion to biofuel production required for cumulative biofuel greenhouse gas reductions, relative to fossil fuels they displace, to repay the biofuel carbon debt. (Source: after Fargione *et al.* 2008)

and other greenhouse gases affect the atmosphere and climate (Mosier *et al.* 2004). Provisional data suggest that such emissions from Kalimantan's peatlands are low (Hadi *et al.* 2005). The impacts of oil palm plantations on non-CO₂ greenhouse gas emissions, the costs, benefits and possible improvements are still unclear.

REDD and carbon funds

At the United Nations Climate Change Conference in Bali (December 2007), climate policy makers agreed that policy approaches and positive incentives that aim to reduce emissions from deforestation and forest degradation (REDD) in developing countries should be considered. This mechanism will entail wealthy nations paying other countries to reduce their rate of deforestation and forest degradation, thereby slowing carbon emissions. If carbon credits tradable on compliance markets are awarded for REDD schemes, this could give national forest conservation agencies access to the rapidly expanding global carbon market, which traded \$30 thousand million in 2006. Recent commitments from the World Bank's Forest Carbon Partnership Facility have made millions and perhaps thousands of millions of dollars available for payments by 2013.

Ideally, to stop further deforestation for oil palm, economic revenues from forest conservation would compensate the lost revenue opportunities. Payments for avoided deforestation may be one

mechanism for this. Venter *et al.* (2009) estimate that an area of one million hectares in Kalimantan proposed for oil palm development will generate \$1 thousand million in profits from the initial timber harvest and a further \$1.78 (\pm SD 0.92)²⁷ thousand million from palm oil profits over the next 30 years (using a discounting rate of 8 per cent). For forest conservation to meet these opportunity costs, emission reductions will need to be compensated in the year they are expected to occur at a carbon price of \$4.66 (\pm SD 1.65) per tonne of CO₂.²⁸ This carbon price accounts for the estimated costs of administration and forest protection. These figures are well within the scope of global carbon markets, which range from about \$5.50 per tonne on the Chicago Climate Exchange (a voluntary carbon market) to about \$30 on European compliance markets (April 2008 values), and should therefore represent an attractive investment by national governments. However, unless REDD carbon credits are allowed to be traded on compliance markets (currently they are restricted to voluntary markets) the conversion of land to oil palm plantations will be more profitable than REDD (Butler *et al.* 2009, Venter *et al.* 2009) except perhaps in the case of carbon-rich peat forests (Venter *et al.* 2009).

In addition to generating direct revenues, forest conservation will provide other benefits not associated with oil palm development, such as the maintenance of important ecosystem services, indigenous cultures and biodiversity.

6

Impacts on the environment

Biodiversity

Most concern about biodiversity loss is directly related to forest loss (discussed above). Indonesia's and Malaysia's lowland forests are among the Earth's most species-rich terrestrial habitats. The loss of Southeast Asia's lowland forests threatens the region's exceptional conservation value (Tinker 1997; Curran *et al.* 2004; Sodhi *et al.* 2004, 2006) and has long been the principle conservation concern in the region (Jepson *et al.* 2001; Gaveau *et al.* 2007). A number of species, including orangutans (*Pongo* spp.) and Sumatran tiger (*Panthera tigris sumatrae*), are the focus of international concern. Several NGOs have campaigned against plantations on the basis of threats posed to orangutan, tiger and other such charismatic species (e.g., FOE 2004, 2005; Brown and Jacobson 2005).

In Indonesia, the majority of oil palm is established in industrial scale monoculture plantations ranging in size from 4000 to 20 000 hectares. The establishment of these plantations usually results in the near total clearing of former vegetation. Not surprisingly, research demonstrates that the natural flora and fauna which occur in oil palm plantations are greatly impoverished when compared to lowland rainforests (e.g., PORIM

1994; Gillison 2002; Peh *et al.* 2006) and even disturbed natural forest (Figure 13; Fitzherbert *et al.* 2008). Extensive field research carried out in oil palm frontier areas on the island of Sumatra has concluded that oil palm plantations result in a significant reduction in biodiversity if plantations replace natural forests, secondary forests, agroforests, or even degraded forests and scrubby unplanted areas (Gillison and Liswanti 1999; Maddox 2007).

Mammals are also affected. For example, in Malaysia researchers found that fewer than 20 of 75 mammal species encountered in primary forest also used oil palm (PORIM 1994). A 4-year study of terrestrial mammals living in and around an oil palm plantation concession in Jambi in Sumatra, Indonesia, concluded that oil palm monocultures are very poor habitats for most terrestrial mammal species (Maddox 2007). This is especially the case for endangered species, such as Sumatran tiger, tapirs (*Tapirus* spp.) and clouded leopards (*Neofelis* spp.). Only four mammal species³⁰ (10 per cent of the number detected within the landscape) were regularly detected in the oil palm itself and none of these species had a high conservation value. Some species, including deer, macaques

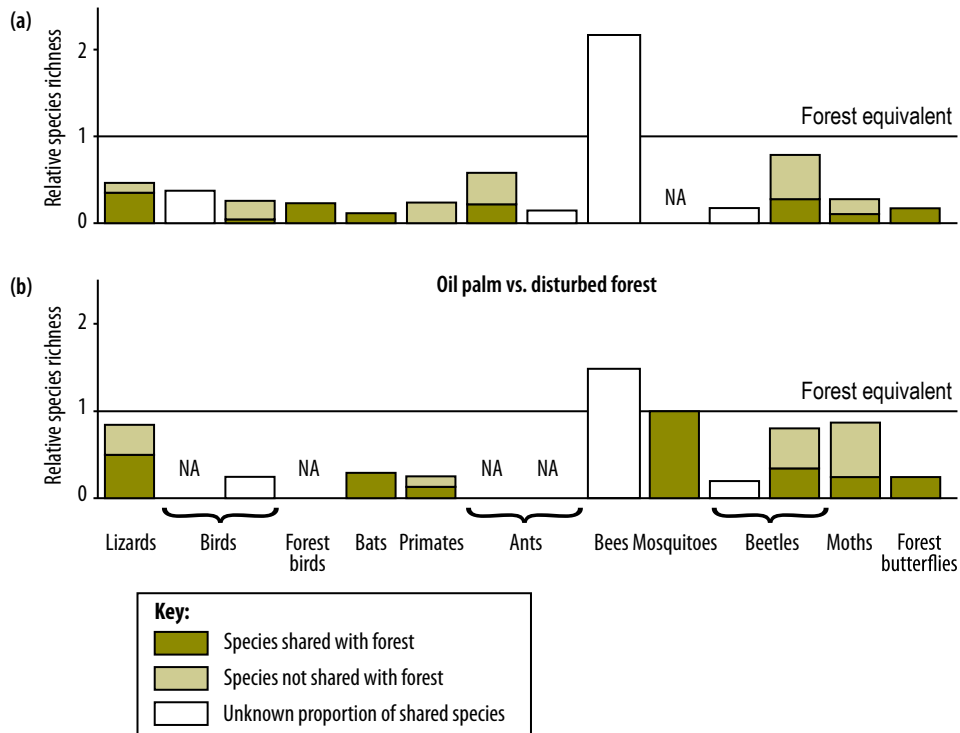


Figure 13. Comparison of species richness in oil palm plantations vs. (a) primary forests and (b) degraded natural forest. Species richness has been scaled such that forest richness is equal to 1. (Source: Fitzherbert *et al.* 2008)

and pangolins, showed limited tolerance but, with the exception of pigs, all species showed a general preference for non-oil palm habitats—even heavily degraded natural habitats (Maddox 2007). In fact, the study highlighted the conservation importance of marginal and degraded habitats often found within oil palm concessions, and that these areas can retain high conservation value (Maddox 2007). Further consideration of the biodiversity impact of oil palm on all vegetation types (not just primary, natural forest) is therefore warranted.

Birds are also affected, with conversion of forest to plantations resulting in a reduction in species richness of at least 60 per cent, especially affecting threatened forest-dependent birds (Aratrakorn *et al.* 2006; see also Figure 14). Endangered species (and subspecies), such as orangutan, Sumatran elephant (*Elephas maximus sumatrensis*) and Sumatran tiger, are especially threatened by oil

palm expansion and are often captured or killed when vegetation is cleared to make way for new plantations. Elephants are considered to pose a risk to the oil palm plantations because they often destroy plantations and feed on the oil-rich palm nuts (Susanto and Ardiansyah 2003). Orangutans have also been known to become violent around oil palm plantations when their food source is threatened and they too are often destroyed (Brown and Jacobson 2005; Buckland 2005). Tigers will also be killed if they are considered to pose a threat to plantation workers (Brown and Jacobson 2005). All of these species are vulnerable to illegal wildlife poachers when forested areas are opened up to establish oil palm plantations.

By comparing a 2006 map of planned and ongoing oil palm developments with a forest cover map and a recent orangutan density map for Kalimantan, Venter *et al.* (2009) find that planned

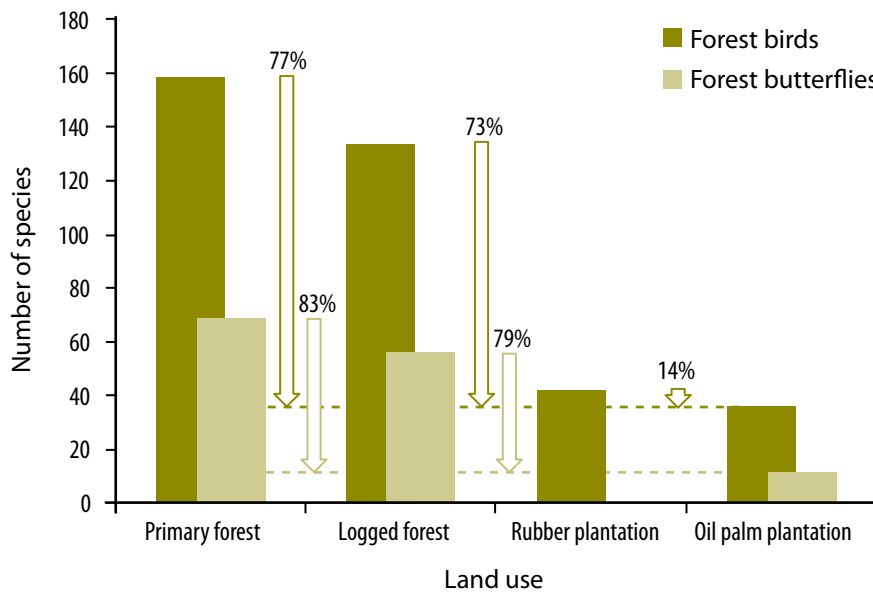


Figure 14. Total number of species of forest birds and forest butterflies recorded from different land use types in southern Peninsular Malaysia and Borneo, respectively. Forest birds and butterflies are species that depend extensively or exclusively on lowland evergreen rainforests. (Source: Koh and Wilcove 2008a)

plantations encompass 1 million hectares of forest containing about 10 000 (20 per cent) of the remaining Bornean orangutans (*P. pygmaeus*). The impacts of oil palm arise not only from the loss of forests, but also from the increases in access, population and proximity to forest edges. The likelihood of further forest loss and degradation, of fire and of increased hunting pressure, though not well documented, seem likely to be prevalent patterns (these are the patterns seen in timber concessions; Meijaard *et al.* 2005).

Nonetheless there are counterarguments. Species richness is a relative concept that makes sense only with respect to comparisons. For example, a typical oil palm plantation has a greater diversity of species than planted forests in many (temperate) developed countries (Basiron 2007). Because planting on steep slopes is avoided, and water courses and less accessible sites are protected, it is possible for plantations to harbour valuable habitats for various species—indeed it would seem that much of the decline in

biodiversity noted around plantations may be due not to habitat change but to direct human impacts (Maddox 2007).

In its native habitat in Africa, wild oil palm provides an important food source to various species, including chimpanzee (*Pan troglodytes*) (Humble and Matsuzawa 2004; Leciak and Hladik 2005), but clearly in an agroindustrial setting, the damage that this causes to plants and the associated financial losses are unacceptable to companies. Still, considering that many species that occur in an oil palm plantation setting are protected by Indonesian and Malaysian law, new management guidelines and regulations are needed that protect crucial habitats for such species and develop a clear understanding that plantation managers are responsible for the continued existence of protected species in their areas.

Turner *et al.* (2008) raise the question of whether it would be possible



Orangutan mother and infant, Borneo. Endangered species, such as the orangutan, Sumatran elephant and Sumatran tiger, are especially threatened by oil palm expansion. They are often captured or killed when vegetation is cleared to make way for new plantations. (Photo: Jacha Potgieter)

to enhance biodiversity in oil palm plantations. An empirical study in about 40 000 hectares of oil palm plantations in Borneo addressed this very question, focusing on approaches the oil palm growers currently use (Koh 2008b). These approaches included the planting of flowering plants to attract the insect predators and parasites of oil palm pests. This study implies that biodiversity in oil palm plantations can be enhanced by altering vegetation characteristics at the local level (e.g., percentage ground weed cover), or by increasing natural forest cover at the landscape level; however, the gains in biodiversity resulting from these practices are quite minor relative to the losses that occur when forests are cleared.

Turner *et al.* (2008) hint that such biodiversity enhancements may bring benefits to oil palm growers. A bird-exclusion experiment in oil palm plantations in Malaysian Borneo tested the hypothesis that insectivorous birds inhabiting plantations provide a natural pest control service for oil palm agriculture. Bird exclusion significantly increased herbivory damage to oil palm seedlings compared to control treatments, and the magnitude of this insect control increased with the abundance of insectivorous birds (Koh 2008a). These results imply that biodiversity friendly practices may benefit growers. To gain a better understanding of the biodiversity impacts of oil palm agriculture, more studies must be conducted for different taxonomic groups and across oil palm-growing regions of the world (Koh 2008b; Turner *et al.* 2008).

The environmental impact of oil palm plantations could be considered to be less than that of most alternative crops, simply because more can be produced on less land. Given that there have to be tradeoffs between conservation and economic growth this is not a minor point. Better management, higher yields from improved varieties and planting on land that is already degraded could improve yields significantly without further deforestation (Hardter *et al.* 1997). Nevertheless, the sheer scale of oil palm plantations threatens biodiversity.

One recent debate asks whether, rather than fighting such developments, the profitability of oil palm might allow conservationists to form profitable collaborations with image-sensitive producers who would in turn allow them to buy up and protect pristine forest (Koh and Wilcove 2007). The role and competencies of conservationists in dealing with such issues is also hotly debated (Clements and Posa 2007; Koh and Wilcove 2007; Venter *et al.* 2008).

Soil erosion and fertility

Land clearing and road construction increase soil erosion in previously forested regions—especially in steeper sites. This can result in landslides (Sidle *et al.* 2006) and steep sites are generally avoided for practical as well as legal reasons. Studies on erosion in oil palm are few. Generalising from studies of tree crops more generally, plantations expose the soil to erosion, especially during initial site preparation and tree establishment (Hartemink 2005). Even after trees have become established, erosion on paths and open areas can be high. In mature oil palm plantations in Malaysia, erosion was estimated at 7.7–14 tonnes per hectare per year (Hartemink 2005).

Studies of soil changes under oil palm in Malaysia indicate that nutrient levels increased in the early stages of cultivation, perhaps because of fertilisers and leguminous cover crops (PORIM 1994 cited in Hartemink 2005). In the longer term, soil nutrients may still decline because applications of fertiliser do not compensate for uptake and retention by crops (Hartemink 2005), though—given the high value of the crop—any systematic decline in soil properties is likely to be addressed by the industry. Mulching has been greatly increased since the mid 1990s—this supplies nutrients and reduces erosion, runoff and evaporation (Weng 2000). There is also increasing interest in examining the potential benefits of various cover crops for their soil improvement properties (and their influence on pests) (Baligar and Fageria 2007).

Some small-scale preliminary studies suggest that well-managed oil palm can serve reasonably well in regulating basic hydrological functions from catchments (Yusop *et al.* 2007). This is an area where more work is needed.

Fertilisers and pesticides

Fertiliser use in Asia increased by 1900 per cent in the last four decades of the 20th century (Zhao *et al.* 2006). The oil palm industry is responsible for some of this increase, as it is one of the largest consumers of mineral fertilisers in Southeast Asia (Hardter and Fairhurst 2003).

Oil palm plantations apply large quantities of nitrogen-based fertilisers to plantations in order to increase and maintain yields. A typical oil palm plantation planted on both mineral and peat soils requires around 354 kg N/ha over the first 5 years (Guyon and Simorangkir 2002). This appears to increase loss of gaseous nitrogen oxides (discussed above as a greenhouse gas) and to increase eutrophication in neighbouring water bodies and wetlands affected by runoff. But such runoff is less than might be expected from the sums involved, perhaps because companies do not wish to see expensive fertiliser washed from their plantations.

Pesticides and herbicides also increase pollution, especially with repeated use (Hartemink 2005). The Malaysian Government banned the use of the hazardous herbicide paraquat despite its popularity with users—the oil palm industry has had to seek alternatives. Initial trials with glyphosate suggest that it is safer (to people and the environment) and more effective for weed control (Wibawa *et al.* 2007).

Integrated biological pest management in plantations, for example using barn owls or snakes to reduce rat populations, has been tested in Malaysia with mixed results (see, e.g., Fee 2000). Such measures can reduce the use of pesticides (Yusoff and Hansen 2007).

Palm oil production, even when well managed, has a significant environmental

impact simply because of its scale. However, many negative environmental impacts could likely be reduced further by good management (Yusoff and Hansen 2007). Most of the positive reports on environmental impacts are generated by companies or their collaborators and can thus lack credibility—while most negative stories come from NGOs. A systematic assessment by unbiased ‘objective observers’ would be valuable, but may prove difficult due to the prevalence of vested interests.

Mills and water quality

Extraction of palm oil results in large amounts of effluent which, in the past, was often returned to natural water courses without treatment (Lord and Clay nd; Humle and Matsuzawa 2004). Runoff and palm oil mill effluents (POME) entering rivers have historically created problems for the aquatic ecosystems in Malaysia (Kittikun 2000). WWF has been quoted as finding ‘effluent from palm oil mills and chemical and fertiliser run-offs enter rivers on which local communities depend and there is a high concentration of heavy metals, particularly lead, in

the fish’ in Malaysia (Johnstone 2008). Action has been taken to address this, but in some locations problems persist, though there is no recent survey to clarify the extent of such concerns. Observations suggest that Indonesia lags behind Malaysia in these measures.

POME is a colloidal suspension that contains 95–96 per cent water, 0.6–0.7 per cent oil and grease, and 4–5 per cent total solids, including 2–4 per cent suspended solids originating from the mixture of sterilised condensate, separator sludge and hydrocyclone wastewater (Ma 2000). It is often discharged hot, i.e., at a temperature of between 80° and 90°C and a fairly acidic pH (4.0–5.0) (Ahmad *et al.* 2005). Although most modern mills have treatment areas, leaks of POME can have significant negative impacts on water quality (Ahmad *et al.* 2003; Wakker 2005). How this affects the ecological functioning of waterways remains largely unstudied.

There is general agreement that further improvements (Yusoff 2006) and research on the environmental costs of current practices to protect waterways are needed (Yusoff and Hansen 2007).

The habitat of many species such as the slow lorises (*Nycticebus* sp.), here a pet in East Kalimantan, are lost when forest is converted to oil palm. (Photo: Jan van der Ploeg)



7

Livelihoods

Winners and losers

Reports on the impacts of large-scale oil palm plantations on local communities differ greatly. Most information, often highly conflicting, is disseminated by companies or by NGOs. Most is based on anecdotes or a small number of selected cases, and objective research is limited. Large-scale oil palm production has documented benefits. The plantation sector in Malaysia is one of the country's largest employers, providing income and employment for many rural people. Basiron (2007) comments that 'involvement in cultivation or downstream activities has uplifted the quality of life of people'.

In Indonesia, 1.7–2 million people work in the oil palm sector (Wakker 2006; Zen *et al.* 2006). Looking at wider benefits, it is estimated by the industry that the oil palm sector benefits around 6 million people, many of whom have been rescued from poverty (Goenadi 2008). There are also national benefits: export revenues earned Indonesia over more than \$12 thousand million in 2007 (Goenadi 2008).

Secure incomes, access to healthcare and education have brought benefits to oil palm workers. Sometimes companies have successfully engaged with local

needs and experimented with how they can benefit local people (Zen *et al.* 2006) (see Box 3). Payment mechanisms can make a difference within families. A study in Papua New Guinea (where men often share little of the income they gain from cash crops, like oil palm, with other family members) found that when women are paid separately from their husbands for their work on family oil palm plots, this greatly enhances their access to income and their motivation to get involved (Koczberski 2007).

Workers can be exploited. For example, 90 per cent of the plantation labourers in Sabah are Indonesians, who are employed for harvesting, weeding and other maintenance work, and do not necessarily get the rights and protection that a Malaysian labourer would demand—the work is physically demanding, the hours

Box 3 A positive impact on livelihoods

In Sumatra, a company distributed three cattle to each of its 500 employee families. The cattle were allowed to graze on plantations, fed on oil palm waste, used for breeding, and for transporting oil palm fruit. The cattle population doubled, harvested areas increased, incomes of workers increased and community relations excelled (Zen *et al.* 2006).

are long, and the labourers are poorly paid (Anonymous 2008b).

Moreover, conversion of forests to plantations has significant impacts on forest-dependent communities (even those who are predominantly farmers), who rely on forests for a wide range of goods and services, especially in times of crop failure (Sheil *et al.* 2006). There are many cases of communities that now have no wood to build with or use (Belcher *et al.* 2004). Oil palm has displaced large areas of rattan and jungle rubber gardens, and this is likely to continue (Belcher *et al.* 2004). Significant erosion of local culture and institutions has been reported by various NGOs—they note how companies often engage community leaders individually so as to undermine community cohesion and united opposition (e.g., Marti 2008).

Forest-dependent people in the region often use diverse resource gathering and cultivating strategies. They derive staples like rice through shifting ‘swidden’ agriculture and supplement

their diets with a wide variety of wild plants and animals (Sheil *et al.* 2006; Van Noordwijk *et al.* 2008). Such strategies are largely opportunistic, and depend (among other things) on time and the widespread availability of forests and other uncultivated areas. Corresponding lifestyles are difficult to reconcile with the more monotonous and disciplined work and landscapes required for developing large-scale plantation monocultures, such as oil palm. Oil palm companies therefore often hire staff from Java, Sumatra or Sulawesi, where farming communities have long traditions of primarily growing single crops like rice. This can contribute to ethnic conflict—such as occurred between indigenous Dayak groups and Madurese in West Kalimantan—as one group gains while the other loses.

Accounts of abuses against local people by oil palm companies are common (e.g., Marti 2008). One sign of these problems is the high level of conflict emerging from the industry (Figure 15). As the Friends of the Earth

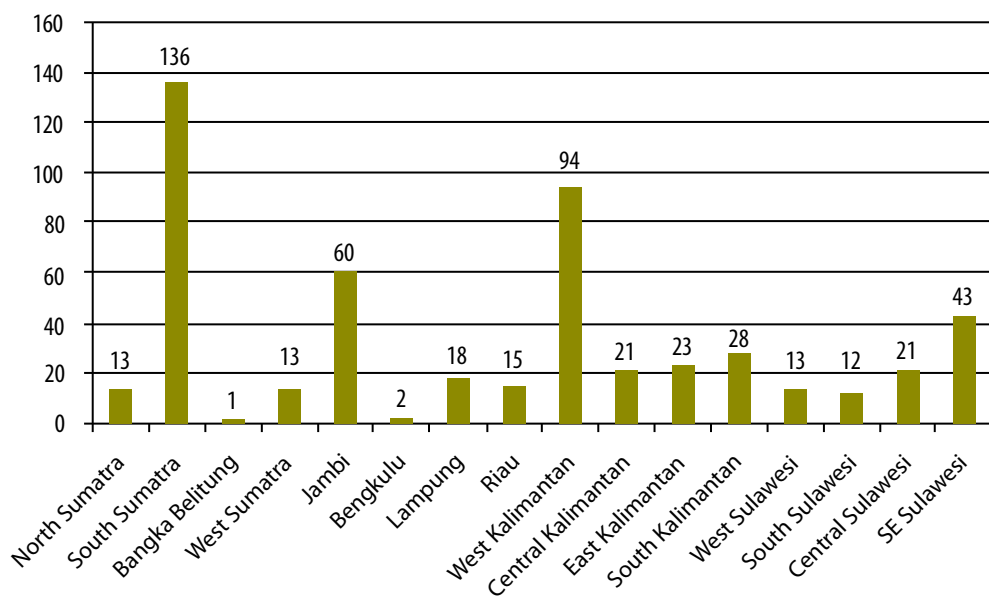


Figure 15. Oil palm conflicts across Indonesia monitored by Sawit Watch in January 2008. (Source: based on Sawit Watch data 2008, from Marti 2008)

concludes in the executive summary of its report *Losing Ground*:

The unsustainable expansion of Indonesia's palm oil industry is leaving many indigenous communities without land, water or adequate livelihoods. Previously self-sufficient communities find themselves in debt or struggling to afford education and food. Traditional customs and culture are being damaged alongside Indonesia's forests and wildlife. Human rights—including the right to water, to health, the right to work, cultural rights and the right to be protected from ill-treatment and arbitrary arrest—are being denied in some communities (FOE 2008).

There are many specific problems that need evaluation—for example, worker health and safety is often poor. Many companies consider women better at applying pesticides and fertilisers (they do it more precisely) and so prefer them for these tasks—many of these women are illiterate and therefore unable to read the warnings written on containers, and are not given training, safety equipment or protective clothing. Many—including pregnant women—subsequently incur serious health problems (Marti 2008). While most commentators accept that serious abuses do occur, there is seldom adequate investigation, and observers disagree concerning the prevalence of these abuses—are they the exception or the rule? Given that the main information comes from critical NGOs, it is often simply dismissed by industry supporters as anti-industry propaganda.

Tenure

Contested tenure affects most large-scale developments in the region. Though communities or individuals have traditional claims, formal recognition

of these claims is very limited, especially where the land is forested or deemed 'underutilised'.

In Indonesia, communities rarely challenged President Suharto's military-backed government and its claims to forested areas. Today, although the state is less feared and despite decentralisation, ownership of considerable areas is still contested. Local politicians are reluctant to lose control over profitable investments such as plantations.

Indonesian regulations enable government to repossess land if deemed in the public interest (Wakker 2006). The rights of indigenous people to customary lands are not fully recognised by the Indonesian state. While laws recognise the rights of customary communities to their lands, procedures for gaining title to such lands are ambiguous, absent, defective or rarely applied (Colchester *et al.* 2006).

Potential tenure conflicts may be one reason why companies prefer developing forested lands and peatlands rather than cleared areas. Forest lands are often within the claim area of one or only a few villages. This makes negotiations relatively simple and, once key leaders in a village can be convinced to give up ownership of a forest area and accept the concomitant financial compensation, companies can lay strong claims to the land. In deforested areas, however, many individuals may move into an area and claim ownership. Companies in such areas need to negotiate with many more stakeholders than in forested ones, increasing costs and potentially delaying plantation establishment.

Land tenure and the recognition of ownership rights affect how locals benefit. In 2000, every oil palm company in Sumatra had land disputes with local communities (Vermeulen and

Goad 2006). In Sarawak, Malaysia, communities have tried to secure their land claims by planting the disputed land with other crops (Cooke 2002). Communities are also demanding the return of land taken during the Suharto regime in Indonesia, and replanting programmes for overmature plantations have revived conflicts with local people who lay claims to land allocated to large-scale plantations (DTE 2001; Potter 2007). Land tenure disputes have led to conflict, injury, intimidation, arrests, torture and even death (DTE 2000; Nicholas 2005).

Plantation developers exploit uncertain tenure. By working closely with the government and accepting government ownership, powerful interests gain easy access to large areas of contested land. However, in some locations such tactics are increasingly difficult, and plantation owners have often found it useful to work more directly with local people.

'Nucleus estates', though not without their problems, provide assistance and socioeconomic benefits to an estimated 500 000 smallholder farmers in Indonesia (Zen *et al.* 2006). These 'nucleus-plasma' schemes recognise local tenure over some land and offer a share of the oil palm development in return for company ownership of the rest of the land. These schemes mean that companies ensure production on both the land they hold (*nucleus*) and the land held by smallholders (*plasma*). However, in practice the schemes are often problematic. Smallholders are often obliged to take out loans to establish plantations and receive limited technical support. The sites allocated are often suboptimal and distant from the community. Social conflict between oil palm companies and smallholders is also common because smallholders enter into price contracts with companies and are not able to benefit from any marked

price rises for CPO. Some smallholders also have a desire to plant other crops on their land, but are contractually obliged to plant oil palm on the majority of their land holding (for more details of problems see Marti 2008).

Information and developments

Although assessments of land suitability are usually undertaken when identifying areas for oil palm, social factors are rarely assessed (Wakker 2006). Often local people, and even local political representatives, are not well informed and are easily duped into believing oil palms will grow and provide high returns in unsuitable areas (Padmanaba and Sheil 2007). Better information about issues and choices would help communities assess the propaganda put out by investors (Padmanaba and Sheil 2007).

The proposed biofuel-driven Kalimantan oil palm megaproject is one example of how communities and NGOs used information about soil types, topography and various other factors to defeat a poorly thought through oil palm development (Wakker 2006; see Box 4).

Smallholder palm oil production

For smallholders seeking good returns from low inputs, oil palm is attractive (Belcher *et al.* 2004). In 1997, the average net income of oil palm smallholders in Indonesia was seven times higher than the average net income of subsistence farmers (Hardter *et al.* 1997; Hartemink 2005). Although, as has already been noted, smallholders generally achieve lower yields than large-scale plantations,³¹ if they have training, support, sufficient inputs and good planting material, they can produce comparable and, at times, higher yields (Hartemink 2005).

Smallholders already play a significant part in the palm oil industry and, particularly in Indonesia, smallholder yields are rising rapidly—averaging around 2.3 kg/ha in 2006 (Vermeulen and Goad 2006). In Indonesia and Malaysia, they may account for a third of the palm oil produced and 35–40 per cent of the productive area (Vermeulen and Goad 2006).

Indeed in Indonesia, oil palm is rapidly becoming a smallholder crop. Some smallholder schemes in Indonesia originally targeted families that migrated from Sumatra and Java to the less populated islands. National statistics on oil palm in Indonesia recognise three strata: smallholders, private companies and state companies. Of a total planted area of 6.2 million hectares in 2006, these three actors controlled 41, 48 and 11 per cent of the area and produced 34, 52 and 14 per cent of national palm oil, respectively. The government plantations have 1 hectare of immature plantation per 20 hectares of mature gardens, which is below the replacement level of 1:10 (if we assume 3 years of immature garden and 30 years of production), while the smallholders and private plantations have 1 hectare of immature per 4 and 3 hectares of productive garden, respectively, indicating rapid expansion.

Box 4. Kalimantan oil palm project

In 2005, the Indonesian Minister of Agriculture announced a plan for a huge oil palm plantation on the Kalimantan–Malaysia border that would affect primary forest in three national parks. The proposed plantation would have been the largest oil palm development in the world, covering 1.8 million hectares of hills and mountains—areas regarded as inappropriate for oil palm cultivation.

The customary land rights of the Dayak people were not considered and there was an outcry. The government retracted the initial plan—though not before conflicts, as communities took matters into their own hands—but oil palm is still reported to have been introduced to this area (Wakker 2006).

The ‘post-productive’ category is 1 hectare per 65, 95 and 83 hectares of mature for smallholder, private and state companies, respectively, suggesting that there is little scope for more active replanting within the oil palm area (Vermeulen and Goad 2006).

The relative share of smallholders in the immature (newly planted) area is 51 per cent in Sumatra, which has 76 per cent of the country’s oil palm area (Table 3). The smallholders’ share of immature area is 43 per cent in Papua and only 15–20 per cent in Kalimantan and Sulawesi, indicating a substantial difference in pattern. Kalimantan and Papua have the highest

Table 3. Geographical distribution of oil palm plantations in Indonesia

Region	Percentage of total area	Immature area in %	Smallholders as percentage of total area			
			Mature	Damaged	Total	Total yield
Sumatra	76.4	51.1	42.3	47.2	43.9	43.2
Java and Bali	0.4	0.0	29.1	62.9	24.7	27.2
Kalimantan	20.2	19.5	37.3	72.3	31.3	33.8
Sulawesi	2.1	14.5	23.1	0.0	21.7	22.3
Nusa Tenggara and Maluku	0.0	0.0	0.0	0.0	0.0	0.0
Papua	1.0	43.5	43.1	0.0	42.9	42.7
Total	100.0	39.3	41.0	49.6	40.8	34.0

This table shows the fraction of land in different stages of production that is managed by smallholders. Nature areas are productive; damaged areas are post-productive. (Source: IPOC 2006)

relative growth rates, with 1 hectare of immature plantations per 3.5 and 1.9 hectares of mature plantations, respectively, compared to 4.1 hectares in Sumatra, 8.4 hectares in Sulawesi and 4.0 hectares for Indonesia as a whole. The production data for smallholders are approximately proportional to their share in the productive area, which may indicate the way the statistics were derived (estimated) rather than reality on the ground. Statistics for smallholders are considered less reliable than those for private plantations.

Smallholders function on two levels—supported and independent—both of which have risks and benefits. Supported smallholders share risks (for example, a poor harvest) with companies or the government, they lose their independence and are less flexible in how they can use their land; however, they may have guaranteed access to international markets where prices are more stable than in local markets. Independent smallholders do not have to share their profits, but face other risks, such as their susceptibility to theft of ripe crops (Vermeulen and Goad 2006).

Regardless of their status, smallholders are tied to a long-term crop and are exposed to significant financial risk (poor harvests, fluctuation in CPO prices, pests and diseases). They also cannot fall back on the natural habitat that the oil palms replaced for wood and non-timber forest products.

Access to capital is an important issue for most smallholders, who cannot get loans or, if loans are approved, face arduous repayment schemes (Vermeulen and Goad 2006).

Smallholders would also benefit from alternatives to large mills. A good example is the simple, low-cost (less than \$20 000) palm oil processing unit with a capacity of 0.5–2 tonnes of fresh

fruit per hour, now available in Indonesia (Bisnis Indonesia 2000 cited in Belcher *et al.* 2004). This could free smallholders from the requirements of large-scale processors and allow them to get into oil palm gradually. Such a change would have a major impact on small-scale producers though such developments are no longer being promoted—perhaps because they would result in powerful commercial interests losing their local monopolies. Expansion and improvement of smallholder production presents a major opportunity for meeting rising demand for palm oil in a socially sustainable manner.

Nevertheless, it is important to note that smallholders are notorious for poor plantation management. Smallholders almost always use fire to clear land. This is because they cannot afford heavy land-clearing machinery and because they are used to using fire in preparing land for cultivation. They are also less regulated and will often clear land and plant oil palm without appropriate permits. In Indonesia, regulations issued to protect against erosion, biodiversity loss, sedimentation and other environmental issues arising from oil palm establishment are also rarely followed by smallholders.

Biofuel versus food

There is an ongoing debate on the competition between biofuels and food production for land and labour (Box 5, see also Chapter 3). The sharp rise in the price of oil has meant that grain, sugar and oilseed crops are increasingly being planted to produce biofuel. This has also linked oil and food prices more strongly³² at a time when oil prices have been rising rapidly. Some commentators suggest that these links will work against regions that consistently experience food shortages or rely on food imports, which will face greater food insecurity (Cassman and Liska 2007).

Box 5. Food or fuel?

'Biofuels are driving up food prices at a time when there are 854 million hungry people in the world and every 5 seconds a child under 10 dies from hunger or disease related to malnutrition.'

– Jean Ziegler, United Nations Special Rapporteur, New York, 26 October 2007, calling for a 5-year moratorium on biofuels

'FAO strongly feels that food security and environmental considerations must be fully addressed before making investments or policy decisions ... a moratorium that ignores the potential of biofuels to support rural development and assist the economies of developing countries would not, in our view, be a constructive approach to this topic.'

– Jeff Tschirley, Head, FAO Environment Assessment and Management Unit

In Southeast Asia, palm oil is the cheapest food oil and it is feared that production for biofuel will link the price of palm oil to rising fuel prices. Using food to produce biofuels might also place further strain on already tight supplies of arable land, thereby pushing up food prices. Domestic prices for palm oil in Indonesia and other countries dramatically increased over the year 2007–08, accentuating this argument. Nevertheless, higher prices for cooking oil and other staple foods (such as soya bean³³) are also attributed to bad weather and floods in major food producing areas.

Mendoza (2007), writing with an emphasis on The Philippines, notes the contribution to increasing water scarcity from biofuel crop production and processing, and suggests the land pressures from large-scale monoculture

Aerial view of oil palm developments in Kutai, East Kalimantan, Indonesia. (Photo: Douglas Sheil)



plantations will reverse many benefits achieved from agrarian reform. Mendoza (2007) concludes, 'biofuels are the single greatest threat to food security especially for the low-income groups in view of their influence on supply and prices of staple foods'.

One specific problem in Indonesia is the limited fertiliser supply and the ever increasing demand from plantations. Farmers and plantations inevitably compete. While the government subsidises some fertilisers, farmers are having difficulties obtaining them because of limited supply (Syafriel 2008). These debates and challenges are so recent that they are playing out in newspapers and political statements rather than in the academic literature. It is clear that biofuel is only one factor. Many blame the recent rises in world food prices on quite separate issues: principally speculators who are turning away from risky 'stock markets and the property sector' to invest in food commodities. In some cases, large-scale commercial hoarding has led to artificial scarcity. However, this does not mean that the threat of plantations *per se* is not real—for example, the fact that oil palm plantations make up 40 per cent of Sarawak has impacted fisheries and other local food production. The Malaysian Government plans to invest more in agricultural food production, though this is likely to benefit large-scale industries rather than the more vulnerable smallholders (Netto 2008).

According to Joachim von Braun (Director General of the International Food Policy Research Institute), there is general evidence that biofuel production has contributed to the volatility of food prices, which adversely affects the poor. The world food situation is

already changing rapidly due to a range of powerful forces—including income growth, climate change, high energy prices, globalisation and urbanisation—that are transforming food consumption, production and markets (von Braun 2007). Even without biofuels, there is a feeling that world cereal and energy prices are increasingly linked. Since 2000, the prices of wheat and petroleum have tripled, while those of maize and rice have almost doubled (von Braun 2007). There is evidence that fuel makes a difference—an increasing link between energy and food prices means that energy price fluctuations are increasingly felt as food price fluctuations. Since 2002, variations in oilseed, wheat and maize price have doubled compared to previous decades (von Braun 2007). More work is needed to examine the role of oil palm in these relationships and processes. There have been urgent calls for a rapid research response (Cassman and Liska 2007):

The critical challenge is not only to produce enough food to meet increased demand from population increase and expansion of biofuel production, but to do so in an environmentally sound manner. Achieving these dual objectives in a relatively short time period will require a substantial increase in research and extension with an explicit focus on increasing the rate of gain in crop yields while protecting soil and water quality and reducing greenhouse gas emissions. It is sobering to note that agronomists have never been asked to develop innovative management systems that both accelerate yield gains and protect natural resources. In the absence of such investment, global demand is likely to exceed supply for crops that can be used for both food and biofuel.

8

Improving standards

New initiatives, new safeguards

The negative media stories about the oil palm industry are seen as a threat to an industry that earned Malaysia \$14.1 thousand million in exports in 2007. Concerns about wider opinions and media campaigns provide important incentives for improved practices.

The Malaysian oil palm industry is adopting self-regulating environmental management tools, such as ISO 14000 EMS and life cycle assessment (LCA), to reduce environmental impacts (Yusoff 2006). In addition, the Malaysian Palm Oil Council (MPOC) is striving to change negative views of oil palm, with the message that 'oil palm is sustainable'; however, their practices have been challenged by environmental groups who believe that many of the lobbying messages of the MPOC are questionable (Raman *et al.* 2008).

In Indonesia, until recently only a handful of companies were providing evidence that their products can meet internationally recognised 'environmental or social standards' (Wakker 2006), though this is changing with the Roundtable for Sustainable

Palm Oil (RSPO) initiative (see below). Financial incentives may encourage developing rainforest-rich countries to optimise degraded lands for plantation developments and to reduce the rate of deforestation (Simamora 2007). For example, the Reduced Emissions for Deforestation and Forest Degradation (REDD) scheme may enable Indonesia to receive funding and support for policies and measures that encourage companies to plant oil palm on degraded lands rather than on forested lands.

Meanwhile, several new international and national initiatives are underway to improve practices in establishing oil palm plantations and using forests. One national initiative in Indonesia is Sawit Watch (oil palm watch, www.sawitwatch.or.id), which campaigns for the rights of indigenous people in land disputes and highlights the social ramifications of oil palm developments in Indonesia. A consortium of organizations, including the World Resources Institute, Sekala and The Nature Conservancy (TNC) are also working together to encourage oil palm companies to utilize available degraded lands rather than forested lands or peat lands for oil palm plantations.

In Indonesia, the existence of problems is not in dispute. Even the Executive Director of the Indonesia Palm Oil Producers Association, Didiek Hadjar Goenadi, has recognised that the political situation in Indonesia has allowed the commodity to be developed widely without adequate safeguards.

Economically, socially, environmentally, and perhaps politically the country has been affected by the unbelievable booming of this so-called liquid gold commodity ... It is indeed not an easy task for the government to make appropriate allocation of land which potentially demands significant trade-offs on livelihoods and on the environments (Goenadi 2008).

International initiatives include the Roundtable for Sustainable Palm Oil (RSPO), established in 2004 by Malaysian and Indonesian companies to ensure that palm oil 'contributes to a better world' (RSPO nd). RSPO believes it has developed a 'verifiable standard for sustainable palm oil' and encourages oil palm companies to adopt more responsible practices. Overall, it aims to promote sustainable palm oil production. Several companies have experimented with the RSPO standard since it was ratified in November 2005, but have found it to be complicated, costly and hard to implement (Paoli 2007). RSPO has also channelled activities towards developing a standard for smallholders, because smallholders cannot afford the additional oversight required for mainstream RSPO certification. Smallholders also struggle to adopt best practices, such as zero burning, because such practices require upfront capital and are more expensive at the outset. The RSPO's Criteria and Indicators for sustainable oil palm are part of a voluntary forest management certification system in Indonesia and the government is investigating how it can be integrated

into current policies (Rietbergen-McCracken *et al.* 2007).

RSPO has its external critics too. Some claim it is simply a cynical attempt at PR and 'greenwashing'. Despite the publicity surrounding the standards, there is little apparent urgency in their application. Greenpeace claims that many RSPO members continue expanding their plantations into forests in breach of both the law and RSPO principles (Greenpeace 2007; Centre for Orangutan Protection 2008; Johnstone 2008).

The High Conservation Value Forests (HCVF) concept, which appears in Principles 5 and 7 of the RSPO standard, encourages companies to address the biodiversity and social aspects of oil palm production. HCVF was originally proposed in 1999 as part of the Forest Steward Council (FSC) standard for certified responsible forestry, but today is used in many other sectors, including plantation forestry, mining and even commercial lenders, as part of due diligence. The HCVF concept aims to identify and manage areas within forest landscapes that contain social, cultural or ecological values of exceptional importance for local and global stakeholders—the so-called High Conservation Values. Companies can voluntarily choose to undertake HCVF analysis for certification purposes. In Indonesia, and indeed most of Southeast Asia, there would be a strong argument for saying that all remaining natural forests, logged or not, are by definition HCVFs—but there is clearly an expectation from industry that only a small proportion will gain such a designation. This means that the widely publicised industry statement that 'HCVF will not be converted' is in fact less rigorous than the claim that further forests will not be converted. But, certification and verification schemes have been abused in many tropical

countries and are unlikely to succeed without legal and political reform.

Due diligence

Pulp and paper producers and oil palm companies are often part of the same conglomerate (WWF 2008). This means that companies can gain maximum profit from timber before planting the oil palm—it also raises questions regarding motives. In some cases, companies affiliated with these groups have used land clearing permits to clear degraded natural forests from sites allocated for oil palm development, without subsequently planting those areas. Although illegal, this practice suggests that the conversion of forested lands scheduled for oil palm development is sometimes driven by the economic rents associated with the wood removed from these sites, rather than serious intentions to develop oil palm estates (WWF 2008).

But these companies usually rely on international finance, especially in developing their processing capacity for pulp and palm oil. So, investors must be held at least partly responsible

for ensuring that the companies they finance meet global environmental and welfare standards. Campaigns by NGOs have positively impacted policies—for example, statements by ABN AMRO, Rabobank and Fortis pledging 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; Simorangkir 2007). However, there is little hard evidence of these pledges being followed up or verified.

Governments too can support better practices. The Dutch Government recently temporarily excluded palm oil from its national green energy subsidy scheme because of the uncertainties of certification and sustainable production (Van de Wiel nd).

Issues of how past mistakes can be avoided and who is responsible for monitoring best practices remains, again, largely unresolved.



9

Trends and the future

Clearly, the biofuel boom boosted speculation and encouraged investors to open new oil palm plantations. But it seems the biofuel bubble has already burst. High CPO prices made palm biodiesel economically unviable in 2008 and Indonesia's state-owned oil palm company ceased developing palm biodiesel capacity because of the cost. Thanks in large measure to NGO-led information campaigns, Western countries are concerned about the relationship between oil palm and tropical deforestation, and are reviewing their biofuel targets. Overall, the outlook for palm oil as a major source of biofuel is not wholly positive—at least in European and North American nations.

But palm biodiesel does have benefits. It is still cheaper than other major biodiesels and, although far from climate neutral at present (Reijnders and Huijbregts 2008), it is recognised that palm oil can 'come clean' if suitable practices are adopted. Certainly fuel derived from oil palm plantations planted on degraded lands may have more positive carbon benefits.

In any case, demand for palm oil remains high—for food and other

uses—and is likely to rise, as China, India and other economies develop. At the same time, there may be a role for crops like oil palm to be managed less intensively to provide for local fuel needs nearer to where the crops are grown, especially in less accessible locations where the costs of importing fuel are high.

Trends in the future will, like any new and profitable land use system, be determined by a variety of factors that will include land availability, access to labour, capital and technology, regulation, investments, security, competing land uses and alternative sources of income—balanced with market trends, notably including demand and consumer perceptions. Many of these factors have been extensively investigated in the context of other crops and innovations (see Angelsen and Kaimowitz 2001), but a clearer examination in the context of oil palm in its various guises is much needed.

We know what many of the key issues are. For oil palm production, most would agree on the importance of good planning, management, transparency and accountability.



10

Conclusions and needs

Here we summarise some key conclusions: first, regarding what appears well established, and second, what we need to know. These generally arise from the references discussed above and from our many discussions with colleagues and experts (see Acknowledgements).

What do we know?

- The global area of productive oil palm plantations is in the order of 9.1 million hectares, of which about 3.8 million hectares are in Malaysia and 4.6 million hectares are in Indonesia. (However, many commentators question the accuracy of these figures.)
- The total area of planted oil palm in Indonesia is estimated at about 6.5 million hectares, less than 4 per cent of the total land area, but reaching 15 per cent in some provinces of Sumatra.
- Global production of palm oil was about 41.1 million tonnes in 2007/2008 (USDA 2008b). Indonesia was the largest producer of CPO in the world as it produced 18.3 million tonnes, while Malaysia produced 17.7 million tonnes (USDA 2008b).
- The projected annual global demand for biodiesel is 24 thousand million litres by 2017, up from nearly 11 thousand million at the end of 2007 and less than 1 thousand million in 2000 (FAO 2008). If this demand were to be met from palm oil alone, the additional area of plantations needed would be 4.6 million hectares by 2017—assuming a yield of 5830 litres of palm oil per hectare per year.
- The current rapid expansion of oil palm plantations in Indonesia and Malaysia is largely driven by (a) growing demand for oil for food and industrial processes in Asia, particularly in India and China, and (b) to a lesser extent demand and speculation for biofuel.
- There is a general consensus that the trend of increasing palm oil yields will continue and accelerate. This trend may allow companies to improve production and profitability without the need for additional land, but it may also provide an incentive to establish new plantations and clear forest.
- Recognised and anticipated consumer concerns, especially in Europe, have been a deterrent to the use of

GMO technology in oil palm. The investments needed in the technology and the planting time to be profitable magnify the financial risks if the market proves limited.

- The area cleared of forest in the name of oil palm establishment is believed to be several times the area actually planted, particularly in Indonesia. This reflects the impacts of associated labour migrations and of plantation failure. It also reflects a form of timber theft in which investors clear-fell the forest in the guise of a plantation development and profit from the timber sales but abandon the project without developing plantations.
- Once the required infrastructure of roads and factories is in place, oil palm plantations provide high returns to land, labour and capital compared to other land uses, with rubber as the main comparison and competitor in Sumatra and Borneo. High profitability ensures that oil palm plantations will be a major driver of land use change in the humid forest zone of Southeast Asia for some time to come.
- Palm biodiesel will only be economically viable if prices for CPO remain at a level where palm biodiesel is more economical than petroleum diesel or if sufficient subsidies are applied (as in the US maize industry).
- Interest in palm oil as a carbon-saving fuel is already waning in Europe and the USA. The short-term carbon costs of deforesting and preparing land, crop management (fertilisers and other inputs), processing and transport greatly outweigh the benefits.
- Oil palm diesel is one of the few biofuels where the mean energy yield exceeds the fossil fuel energy input for fertiliser and transport, but the carbon emission costs of clearing forest may take 80–90 years of biofuel production to be offset on mineral soils. On peat soils, annual CO₂ emissions may be several times the CO₂ equivalent of fossil fuel substituted. Full carbon accounting data are still scarce.
- The use of fire to clear land is still common in Indonesia.
- Species diversity in oil palm plantations is much less than in natural forests, even degraded forests. Forest clearing for oil palm leads to species losses. Many of the species impacted are protected by law.
- Various ‘best practices’ for minimising the environmental impacts of oil palm plantations and processing palm oil have been developed, but few independent assessments of their application and effectiveness have been made.
- Oil palm is a very profitable crop in both industrial plantations and smallholder contexts. But in the acquisition of land and relations between companies and local people, the principle of ‘free and prior informed consent’ has rarely been followed. Benefits are not shared with everyone impacted by or involved in palm oil production.
- The development and implementation of oil palm plantations involve various cases of legal and social abuse (excuses for logging forest, land theft or coercion, misrepresentation by investors who play up the positive and ignore the negative).

Research needs

Oil palm plantations and biofuels

- **Lifecycle analysis throughout the palm oil biofuel production chain** would help us understand under what circumstances—for example, with no attributed responsibility for preceding land clearance, high internal nutrient use efficiency—palm biodiesel would be acceptable as a carbon-saving fuel.
- **Analysis of new policy mechanisms** introduced in the EU and other countries/regions (particularly Asian countries, such as Indonesia and Malaysia) **and their impact** on CPO prices, biofuel development, oil palm expansion, and tropical forests in developing countries.
- Given that oil palm is a high-yielding oil crop, under what circumstances—for example, in remote areas, if prices rise—**could palm biodiesel compete with hydrocarbon oil products and other sources of energy? What technologies are needed to achieve this?**
- **Determination of the options for independent smallholders to use oil palm as part of a farm diversification approach and their choices on the management spectrum.** What are the needs of these producers and how can they be met?
- **Development of scenarios for different levels of demand, regulation, production efficiency, and bioenergy processing technologies, and their impacts on land use.**
- **Research into the impact of increased interest in biofuels, and oil palm, to**

food security. Is the threat real and significant? If so, how can this be remedied effectively?

- **How can palm oil contribute to meeting future global energy demands?**
- **How can biofuel developments be made more beneficial to biodiversity and the environment? What are the key points for intervention? What are the options for mitigation? How can these be effectively acted upon?**

Oil palm plantations and environmental concerns

- **Development of guidelines for a carbon-neutral oil palm industry.**
- **Investigation into how the carbon benefits (if any) and energy benefits of palm oil plantations can be maximised** (e.g., by improving management systems).
- Given that the carbon balance is negative when peatlands are drained to make way for oil palm plantations:
 - **Research into how already damaged, drained or planted peat can be treated or managed to restore the carbon balance.**
 - **Research into peatland restoration and re-establishment.** Is restoration and re-establishment desirable?
 - **Research into how oil palm plantations on peatlands can be productive without drainage and the consequences of making them productive** (e.g., applying fertiliser may improve yields but negatively impact the carbon balance).

- **Determination of the level of emission and impact of greenhouse gases other than CO₂ from oil palm plantations.** What are the management options that influence these emissions and how can emissions be most effectively reduced?
- **Examination and comparison of the carbon implications of clearing different vegetation types** (primary forest, secondary forest, degraded forest, grasslands, agroforests) **and replacing them with oil palm.**
- **Research into the role of isoprene and other volatile organic compounds (VOCs) in climate change and atmospheric chemistry.** We know that oil palms are major emitters of VOCs.
- **Better accounting methods for greenhouse gases from oil palm production, especially methane** (processing stage) **and nitrogen oxides** (linked to fertiliser use).
- **Assessment of the value that environmental guidelines on oil palm have for maintaining ecological functions and species diversity, and how these can be improved.** Environmental guidelines for plantation development are similar to those for natural timber concessions (e.g., requirement to maintain narrow [<100 m] riparian buffer zones), but the non-forest matrix of plantations is ecologically very different from the forest matrix of timber concessions.
- **Assessments of the environmental impact of clearing riparian forests, and mill effluent and fertiliser discharges on river ecosystems, including stocks of fish and crustaceans that are important to local economies.**

Oil palm plantations and benefits to the poor

- **Research into the technical issues of small-scale processing and rural enterprises in palm oil production.** Conventional processing plants are only economic on a large scale. Small-scale processing is costly. Cooperatives may bring greater benefits to small-scale producers, but strong vested interests are suspected to have suppressed such developments in the region.
- **Development of mechanisms that would give smallholders access to better prices, help them avoid debt and enable them to build up capital.** Smallholder producers often have no option but to sell to monopoly buyers at low prices.
- **Ensure smallholders are well informed of the management alternatives in using oil palm.** How to ensure access to high-yielding varieties and protecting against fraud, etc.
- **Research into the risks of specialising in such a long-term crop (20–25 years) and how vulnerable industry players—large and small—are to changing markets.** How can such vulnerability be reduced?
- **Research into oil palm-based agroforestry combinations that could be economically viable for smallholders.** Smallholders often want to diversify and plant 2–3 crops on land holdings rather than just one crop. What are the benefits and costs of these strategies? What are the best options and how can they be promoted?

- **Emergence of independent smallholders with access to multiple processing plants.** The social aspects of oil palm are bound to change with the trend towards smaller enterprise units making decisions. How to effectively monitor adherence to environmental and product quality standards.

Incentives for good practice in oil palm plantations

- **Research into the extent to which the palm oil industry can regulate itself effectively through initiatives such as the Roundtable for Sustainable Palm Oil, and the dangers of such initiatives being hijacked by vested interests.**
- **Development of ‘criteria and indicators’ for ‘good’ ecological production of palm oil in any given location.** In what ways can we maximise the good and minimise the bad? How can we integrate this process into wider land use planning?
- **Certification of oil production standards and the concerns of consumers.** What are the best options for industry and the consumers?
- **Research into optimal planning and management of oil palm plantations (under multiple demands).** For example, where to plant, how to prepare land (without burning) and manage plantations.
- **Research into incentives and assistance that would allow smallholders to adopt best management practices, such as zero burning.**
- **Research into how oil palm and biodiversity can better coexist in landscapes, and the mechanisms by which this may occur.** How can these benefits be brought about?
- **Collection of quality statistical and spatial data** in Indonesia, and perhaps other countries, to be able to more accurately determine the area of existing oil palm plantations, areas allocated for new oil palm plantations, forested areas, degraded areas, peat areas, etc. These data are needed to more accurately determine the impact of oil palm expansion on forests, peat lands and carbon emissions, and to ensure that future expansion minimises similar impacts.

Endnotes

- 1 Discussions suggest little agreement on virtually all of these area figures. Some suggest the true figure for area designated to oil palm may be more than 50 per cent higher (i.e., more than half again).
- 2 Demand for oil alone may rise 40 per cent by 2030 as reported by the president of the Roundtable on Sustainable Palm Oil (RSPO), Jan Kees Vis of Unilever (Anonymous 2005).
- 3 Ethanol, from sugar cane for example, already accounts for a quarter of Brazil's ground transportation fuel (Kennedy 2007).
- 4 A second species, *E. oleifera*, is native to tropical Central and South America. While *E. oleifera* is generally not as high yielding as African oil palm, it has various potentially valuable properties including shorter stature and different disease susceptibility. The two species are easily hybridised and produce fertile stock. Thus *E. oleifera* is the subject of commercial interest and crop improvement programs.
- 5 See also <http://www.icraf.org/sea/Products/AFDbases/AF/asp/SpeciesInfo.asp?SpID=724>.
- 6 Land with slope of 40 per cent or more cannot be converted to agriculture in Indonesia and should remain forested (Rencana Tata Ruang Wilayah Propinsi/RTRWP cited in Basuki and Sheil 2005). In Malaysia, slopes above 20° cannot be lawfully cultivated (Weng 2000). Both Indonesia and Malaysia prohibit the use of fire to clear land.
- 7 A labour-intensive manual process.
- 8 The Malaysian Palm Oil Board maintains the world's largest collection of *Elaeis* germplasm.
- 9 It is suggested that yields in Sumatra and Peninsular Malaysia were already at 15–25 tonnes of fruit bunches per hectare per year in the mid 1990s, with some fields producing 30–38 tonnes (NewCROP 1996). Moreover, yields in excess of 20 tonnes of fruit bunches per hectare per year were being reported at the turn of the millennium (Poku 2002).
- 10 Palm oil is rich in desirable oleic acid, and in less desirable palmitic acid. High levels of palmitic acid lower the value compared to soya and sunflower oils.
- 11 Soya bean oil production will continue to increase mainly because oil is a byproduct of a crop grown primarily for animal feedstock.
- 12 The principle costs in establishing oil palm are land clearing and development, planting, fertilising, pest and weed control, and harvesting (Belcher *et al.* 2004).
- 13 It is these impurities that give the distinctive red colour and flavour to oil from cottage industry in Africa (Poku 2002).
- 14 <http://www.eia.doe.gov/oiaf/ieo/pdf/highlights.pdf> (7 Nov. 2007).
- 15 Palm oil currently achieves 32 per cent (European Commission 2008).
- 16 The export tax on CPO exports has fluctuated between 60% in 1999 and 2.5%. A ban on CPO exports was also put in place between January and April 1998 to ensure a constant supply of cooking oil to the domestic market when CPO prices peaked at \$770/tonne. The government increased the CPO export tax from 2.5% to 6.5% in 2007 for similar reasons, as the price of palm oil reached over \$800/tonne (Casson *et al.* 2007).

- 17 While Africa as a whole imports over 1 million tonnes of palm oil annually despite local production.
- 18 Much of the uncertainty results from conversion of rubber plantations.
- 19 The authors note that they may have neglected grassland or urban areas, but believe that any such contribution is very slight.
- 20 These figures are uncertain because the FAO definition of forests includes degraded forests and secondary regrowth as well as plantations, though the authors attempted to take account of this in their assessment.
- 21 At the same time, many Malaysian companies, who claim good practice locally—such as Sime Darby (the largest oil palm plantation company)—are said by NGOs to be behind major forest conversion in Indonesia (Greenpeace 2007).
- 22 It is also argued that there is no cost benefit to using fire to clear any land (Sargeant 2001).
- 23 Drainage incurs costs. Technically, there is no need to drain peat for oil palm production (the plant copes with waterlogged soils); however, it is necessary to create access.
- 24 Preventing fires but not drainage merely slows the rate at which the carbon is released as CO₂ (Hooijer *et al.* 2006).
- 25 A land use permit gives the user the legal right to use the land for oil palm plantations.
- 26 A location permit is given out prior to a land use permit and allows companies to begin the process of gaining a right to use the land for oil palm plantations. The permit is linked to a map that identifies the location of the planned oil palm plantation.
- 27 Using an average value of \$840/ha per year (Lestari 2006; Lonsum 2006; Wilmar 2006).
- 28 Includes C from peat drainage in peat areas.
- 29 An independent global assessment reports the highest estimate of regional plant species richness occurs in the Borneo lowlands (Kier *et al.* 2005).
- 30 Wild pig (*Sus scrofa*), bearded pig (*Sus barbatus*), common palm civet (*Paradoxurus hermaphroditus*) and leopard cat (*Prionailurus bengalensis*).
- 31 One case study in Sumatra reported smallholders produced 66% less than large-scale plantations (Hasnah and Coelli 2004).
- 32 Even without land competition, food prices rise with increased fuel costs due to the increased costs of management, inputs, processing and transport (Cassman and Liska 2007).
- 33 In early 2007, a tonne of soya bean cost \$610 in Indonesia, when only a year before it was \$332.

References

- Abdullah, S.A. and Nakagoshi, N. 2007 Forest fragmentation and its correlation to human land use change in the state of Selangor, peninsular Malaysia. *Forest Ecology and Management* 241: 39–48.
- Ahmad, A.L., Ismail, S. and Bhatia, S. 2003 Water recycling from palm oil mill effluent (POME) using membrane technology. *Desalination* 157: 87–95.
- Ahmad, A.L., Sumathi, S. and Hameed, B.H. 2005 Adsorption of residue oil from palm oil mill effluent using powder and flake chitosan: equilibrium and kinetic studies. *Water Research* 39(12): 2483–2494.
- Ahmad, A.L., Loh, M.M. and Aziz, J.A. 2007 Preparation and characterization of activated carbon from oil palm wood and its evaluation on methylene blue adsorption. *Dyes and Pigments* 75: 263–272.
- Al-Zuhair, S., Ling, F.W. and Jun, L.S. 2007 Proposed kinetic mechanism of the production of biodiesel from palm oil using lipase. *Process Biochemistry* 42: 951–960.
- Angelsen, A. and Kaimowitz, D. 2001 *Agricultural technologies and tropical deforestation*. CABI and CIFOR, Wallingford, Oxford, UK and Bogor, Indonesia.
- Anonymous 2005 Defining sustainable palm oil. *Focus on Surfactants* 2005(2): 2.
- Anonymous 2007 Sequence oil palm genome. *Clean—Soil, Air, Water* 35(4): 299.
- Anonymous 2008a Unilever and emerging markets: the legacy that got left on the shelf. *The Economist*, 31 January. http://www.economist.com/business/displaystory.cfm?story_id=10601552 (18 Sep. 2008).
- Anonymous 2008b Oil palm tree. <http://www.etawau.com/HTML/OilPalm/OilPalm.htm> (13 Jun. 2008).
- Aratrakorn, S., Thunhikorn, S. and Donald, P.F. 2006 Changes in bird communities following conversion of lowland forest to oil palm and rubber plantations in southern Thailand. *Bird Conservation International* 16: 71–82.
- Astyk, S. 2006 Ethics of biofuels. *Energy Bulletin*, <http://www.energybulletin.net/node/24169> (30 Sep. 2008).
- Auxtero, E.A. and Shamshuddin, J. 1991 Growth of oil palm (*Elaeis-guineensis*) seedlings on acid sulfate soils as affected by water regime and aluminum. *Plant and Soil* 137: 243–257.
- Bahurmiz, O.M. and Ng, W.K. 2007 Effects of dietary palm oil source on growth, tissue fatty acid composition and nutrient digestibility of red hybrid tilapia, *Oreochromis* sp., raised from stocking to marketable size. *Aquaculture* 262: 382–392.
- Balasundram, S.K., Robert, P.C., Mulla, D.J. and Allan, D.L. 2006 Relationship between oil palm yield and soil fertility as affected by topography in an Indonesian plantation. *Communications in Soil Science and Plant Analysis* 37: 1321–1337.
- Baligar, V.C. and Fageria, N.K. 2007 Agronomy and physiology of tropical cover crops. *Journal of Plant Nutrition* 30: 1287–1339.
- Basiron, Y. 2007 Palm oil production through sustainable plantations. *European Journal of Lipid Science and Technology* 109: 289–295.
- Basuki, I. and Sheil, D. 2005 Local perspectives of forest landscapes: a preliminary evaluation of land and soils, and their importance in Malinau, East Kalimantan, Indonesia. Center for International Forestry Research (CIFOR), Bogor, Indonesia.
- Belcher, B., Rujehan, Imang, N. and Achdiawan, R. 2004 Rattan, rubber, or oil palm: cultural and financial considerations for farmers in Kalimantan. *Economic Botany* 58: S77–S87.
- BisInfocus 2006 *Prospek Perkebunan and Industri Minyak sawit Di Indonesia*

- 2006-2020. PT Bisinfocus Data Pratama, Jakarta.
- Breure, K. 2003 The search for yield in oil palm: basic principles. *In*: Fairhurst, T. and Hardter, R. (eds.) *The oil palm. Management for large and sustainable yields*, 59–98. Potash Institute of Canada and International Potash Institute.
- Brown, E. and Jacobson, M.F. 2005 *Cruel oil*. Center for Science in the Public Interest, Washington, DC.
- Buckland, H. 2005 *The oil for ape scandal: how palm oil is threatening orang-utan survival*. Friends of the Earth, London, UK. 49p. http://www.foe.co.uk/campaigns/corporates/news/orangutan_report.html#ape (10 Nov. 2008).
- Butler, R.A., Koh, L.P. and Ghazoul, J. 2009 REDD in the red: palm oil could undermine carbon payment schemes. *Conservation Letters*, in Press. doi: 10.1111/j.1755-263X.2009.00447.x.
- Cassman, K.G. and Liska, A.J. 2007 Food and fuel for all: realistic or foolish? *Biofuels, Bioproducts and Biorefining* 1: 18–23.
- Casson, A. 2000 *The hesitant boom: Indonesia's oil palm sub-sector in an era of economic crisis and political change*. CIFOR, Bogor, Indonesia.
- Casson, A. 2003 *Oil palm, soybeans and critical habitat loss*. WWF Forest Conservation Initiative.
- Casson, A. Tacconi, L. and Deddy, K. 2007 Strategies to reduce carbon emissions from the oil palm sector in Indonesia. Paper prepared for the Indonesian Forest Climate Alliance, Jakarta.
- Centre for Orangutan Protection 2008 *Palm oil kills* [YouTube video]. http://www.rspo.org/Vision_and_Mission_of_RSPO.aspx (10 Jun. 2008).
- Chavalparit, O., Rulkens, W.H., Mol, A.P.J. and Khaodhair, S. 2006 Options for environmental sustainability of the crude palm oil industry in Thailand through enhancement of industrial ecosystems. *Environment, Development and Sustainability* 8: 271–287.
- Chisti, Y. 2008 Biodiesel from microalgae beats bioethanol. *Trends in Biotechnology* 26: 126–131.
- Clay, J. 2004 *Palm oil*. *In*: *World agriculture and the environment: a commodity-by-commodity guide to impacts and practices*, 203–235. Island Press, Washington, DC.
- Clements, R. and Posa, M.R.C. 2007 Conservationists could slip up in oil-palm enterprise. *Nature* 449: 403.
- Colchester, M., Jiwan, N., Andiko, Sirait, M., Firdaus, A.Y., Surambo, A. and Pane, H. 2006 *Promised land: palm oil and land acquisition in Indonesia—implications for local communities and indigenous peoples*. Forest People Programme, Sawit Watch and World Agroforestry Centre, Bogor, Indonesia. 197p.
- Colon-Ramos, U., Kabagambe, E.K., Baylin, A., Ascherio, A., Campos, H. and Peterson, K.E. 2007 Socio-economic status and health awareness are associated with choice of cooking oil in Costa Rica. *Public Health Nutrition* 10: 1214–1222.
- Cooke, F.M. 2002 Vulnerability, control and oil palm in Sarawak: globalization and a new era? *Development and Change* 33: 189–211.
- Corley, R.H.V. 1998 What is the upper limit to oil extraction ratio? *In*: Rajanaidu, N., Henson, I.E. and Jalani, B.S. (eds.) *Proceedings of International Conference on Oil and Kernel Production in Oil Palm—A Global Perspective*, 256–269. Palm Oil Research Institute of Malaysia, Bangi, Malaysia.
- Corley, R.H.V. 2005 Is oil palm sustainable? *In*: Din, A.K. (ed.) *Proceedings of the 2005 International Oil Palm Conference*, 89–107. Malaysia Palm Oil Board, Kuala Lumpur, Malaysia.
- Corley, R.H.V. and Tinker, P.B. 2003 *The oil palm*. 4th ed. Blackwell Science, Oxford, UK.
- Crowley, L. 2008 Oil palm genome sequencing may aid sustainability. *Food Navigator-USA.com*. 21 May 2008. <http://www.foodnavigator-usa.com/Science-Nutrition/Oil-palm-genome-sequencing-may-aid-sustainability> (29 Oct. 2008).
- Curran, L.M., Trigg, S.N., McDonald, A.K., Astiani, D., Hardiono, Y.M., Siregar, P., Caniago, I. and Kasischke, E. 2004 Lowland forest loss in protected areas of Indonesian Borneo. *Science* 303: 1000–1003.
- Danielsen, F., Beukema, H., Burgess, N.D., Parish, F., Brühl, C.A., Donald, P.F., Murdiyarto, D., Phalan, B., Reijnders, L., Struebig, M. and Fitzherbert, E.B. 2008. Biofuel plantations on forested lands: double jeopardy for biodiversity and climate. *Conservation Biology* 23 (2): 348–358. DOI: 10.1111/j.1523-1739.2008.01096.x
- Demirbas, A. 2007a Fuel alternatives to gasoline. *Energy Sources Part B-Economics Planning and Policy* 2: 311–320.
- Demirbas, A. 2007b Importance of biodiesel as transportation fuel. *Energy Policy* 35(9): 4661–4670.
- Demirbas, A. 2007c Production of gasoline and diesel fuels from bio-materials. *Energy Sources Part A-Recovery Utilization and Environmental Effects* 29: 753–760.

- Dennis, R.A., Mayer, J., Applegate, G., Chokkalingam, U., Colfer, C.J.P., Kurniawan, I., Lachowski, H., Maus, P., Permana, R.P., Ruchiat, Y. *et al.* 2005 Fire, people and pixels: linking social science and remote sensing to understand underlying causes and impacts of fires in Indonesia. *Human Ecology* 33: 465–504.
- de Vries, S.C. In press. The bio-fuel debate and fossil energy use in palm oil production: a critique of Reijnders and Huijbregts 2007. *Journal of Cleaner Production*.
- Direktorat Jenderal Perkebunan 2006 Statistik Perkebunan Indonesia 2004–2006, Kelapa Sawit. Departemen Pertanian, Jakarta, Indonesia.
- Down to Earth (DTE) 2000 Villagers shot, one killed in Sosa land dispute. *Down to Earth* 47. <http://dte.gn.apc.org/47olp.htm> (2 Oct. 2008).
- Down to Earth (DTE) 2001 Oil palm investments opposed. *Down to Earth* 49. <http://dte.gn.apc.org/49OP.htm> (2 Oct. 2008).
- Dufrene, E., Ochs, R. and Saugier, B. 1990 Oil palm photosynthesis and productivity linked to climatic factors. *Oleagineux* 45: 345–353.
- Durand-Gasselin, T., Kouame, R.K., Cochard, B., Adon, B. and Amblard, P. 2000 Dissemination of oil palm (*Elaeis guineensis* Jacq.) varieties. *Ocl-Oleagineux Corps Gras Lipides* 7: 207–214.
- Eggleton, P., Homathevi, R., Jones, D.T., MacDonald, J.A., Jeeva, D., Bignell, D.E., Davies, R.G. and Maryati, M. 1999 Termite assemblages, forest disturbance and greenhouse gas fluxes in Sabah, East Malaysia. *Philosophical Transactions of the Royal Society of London Series B-Biological Sciences* 354: 1791–1802.
- European Biodiesel Board 2008 Statistics. <http://www.ebb-eu.org/stats.php> (31 Oct. 2008).
- European Commission 2008 Proposal for a Directive of the European Parliament and of the Council on the promotion of the use of energy from renewable sources. Commission of the European Communities, Brussels. http://ec.europa.eu/energy/res/legislation/doc/strategy/res_directive.pdf (2 Oct. 2008).
- Fairhurst, T. and Härdter, R. 2003 Oil palm: management for large and sustainable yields. PPI/PPIC and IPI, Singapore. 384p.
- Fairhurst, T.H. and Mutert, E. 1999 Introduction to oil palm production. *Better Crops International* 13: 1–6.
- FAOSTAT <http://faostat.fao.org> (18 Sep. 2008).
- Fargione, J., Hill, J., Tilman, D., Polasky, S. and Hawthorne, P. 2008 Land clearing and the biofuel carbon debt. *Science* 319: 1235–1238.
- Farrell, A.E. and Gopal, A.R. 2008 Bioenergy research needs for heat, electricity, and liquid fuels. *MRS Bulletin* 33: 373–380.
- Fee, C.G. 2000 Vertebrate pests of oil palm. *In: Basiron, Y., Jalani, B.S. and Chan, K.W. (eds.) Advances in oil palm research vol. 1, 542–595. Malaysian Palm Oil Board.*
- Fitzherbert, E.B., Struebig, M.J., More, A., Danielsen, F., Bruhl, C.A., Donald, P.F. and Phalan, B. 2008 How will oil palm expansion affect biodiversity? *Trends in Ecology and Evolution* 23(10): 538–545.
- Focus on Finance 2001 Campaign case study: Dutch banks commit to forest conservation. *In: Focus on Finance News. Special issue. 7 November.*
- Food and Agriculture Organization (FAO) 2005 Global forest resources assessment 2005: progress towards sustainable forest management. FAO, Rome. <http://www.fao.org/forestry/fra2005/en/> (10 Nov. 2008).
- Food and Agriculture Organization (FAO) 2008 The state of food and agriculture 2008. Biofuels: prospects, risks and opportunities. FAO, Rome. <http://www.fao.org/docrep/011/i0100e/i0100e00.htm> (31 Oct. 2008).
- Friends of the Earth (FOE) 2004 Greasy palms—palm oil, the environment and big business. Friends of the Earth, London, UK. http://www.foe.co.uk/resource/reports/greasy_palms_summary.pdf (28 Oct. 2008).
- Friends of the Earth (FOE) 2008 Executive summary. *In: Losing ground: the human rights impacts of oil palm plantation expansion in Indonesia. LifeMosaic, Sawit Watch Indonesia and Friends of the Earth.* <http://www.foe.co.uk/resource/reports/losingground-summary.pdf> (7 Oct. 2008).
- Frondel, M. and Peters, J. 2007 Biodiesel: a new Oildorado. *Energy Policy* 35: 1675–1684.
- Fuller, D.O., Jessup, T.C. and Salim, A. 2004 Loss of forest cover in Kalimantan, Indonesia, since the 1997–1998 El Niño. *Conservation Biology* 18: 249–254.
- Gaveau, D.L.A., Wandono, H. and Setiabudi, F. 2007 Three decades of deforestation in southwest Sumatra: have protected areas halted forest loss and logging, and promoted re-growth? *Biological Conservation* 134: 495–504.
- Gibbs, H., Johnston, M., Foley, J.A., Holloway, T., Monfreda, C., Ramankutty, N. and Zaks, D. 2008 Carbon payback times for crop-based biofuel expansion in the tropics: the effects of changing yield and technology.

- Environmental Research Letters 3: 034001. doi:10.1088/1748-9326/3/3/034001
- Gillison, A. 2002 A generic, computer-assisted method for rapid vegetation classification and survey: tropical and temperate case studies. *Conservation Ecology* 6.
- Gillison, A. and Liswanti, N. 1999 Impact of oil palm plantations on biodiversity in Jambi, Central Sumatra, Indonesia. CIFOR. <http://www.asb.cgiar.org/data/dataset/IDA1AMZB.htm> (2 Oct. 2008).
- Goenadi, D.H. 2008 Perspective on Indonesian palm oil production. Paper to 41st IPC Seminar Food, Fuel, and Forests: A Seminar on Climate Change, Agriculture, and Trade. Bogor, Indonesia, 12 May 2008. International Food and Agricultural Trade Policy Council. <http://www.agritrade.org/events/documents/Goenadi2008.pdf> (10 Nov. 2008).
- Greenpeace 2007 How Unilever palm oil suppliers are burning up Borneo. www.greenpeace.org.uk/media/reports/burning-up-borneo (9 Jun. 2008).
- Guenther, A. 2008 Are plant emissions green? *Nature* 452: 701–702.
- Guyon, A. and Simorangkir, D. 2002 The economics of fire use in agriculture and forestry: a preliminary review for Indonesia. Project FireFight South East Asia, Jakarta.
- Hadi, A., Inubushi, K., Furukawa, Y., Purnomo, E., Rasmadi, M. and Tsuruta, H. 2005 Greenhouse gas emissions from tropical peatlands of Kalimantan, Indonesia. *Nutrient Cycling in Agroecosystems* 71: 73–80.
- Hansen, T.S. 2005. Spatio-temporal aspects of land use and land cover changes in the Niah catchment, Sarawak, Malaysia. *Singapore Journal of Tropical Geography* 26: 170–190.
- Hardter, R. and Fairhurst, T. 2003 Introduction: oil palm: management for large and sustainable yields. *In: Fairhurst, T. and Hårdter, R. Oil palm: management for large and sustainable yields, 1–12. PPI/PPIC and IPI, Singapore.*
- Hardter, R., Chow, W.Y. and Hock, O.S. 1997 Intensive plantation cropping, a source of sustainable food and energy production in the tropical rain forest areas in Southeast Asia. *Forest Ecology and Management* 91: 93–102.
- Hartemink, A.E. 2005 Plantation agriculture in the tropics—environmental issues. *Outlook on Agriculture* 34: 11–21.
- Hasnah, E.F. and Coelli, T. 2004 Assessing the performance of a nucleus estate and smallholder scheme for oil palm production in West Sumatra: a stochastic frontier analysis. *Agricultural Systems* 79: 17–30.
- Henderson, J. and Osborne, D.J. 2000 The oil palm in all our lives: how this came about. *Endeavour* 24: 63–68.
- Henson, I.E. 1999 Comparative ecophysiology of oil palm and tropical rainforest. *In: Singh, G., Huan, L.K., Leng, T. and Kow, D.L. (eds.) Oil palm and the environment, a Malaysian perspective, 9–39. Malaysian Oil Palm Growers Council, Kuala Lumpur.*
- Herrera, S. 2006 Bonkers about biofuels. *Nature Biotechnology* 24: 755–760.
- Hill, J., Nelson, E., Tilman, D., Polasky, S. and Tiffany, D. 2006 Environmental, economic, and energetic costs and benefits of biodiesel and ethanol biofuels. *Proceedings of the National Academy of Sciences of the United States of America* 103: 11206–11210.
- Hirano, T., Segah, H., Harada, T., Limin, S., June, T., Hirata, R. and Osaki, M. 2007 Carbon dioxide balance of a tropical peat swamp forest in Kalimantan, Indonesia. *Global Change Biology* 13: 412–425.
- Hooijer, A., Silvius, M., Wösten, H. and Page, S. 2006 Peat-CO₂, assessment of CO₂ emissions from drained peatlands in SE Asia. *In: Delft Hydraulics 36, Delft, The Netherlands.*
- Humle, T. and Matsuzawa, T. 2004 Oil palm use by adjacent communities of chimpanzees at Bossou and Nimba Mountains, West Africa. *International Journal of Primatology* 25: 551–581.
- Ibrahim, M.N.M., Nadiah, M.Y.N., Norliyana, M.S., Sipaut, C.S. and Shuib, S. 2008 Separation of vanillin from oil palm empty fruit bunch lignin. *Clean—Soil, Air, Water* 36: 287–291.
- Indonesian Ministry of Agriculture Agricultural Statistical Database (BDSP) <http://database.deptan.go.id/bdsp/index-e.asp> (14 Oct. 2008).
- Indonesian Palm Oil Commission (IPOC) 2006 Statistik Kelapa Sawit Indonesia 2005. Department of Agriculture, Jakarta, Indonesia.
- International Energy Agency (IEA) Statistics Division 2006 Energy balances of OECD countries—extended balances and energy balances of non-OECD countries. IEA, Paris.
- International Palm Oil Congress 2007 Proceedings of the Economics and Marketing Conference. Malaysian Palm Oil Board, Kuala Lumpur, Malaysia. 210p.
- Intergovernmental Panel on Climate Change (IPCC) 2007 Contribution of Working Group III to the fourth assessment report

- of the Intergovernmental Panel on Climate Change, technical summary. p. 39, 90, 776.
- Isa, M.H., Ibrahim, N., Aziz, H.A., Adlan, M.N., Sabiani, N.H.M., Zinatizadeh, A.A.L. and Kutty, S.R.M. 2008 Removal of chromium (VI) from aqueous solution using treated oil palm fibre. *Journal of Hazardous Materials* 152: 662–668.
- Jekayinfa, S.O. and Bamgboye, A.I. 2007 Development of equations for estimating energy requirements in palm-kernel oil processing operations. *Journal of Food Engineering* 79: 322–329.
- Jepson, P., Jarvie, J., MacKinnon, K. and Monk, K. 2001 The end for Indonesia's lowland forests? *Science* 292: 859–861.
- Johnstone, N. 2008 Can palm oil ever be sustainable? *Mail and Guardian online*. 5 May. <http://www.mg.co.za/article/2008-05-02-can-palm-oil-ever-be-sustainable> (8 Nov. 2008).
- Journey to Forever. Oil yields and characteristics. http://journeytoforever.org/biodiesel_yield.html (9 Jun. 2008).
- Kaimowitz, D. and Angelsen, A. 1998 Economic models of tropical deforestation—a review. Center for International Forestry Research (CIFOR), Bogor, Indonesia. 139p.
- Kamarudin, N., Moslim, R., Arshad, O., Wahid, M.B. and Chong, A. 2007 Potential of utilizing rhinoceros beetles (*Oryctes rhinoceros*) as an ornamental fish feed supplement. *Journal of Oil Palm Research* 19: 313–318.
- Karsulinova, L., Folprechtova, B., Dolezal, M., Dostalova, J. and Velisek, J. 2007 Analysis of the lipid fractions of coffee creamers, cream aerosols, and bouillon cubes for their health risk associated constituents. *Czech Journal of Food Sciences* 25: 257–264.
- Kennedy, D. 2007 The biofuels conundrum. *Science* 312: 515.
- Kier, G., Mutke, J., Dinerstein, E., Ricketts, T.H., Küper, W., Kreft, H. and Barthlott, W. 2005 Global patterns of plant diversity and floristic knowledge. *Journal of Biogeography* 32: 1107–1116.
- Kittikun, A.H.O. 2000 Environmental management for palm oil mill. *In: Proceedings of the Internet Conference on Material Flow Analysis of Integrated Bio-Systems* (March–October 2000).
- Koczberski, G. 2007 Loose fruit mamas: creating incentives for smallholder women in oil palm production in Papua New Guinea. *World Development* 35: 1172–1185.
- Koh, L.P. 2008a Birds defend oil palms from herbivorous insects. *Ecological Applications* 18: 821–825.
- Koh, L.P. 2008b Can oil palm plantations be made more hospitable for forest butterflies and birds? *Journal of Applied Ecology* 45: 1002–1009.
- Koh, L.P. and Ghazoul, J. 2008. Biofuels, biodiversity, and people: understanding the conflicts and finding opportunities. *Biological Conservation* 141: 2450–2460.
- Koh, L.P. and Wilcove, D.S. 2007 Cashing in palm oil for conservation. *Nature* 448: 993–994.
- Koh, L.P. and Wilcove, D.S. 2008a Is oil palm agriculture really destroying tropical biodiversity? *Conservation Letters* 1: 60–64.
- Koh, L.P. and Wilcove, D.S. 2008b Oil palm: disinformation enables deforestation. *Trends in Ecology and Evolution* 24 (2).
- Ladeia, A.M., Costa-Matos, E., Barata-Passos, R. and Guimaraes, A.C. 2008 A palm oil-rich diet may reduce serum lipids in healthy young individuals. *Nutrition* 24: 11–15.
- Laurance, W.F. 2003 Slow burn: the insidious effects of surface fires on tropical forests. *Trends in Ecology and Evolution* 18(5): 209–212.
- Leciak, E. and Hladik, A. 2005 The oil palm (*Elaeis guineensis*) and the cores of high biodiversity in gallery forests of Guinea in relation to human and chimpanzees commensalism. *Revue d'Ecologie-La Terre et la Vie* 60(2): 179–184.
- Lelieveld, J., Butler, T.M., Crowley, J.N., Dillon, T.J., Fischer, H., Ganzeveld, L., Harder, H., Lawrence, M.G., Martinez, M., Taraborrelli, D. and Williams, J. 2008 Atmospheric oxidation capacity sustained by a tropical forest. *Nature* 452: 737–740.
- Leow, C. 2007 Palm oil may reach \$1,000 a ton next year on shortage (Update4). *Bloomberg.com* http://www.bloomberg.com/apps/news?pid=20601091&sid=aZfBR_uY3nJI&refer=india (14 Nov. 2008).
- Lerdau, M. and Slobodkin, K. 2002 Trace gas emissions and species-dependent ecosystem services. *Trends in Ecology and Evolution* 17: 309–312.
- Lestari 2006 Financial report. PT Astra Agro Lestari, Jakarta, Indonesia. <http://www.astra-agro.co.id> (Jan. 2008).
- Lin, Y.-C., Lee, W.-J. and Hou, H.-C. 2006 PAH emissions and energy efficiency of palm-biodiesel blends fueled on diesel generator. *Atmospheric Environment* 40: 3930–3940.
- Lonsum 2006 Annual report. PT London Sumatra Indonesia, Jakarta, Indonesia. <http://www.londonsumatra.com/default.asp> (Jan. 2008).

- Lord, S. and Clay, J. nd Environmental impacts of oil palm—practical considerations in defining sustainability for impacts on the air, land and water. New Britain Palm Oil and World Wildlife Fund, Kimbe, Papua New Guinea and Washington, DC. [http://www.rspo.org/resource_centre/Environmental%20impact%20of%20oil%20palm%20\(Simon%20Lord\).pdf](http://www.rspo.org/resource_centre/Environmental%20impact%20of%20oil%20palm%20(Simon%20Lord).pdf) (8 Nov. 2008).
- Lutz, G., Chavarria, M., Arias, M.L. and Mata-Segreda, J.F. 2006 Microbial degradation of palm (*Elaeis guineensis*) biodiesel. *Revista De Biologia Tropical* 54: 59–63.
- Ma, A.N. 2000 Management of palm oil industrial effluents. *In*: Yusof, B., Jalani, B.S. and Chan, K.W. (eds.) *Advances in oil palm research vol. II*, 1439–1461. Malaysian Palm Oil Board, Ministry of Primary Industries, Kuala Lumpur.
- MacDonald, J.A., Jeeva, D., Eggleton, P., Davies, R., Bignell, D.E., Fowler, D., Lawton, J. and Maryati, M. 1999 The effect of termite biomass and anthropogenic disturbance on the CH₄ budgets of tropical forests in Cameroon and Borneo. *Global Change Biology* 5: 869–879.
- Maddox T.M. 2007 Oil palm and mammal conservation. Paper to the International Conference on Oil Palm and Environment 2007, Bali, Indonesia.
- Malaysian Palm Oil Board (MPOB) 2008 Overview of the Malaysian palm oil industry 2007. <http://econ.mpob.gov.my/economy/overview07.htm> (3 Oct. 2008).
- Maley, J. and Chepstow-Lusty, A. 2001 *Elaeis guineensis* Jacq. (oil palm) fluctuations in central Africa during the late Holocene: climate or human driving forces for this pioneering species? *Vegetation History and Archaeobotany* 10: 117–120.
- Marti, S. 2008 Losing ground: the human rights impacts of oil palm plantation expansion in Indonesia. *LifeMosaic, Sawit Watch Indonesia and Friends of the Earth*.
- Meijaard, E., Sheil, D., Nasi, R., Augeri, D., Rosenbaum, B., Iskandar, D., Setyawati, T., Lammertink, A., Rachmatika, I., Wong, A. *et al.* 2005 Life after logging: reconciling wildlife conservation and production forestry in Indonesian Borneo. CIFOR, UNESCO and ITTO, Bogor, Indonesia.
- Melling, L., Goh, K.J. and Hatano, R. 2006 Short-term effect of urea on CH₄ flux under the oil palm (*Elaeis guineensis*) on tropical peatland in Sarawak, Malaysia. *Soil Science and Plant Nutrition* 52: 788–792.
- Mendoza, T.C. 2007 Are biofuels really beneficial for humanity? *Philippine Journal of Crop Science* 32: 85–100.
- Mielke, S. 1991 Economic prospects for oilseeds, oils and fats toward the 21st century. *In*: Basiron, Y. and Ibrahim, A. (eds.) *The proceedings of the 1991 PORIM International Palm Oil Conference*. Kuala Lumpur, 9–14 September 1991. Module iv: Promotion and marketing, 1–16. Palm Oil Research Institute of Malaysia, Kuala Lumpur.
- Mita Valina Liem 2008 Indonesia biofuel not behind environment, food woes. Reuters. 2 May.
- Mosier, A., Wassmann, R., Verchot, L., King, J. and Palm, C. 2004 Methane and nitrogen oxide fluxes in tropical agricultural soils: sources, sinks and mechanisms. *Environment, Development and Sustainability* 6: 11–49.
- Murdiyarso, D. and Adiningsih, E.S. 2006 Climate anomalies, Indonesian vegetation fires and terrestrial carbon emissions. *Mitigation and Adaptation Strategies for Global Change* 12: 101–112.
- Murdiyarso, D., van Noordwijk, M., Wasrin, U.R., Tomich, T.P. and Gillison, A. 2002. Environmental benefits and sustainable land-use in Jambi transect, Sumatra, Indonesia. *Journal of Vegetation Science* 13: 429–438.
- Murphy, D.J. 2007 Future prospects for oil palm in the 21(st) century: biological and related challenges. *European Journal of Lipid Science and Technology* 109: 296–306.
- Naylor, R., Liska, A., Burke, M., Falcon, W., Gaskell, J., Rozelle, S. and Cassman, K. 2007 The ripple effect: biofuels, food security, and the environment. *Environment: Science and Policy for Sustainable Development* 49(9): 30–43.
- Nellemann, C., Miles, L., Kaltenborn, B.P., Virtue, M. and Ahlenius, H. (eds.) 2007 *The last stand of the orangutan—state of emergency: illegal logging, fire and palm oil in Indonesia's national parks*. Rapid Response Assessment. United Nations Environment Programme. 11p.
- Netto, A. 2008 Malaysia: food futures behind rising prices. *Inter Press Service News Agency (IPS)*, 6 May. <http://ipsnews.net/news.asp?idnews=42246> (11 Nov. 2008).
- NewCROP 1996 *Elaeis guineensis* Jacq. Center for New Crops and Plant Products, Purdue University, West Lafayette, IN. http://www.hort.purdue.edu/newcrop/duke_energy/Elaeis_guineensis.html (13 Jun. 2008).

- Nicholas, C. 2005 Certifying the oil palm plantation business and protecting indigenous peoples' rights (Summary of presentation). *In*: Public Forum on Sustainable Palm Oil, 6 January 2005. Center for Orang Asli Concerns, Kuala Lumpur.
- Nikiema, J. and Heitz, M. 2008 Biodiesel. II. Production—a summarization. *Canadian Journal of Civil Engineering* 35: 107–117.
- Ooi, Y.S. and Bhatia, S. 2007 Aluminum-containing SBA-15 as cracking catalyst for the production of biofuel from waste used palm oil. *Microporous and Mesoporous Materials* 102: 310–317.
- Padmanaba, M. and Sheil, D. 2007 Finding and promoting a local conservation consensus in a globally important tropical forest landscape. *Biodiversity and Conservation* 16: 137–151.
- Page, S.E., Siegert, F., Rieley, J.O., Boehm, H.D.V., Jaya, A. and Limin, S. 2002 The amount of carbon released from peat and forest fires in Indonesia during 1997. *Nature* 420: 61–65.
- Palm Oil Research Institute of Malaysia (PORIM) 1994 Annual research report for 1994. Biology Division, PORIM, Bangi, Malaysia.
- Paoli, G.D. 2007 Toward improved use of the HCVF Framework to guide responsible development of oil palm in Indonesia. Paper to the International Conference on Oil Palm and Environment 2007, Bali, Indonesia.
- Parveez, G.K.A., Masri, M.M., Zainal, A., Majid, N.A., Yunus, A.M.M., Fadilah, H.H., Rasid, O. and Cheah, S.C. 2000 Transgenic oil palm: production and projection. *Biochemical Society Transactions* 28: 969–972.
- Paterson, R.R.M. 2007 *Ganoderma* disease of oil palm—a white rot perspective necessary for integrated control. *Crop Protection* 26: 1369–1376.
- Peh, K.S.H., Sodhi, N.S., de Jong, J., Sekercioglu, C.H., Yap, C.A.M. and Lim, S.L.H. 2006 Conservation value of degraded habitats for forest birds in southern Peninsular Malaysia. *Diversity and Distributions* 12: 572–581.
- Peters, J. and Thielmann, S. 2008 Promoting biofuels: implications for developing countries. *Energy Policy* 36: 1538–1544.
- Poku, K. 2002 Small-scale palm oil processing in Africa. *FAO Agricultural Services Bulletin* 148. FAO, Rome. <http://www.fao.org/docrep/005/y4355e/y4355e00.HTM> (28 Oct. 2008).
- Potter, L. 2007 Agrarian transitions in Kalimantan: characteristics, limitations and accommodations. Paper to Meeting of the Canadian Council of South East Asian Studies, Quebec City.
- Ramachandran, S., Singh, S.K., Larroche, C., Soccol, C.R. and Pandey, A. 2007 Oil cakes and their biotechnological applications—a review. *Bioresource Technology* 98: 2000–2009.
- Raman, M., van Schaik, A., Richter, K. and de Clerck, P. 2008 Malaysian palm oil: green gold or green wash? *Social Justice, Forests & Agrofuels* 144. Friends of the Earth, London, UK. <http://www.foei.org/en/publications/pdfs/malaysian-palm-oil-report> (28 Oct. 2008).
- Raw Materials Research and Development Council (RMRDC) 2004 Oil palm. Report on survey of selected agricultural raw materials in Nigeria. RMRDC, Abuja, Nigeria. 140p. <http://www.mrdc.gov.ng/surveyreport2005/Oil%20Palm.pdf> (13 Jun. 2008).
- Rees, R.W., Flood, J., Hasan, Y. and Cooper, R.M. 2007 Effects of inoculum potential, shading and soil temperature on root infection of oil palm seedlings by the basal stem rot pathogen *Ganoderma boninense*. *Plant Pathology* 56: 862–870.
- Reijnders, L. and Huijbregts, M.A.J. 2008 Palm oil and the emission of carbon-based greenhouse gases. *Journal of Cleaner Production* 16: 477–482.
- Rietbergen-McCracken, J., Steinlegger, G. and Koon, C.S. 2007 High conservation value forests: the concept in theory and practice. WWF International. http://www.panda.org/about_wwf/what_we_do/forests/publications/index.cfm?uNewsID=93560 (8 Nov. 2008)
- Roundtable for Sustainable Palm Oil (RSPO) nd. Vision and mission of RSPO. http://www.rspo.org/Vision_and_Mission_of_RSPO.aspx (10 Jun. 2008).
- Rupilius, W. and Ahmad, S. 2007 Palm oil and palm kernel oil as raw materials for basic oleochemicals and biodiesel. *European Journal of Lipid Science and Technology* 109: 433–439.
- Sargeant, H.J. 2001 Vegetation fires in Sumatra, Indonesia. Oil palm agriculture in the wetlands of Sumatra: destruction or development? European Union Forest Fire Prevention and Control Project with Dinas Kehutanan Propinsi Sumatra Selatan. European Union and Ministry of Forestry, Jakarta, Indonesia.

- Scharlemann, J.P.W. and Laurance, W.F. 2008 How green are biofuels? *Science* 319: 43–44.
- Sheil, D., Puri, R., Wan, M., Basuki, I., van Heist, M., Liswanti, N., Rukmiyati, Rachmatika, I. and Samsuudin, I. 2006 Recognizing local people's priorities for tropical forest biodiversity. *Ambio* 35: 17–24.
- Sidle, R.C., Ziegler, A.D., Negishi, J.N., Nik, A.R., Siew, R. and Turkelboom, F. 2006 Erosion processes in steep terrain—truths, myths, and uncertainties related to forest management in South East Asia. *Forest Ecology and Management* 224: 199–225.
- Simamora, A.P. 2007 REDD, not green, scheme for reducing emissions. *Jakarta Post*. 26 October.
- Simamora, A.P. 2008 Palm oil firms vow to stop using forests. *Jakarta Post*. 13 May.
- Simorangkir, D. 2007 Fire use: is it really the cheaper land preparation method for large-scale plantations? *Mitigation and Adaptation Strategies for Global Change* 12(1): 147–164.
- Sodhi, N.S., Koh, L.P., Brook, B.W. and Ng, P.K.L. 2004 Southeast Asian biodiversity: an impending disaster. *Trends in Ecology and Evolution* 19: 654–660.
- Sodhi, N.S., Brooks, T.M., Koh, L.P., Acciaioli, G., Erb, M., Tan, A.K.-J., Curran, L.M., Brosius, P., Lee, T.M., Patlis, J.M. *et al.* 2006 Biodiversity and human livelihood crises in the Malay archipelago. *Conservation Biology* 20: 1811–1813.
- Somerville, C. 2007 Biofuels. *Current Biology* 17: 115–119.
- Southworth, A. 1985 Palm oil and palm kernels. *Journal of the American Oil Chemists' Society* 62: 250–254.
- Stone, R. 2007 Can palm oil plantations come clean? *Science* 317: 1491.
- Sulaiman, N. and Saleh, K. 2007 Forest fires rage in Sumatra, Kalimantan. *Jakarta Post*. 1 October.
- Susanto, P. and Ardiansyah, F. 2003 The palm oil industry in Riau: Dari hutan sampai ke wajan, laporan Yayasan. WWF Indonesia, Jakarta.
- Syafriel, A. 2008 Increasing national food production easier said than done. *Jakarta Post*. 14 May.
- Tacconi, L. 2003 Fires in Indonesia: causes, costs, and policies. Occasional Paper No. 38. Center for International Forestry Research, Bogor, Indonesia.
- Tailliez, B. 1998 Oil palm: a new crop ... for what future? *Ocl-Oleagineux Corps Gras Lipides* 5: 106–109.
- Talukder, M.M.R., Beatrice, K.L.M., Song, O.P., Puah, S., Wu, J.C., Won, C.J. and Chow, Y. 2008 Improved method for efficient production of biodiesel from palm oil. *Energy and Fuels* 22: 141–144.
- Tamunaidu, P. and Bhatia, S. 2007 Catalytic cracking of palm oil for the production of biofuels: optimization studies. *Bioresource Technology* 98: 3593–3601.
- Tangchirapat, W., Saeting, T., Jaturapitakkul, C., Kiattikomol, K. and Siripanichgorn, A. 2007 Use of waste ash from palm oil industry in concrete. *Waste Management* 27: 81–88.
- Tinker, P.B. 1997 The environmental implications of intensified land use in developing countries. *In: Greenland, D.J., Gregory, P.J. and Nye, P.H. (eds.) On the edge of the Malthusian precipice?* 1023–1033. The Royal Society, London.
- Tomich, T.P., Van Noordwijk, M., Budidarseno, S., Gillison, A., Kusumanto, T., Murdiyarso, D., Stolle, F. and Fagi, A.M. 2001 Agricultural intensification, deforestation, and the environment: assessing tradeoffs in Sumatra, Indonesia. *In: Lee D.R. and Barrett, C.B. (eds.) Tradeoffs or synergies? Agricultural intensification, economic development and the environment*, 221–244. CAB International, Wallingford, UK.
- Tomich, T., de Foresta, H., Dennis, R., Ketterings, Q., Murdiyarso, D., Palm, C., Stolle, F., Suyant and Van Noordwijk, M. 2002 Carbon offsets for conservation and development in Indonesia. *American Journal of Alternative Agriculture* 17(3): 125–127.
- Turner, E.C., Snaddon, J.L., Fayle, T.M. and Foster, W.A. 2008 Oil palm research in context: identifying the need for biodiversity assessment. *PLoS One* 3(2): e1572. doi:10.1371/journal.pone.0001572 (11 Nov. 2008).
- Unilever 2008 Unilever commits to certified sustainable palm oil <http://www.unilever.com/mediacentre/pressreleases/2008/Unilevercommitstocertifiedsustainablepalmoil.aspx> (30 March 2009)
- United Nations Environment Programme (UNEP) (content partner), Cleveland, C.J. (topic ed.) 2008 Global environment outlook (GEO-4): Chapter 5. *In: Cleveland, C.J. (ed.) Encyclopaedia of Earth. Environmental Information Coalition, National Council for Science and the Environment, Washington, DC.* [http://www.eoearth.org/article/Global_Environment_Outlook_\(GEO-4\):_Chapter_5](http://www.eoearth.org/article/Global_Environment_Outlook_(GEO-4):_Chapter_5) (9 Nov. 2008).

- United States Department of Agriculture (USDA) 2008a Palm oil: world supply and distribution. Production, Supply and Distribution Online. <http://www.fas.usda.gov/psdonline/psdHome.aspx> (6 Oct. 2008).
- United States Department of Agriculture (USDA) 2008b Oilseeds: world markets and trade. Circular Series FOP 10-08, October 2008. <http://www.fas.usda.gov/psdonline/psdDataPublications.aspx> (31 Oct. 2008).
- Van de Wiel, H. nd Bio-fuels: Dutch government marks time. People Planet Profit (P+). <http://www.peopleplanetprofit.be/artikel.php?IK=1213> (10 Jun. 2008).
- van der Werf, G.R., Dempewolf, J., Trigg, S.N., Randerson, J.T., Kasibhatla, P.S., Giglio, L., Murdiyarso, D., Peters, W., Morton, D.C., Collatz, G.J., Dolman, A.J. and DeFries, R.S. 2008 Climate regulation of fire emissions and deforestation in equatorial Asia. *Proceedings of the National Academy of Sciences of the United States of America* 105 (51): 20350–20355
- Van Noordwijk, M., Mulyoutami, E., Sakuntaladewi, N. and Agus, F. 2008 Swiddens in transition: shifted perceptions on shifting cultivators in Indonesia. Occasional Paper no. 9. Bogor, Indonesia: World Agroforestry Centre.
- van Rooyen, J., Esterhuyse, A.J., Engelbrecht, A.M. and du Toit, E.F. 2008 Health benefits of a natural carotenoid rich oil: a proposed mechanism of protection against ischaemia/reperfusion injury. *Asia Pacific Journal of Clinical Nutrition* 17: 316–319.
- Venter, O., Meijaard, E., Possingham, H.P., Dennis, R., Sheil, D., Wich, S. and Wilson, K. 2009. Confronting the carbon crisis—a safeguard for tropical forest wildlife. In press. *Conservation Letters*.
- Venter, O., Meijaard, E. and Wilson, K. 2008 Strategies and alliances needed to protect forest from palm-oil industry. *Nature* 451: 16.
- Vermeulen, S. and Goad, N. 2006 Towards better practice in smallholder palm oil production. IIED, London, UK.
- von Braun, J. 2007 The world food situation: new driving forces and required actions. IFPRI's Biannual Overview of the World Food Situation presented to CGIAR Annual General Meeting, Beijing, 4 December.
- Wahid, M.B., Abdullah, S.N.A. and Henson, I.E. 2005 Oil palm—achievements and potential. *Plant Production Science* 8: 288–297.
- Wakker, E. 2005 Greasy palms. The social and ecological impacts of large-scale oil palm plantation development in Southeast Asia. Friends of the Earth. www.foe.co.uk/resource/reports/greasy_palms_impacts.pdf (6 Oct. 2008).
- Wakker, E. 2006 The Kalimantan Border Oil Palm Mega-project. Friends of the Earth Netherlands and the Swedish Society for Nature Conservation (SSNC), Amsterdam.
- Wanrosli, W.D., Zainuddin, Z., Law, K.N. and Asro, R. 2007 Pulp from oil palm fronds by chemical processes. *Industrial Crops and Products* 25: 89–94.
- Weiss, D., Shotyky, W., Rieley, J., Page, S., Gloor, M., Reese, S. and Martinez-Cortizas, A. 2002 The geochemistry of major and selected trace elements in a forested peat bog, Kalimantan, SE Asia, and its implications for past atmospheric dust deposition. *Geochimica et Cosmochimica Acta* 66: 2307–2323.
- Weng, C.K. 1999 Biomass production of the oil palm industry. In: Singh, G., Huan, L.K., Leng, T. and Kow, D.L. (eds.) *Oil palm and the environment, a Malaysian perspective*, 41–53. Malaysian Oil Palm Growers Council, Kuala Lumpur.
- Weng, C.K. 2000 Soils management for sustainable oil palm cultivation. In: Basiron, Y., Jalani, B.S. and Chan, K.W. (eds.) *Advances in oil palm research*, 371–410. Malaysian Palm Oil Board, Kuala Lumpur.
- Wibawa, W., Mohamad, R., Omar, D. and Juraimi, A.S. 2007 Less hazardous alternative herbicides to control weeds in immature oil palm. *Weed Biology and Management* 7: 242–247.
- Wilkinson, M.J., Owen, S.M., Possell, M., Hartwell, J., Gould, P., Hall, A., Vickers, C. and Hewitt, C.N. 2006 Circadian control of isoprene emissions from oil palm (*Elaeis guineensis*). *Plant Journal* 47: 960–968.
- Wilmar 2006 Wilmar annual report. Wilmar, Singapore. <http://www.wilmar-international.com> (Jan. 2008).
- Wong, C.K. and Bernardo, R. 2008 Genomewide selection in oil palm: increasing selection gain per unit time and cost with small populations. *Theoretical and Applied Genetics* 116: 815–824.
- World Bank 2001 World development indicators: deforestation and biodiversity. World Bank, Washington, DC.
- World Resources Institute 2009 Climate Analysis Tool (CAIT) Database. <http://cait.wri.org> (5 May 2009).
- World Wide Fund for Nature (WWF) 2008. How pulp & paper and palm oil from Sumatra increase global climate change and drive tigers and elephants to local extinction.

- Excerpts from: Deforestation, forest degradation, biodiversity loss and CO₂ emissions in Riau, Sumatra, Indonesia. WWF Indonesia Technical Report. WWF Indonesia, Jakarta.
- Wosten, J.H.M. 1997 Pedotransfer functions to evaluate soil quality. *In*: Gregorich, E.G. and Carter M.R. (eds.) Soil quality for crop production and ecosystem health, 221–245. Developments in Soil Science. Elsevier Science, Amsterdam.
- Wuebbles, D.J. and Hayhoe, K. 2002 Atmospheric methane and global change. *Earth-Science Reviews* 57: 177–210.
- Yacob, S., Hassan, M.A., Shirai, Y., Wakisaka, M. and Subash, S. 2006 Baseline study of methane emission from anaerobic ponds of palm oil mill effluent treatment. *Science of the Total Environment* 366: 187–196.
- Yusoff, S. 2006 Renewable energy from palm oil—innovation on effective utilization of waste. *Journal of Cleaner Production* 14: 87–93.
- Yusoff, S. and Hansen, S.B. 2007 Feasibility study of performing a life cycle assessment on crude palm oil production in Malaysia. *International Journal of Life Cycle Assessment* 12: 50–58.
- Yusop, Z., Chan, C.H. and Katimon, A. 2007 Runoff characteristics and application of HEC-HMS for modelling stormflow hydrograph in an oil palm catchment. *Water Science and Technology* 56: 41–48.
- Zah, R., Böni, H., Gauch, M., Hirschler, R., Lehman, M. and Wäger, P. 2007 Ökobilanz von Energieprodukten: Ökologische Bewertung von Biotreibstoffen (Environmental impacts of biofuels). Bern. <http://www.news-service.admin.ch/NSBSubscriber/message/attachments/8514.pdf> (8 Nov. 2008).
- Zen, Z., Barlow, C. and Gondowarsito, R. 2006 Oil palm in Indonesian socio-economic improvement: a review of options. *Oil Palm Industry Economic Journal* 6: 18–29.
- Zhao, S.Q., Peng, C.H., Jiang, H., Tian, D.L., Lei, X.D. and Zhou, X.L. 2006 Land use change in Asia and the ecological consequences. *Ecological Research* 21: 890–896.

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The ongoing expansion of oil palm plantations in the humid tropics, especially in Southeast Asia, is generating considerable concern and debate. Amid industry and environmental campaigners' opposing claims, it can be hard to perceive reality. Is oil palm a valuable route to sustainable development or a costly road to environmental ruin? Inevitably, any answer depends on many choices. But do decision makers have the information they require to avoid pitfalls and make good choices?

This report examines what we know and what we don't know about oil palm developments. Our sources include academic publications and 'grey' literature, along with expert consultations. Some facts are indisputable: among these is the fact that oil palm is highly productive and commercially profitable at large scales, and that palm oil demand is rising. Oil palm's considerable profitability offers wealth and development where wealth and development are needed—but also threatens traditional livelihoods. It offers a renewable source of fuel, but also threatens to increase global carbon emissions. How can local, regional and international benefits be increased while costs are minimised? At the end of this report we present a list of pressing questions requiring further investigation. Credible, unbiased research on these issues will move the discussion and practice forward.



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