Chapter 1
The Origin and Development of the Oil Palm Industry

The oil palm gives the highest yields per hectare of all oil crops (Table 1.3). The high yields have led to a rapidly expanding industry in the tropics of Asia, Africa and America, and palm oil and kernel oil represented 37% of world vegetable oil production in 2012 (Table 1.2). The major producers were Malaysia and Indonesia, which provided nearly 90% of the oil entering international trade (Table 1.5).

The fruit of the oil palm *Elaeis guineensis* has a hard-shelled nut surrounded by pulp (mesocarp) which contains the palm oil of commerce. The nut contains the palm kernel, from which a different oil, palm kernel oil, is extracted, leaving a proteinaceous residue, palm kernel cake, used as animal feed.

1.1 ORIGIN OF THE OIL PALM

1.1.1 Physical evidence

The oil palm (*E. guineensis*) exists in a wild, semi-wild or cultivated state in three main areas of the equatorial tropics: Africa, South East Asia and South and Central America (Fig. 1.1). Most of this spread has been a result of its domestication by man. There is fossil, historical and linguistic evidence for an African origin of the oil palm. Fat found in a tomb at Abydos in Egypt from around 5000 BP may possibly have been palm oil (Raymond, 1961). Botanical evidence of the American origin of related palm genera suggests a South American origin, and there are apparently wild palm groves in Brazil as well as in Africa. There was controversy on this point (Cook, 1942), and it has been suggested that the oil palm was transported to Africa in pre-Colombian times (Corner, 1966). However, direct evidence of an African origin has been found by the dating of pollen in Miocene sediments in Nigeria (Zeven, 1964). Elenga *et al*. (1994) reported oil palm pollen in two deep cores taken in the Congo. The climate became more humid from 13,000 BP, and pollen of *E. guineensis* was found more and more frequently at levels corresponding to about 2850 BP onwards. Probably, this was caused by increasing human populations, which were already using the oil palm for food. Raynaud-Farrera *et al*. (1996) also found pollen in lake sediment cores from the south-west Cameroons, which covered the period after 2730 BP, when many pioneer species started to appear, and Ergo (1997) found fossilised seeds of oil palm in Uganda. Sowunmi (1999) also discovered oil palm nutshells in a rainforest site and suggested a marked rainfall increase around 5000 BP that started the increase of the palm.

The physical evidence for the African origin of the oil palm is therefore very strong, and the evidence for human use of the oil palm from several thousand years ago is also convincing.

A study on genetic diversity was undertaken by Maizura *et al*. (2006) on 359 accessions of oil palm material from 11 countries in Africa. These were characterised by the RFLP method (see Section 6.2.8) using standard Deli *dura* material as a check. All these accessions had a higher natural diversity than the Deli *dura* standard. The material from Nigeria showed the highest number of alleles per locus and the highest percentage of polymorphic loci. These findings indicate that Nigeria may well be the centre of diversity of the wild oil palm.

1.1.2 Historical evidence

The historical record about the oil palm is meagre (Rees, 1965a; Zeven, 1965). Portuguese exploration and trade on the West African coast began in 1434, with

The Oil Palm, Fifth Edition. R.H.V. Corley and P.B. Tinker.

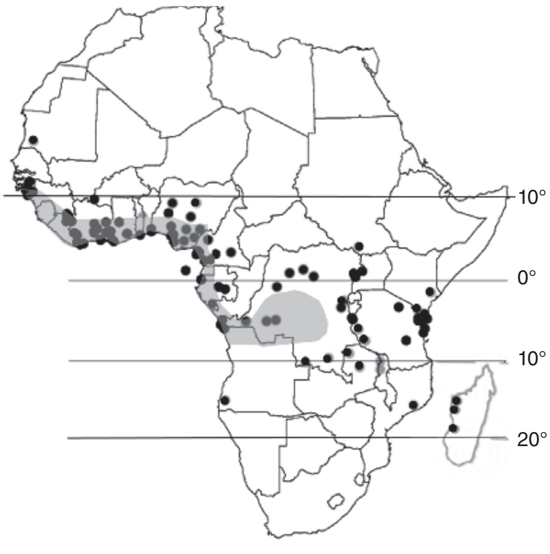

Fig. 1.1 Distribution of the oil palm in Africa. Shaded area is the main oil palm belt, according to Hartley (1988). Black dots are locations of isolated populations (Hartley, 1988) and individual collections listed by Rajanaidu and Jalani (1994a) and Blach-Overgaard *et al*. (2010).

the Dutch and English some 150 years later. The first record of what may be the oil palm is by Ca' da Mosto (1435–1460) who noted 'a species of tree bearing red nuts with black eyes in great quantity, but they are small' (Crone, 1937). He wrote of the food, '[It] has the scent of violets, the taste of our olive oil and a colour which tinges the food like saffron, but is more attractive'. Duarte Pacheco Pereira observed palm groves in Liberia (1506–1508), and trade in palm oil (*azeite de palma*) near Forcados. Later accounts also mention palm wine and refer to oil palms or palm oil as something originating from West Africa (Opsomer, 1956). There are no early reports of oil palms in the literature of early Brazilian exploration, and Brazilian terms describing oil palms are largely of African origin (Hartley, 1988).

1.1.3 Natural habitat

The difficulty of assigning a natural, original habitat is that the oil palm does not normally grow well in either the primary forest or the savannah, but it flourishes when humans start to fell the forest, settle there and use the palm and possibly enrich the soil. The felling of trees allows the palm to act as a pioneer species, and its seed may be spread by animals and by some bird species. However, it is likely that the main agent spreading the oil palm has been man when using oil palm products. Hence, a large number of semi-domesticated palms grow around homes or along pathways. The system of shifting cultivation led to movement of villages through the surrounding forest, thus ensuring ever wider spread of the palm. These spread mechanisms are widely believed to be responsible for the palm groves of West Africa, which were well established at the time of the European explorations. The palm groves of Brazil have presumably been formed by a similar process.

An alternative view was put forward by Maley (1999) and Maley and Chepstow-Lusty (2001), who suggested that the distribution of palms in Central Africa followed a decline of forests in many areas. This was ascribed to a widespread drier phase in the climate around 2500–2800 BP, which was reversed later, perhaps around 2000 BP. The palm might have acted as a pioneer species as the forest re-expanded into surrounding areas. This is possible, but the historical association of the palm with human habitation was so close that it seems unlikely. There seems little doubt that the human population distributed seed, although people did not 'cultivate' the palm and plant it deliberately.

Chevalier (1934) suggested the origin of the oil palm was in forest outliers close to rivers. This forest is not high or dense enough to shade the palms out, and the water supply will be excellent. Freshwater swamp was suggested by Waterston (1953), and in Sumatra and Malaysia, similar habitats have been colonised by 'escaped' oil palms. Such places can be found virtually throughout Africa, and wild palms are still found in them. The oil palm does not tolerate salinity or stagnant water above the soil surface, but it accepts fluctuating freshwater tables 50 cm or more below the soil surface and less in light-textured soils and sediments (Section 4.3). It seems likely that its original habitat was of this type.

1.1.4 The American oil palm

The second species of *Elaeis*, *E. oleifera*, originated in South or Central America and has been taken to other continents for breeding and research purposes. From genome sequences, Rajinder *et al*. (2013a) estimated that the two species of *Elaeis* diverged as long as 51 Myr ago. Despite this, the two species can form more or less fertile hybrids, perhaps because with geographic isolation, there has been no selective pressure to evolve reproductive isolation.

1.2 THE OIL PALM IN AFRICA

1.2.1 Geographical distribution

Blach-Overgaard *et al.* (2010) studied the distribution of 29 palm species, including the oil palm, based on herbarium specimens and a literature survey. This gave information on the relative importance of climate, other environmental factors such as soil or non-environmental factors such as biotic interactions. The information on range may be useful to understand the possible impact of climate change (Chapter 17). For the oil palm, the availability of water seemed more important than temperature (see Chapter 3), and non-environmental factors were also important.

The detailed distribution of grove palms was described by Zeven (1967) and Schad (1914). Starting from the most northerly occurrences along the West African coast, concentrations of palms occur in the highlands of Guinea, at 10–11°N. The palm belt runs through Sierra Leone, and all the countries to the Cameroons and the Democratic Republic of Congo. In West Africa, the belt is narrow because of the rapid decline in rainfall northwards. Thus, in Nigeria, there are no semi-wild palms north of about 7°N, except where there are shallow water tables and rivers, but in equatorial Africa, the belt is broader.

In Central Africa, oil palms grow in much of the Congo and in Angola. Most are between 3°N and 7°S, but sparse palms can be found as far south as 15°S. Stands of semi-wild palms are found on the Congo–Uganda border, but most of eastern Africa is too dry for commercial oil palms, or at too high an altitude, or both.

Low rainfall and high altitude are the greatest barriers to oil palm establishment and growth, and normally, the palm does not grow above about 300 m. However, with sufficient rainfall, it grows up to 1300 m on the Cameroon mountain, and to 1000 m in Guinea, the East Cameroons and in East Africa, although the yields tend to be low. The development of palms that are tolerant of higher altitudes (or lower temperatures) is proceeding (Section 6.3.6.2). The oil palm reaches 21°S on Madagascar. It occurs mainly on the west coast, whereas the local climate appears most favourable on the east, suggesting that it was imported to the west.

The controls that the natural environment place on the productivity of the oil palm are only some of its limits. The effect of political turmoil and lack of encouragement or resources can be larger – for example, in the drastic decline in the export of oil and kernels from Nigerian palm groves (Section 1.4.4.1).

1.2.2 African palm grove oil production

Before the twentieth century, the only commercial sources of oil palm products were the large semi-wild groves of Africa; produce from the smaller groves of Brazil was only used locally. In Africa, there were exportable surpluses of oil and of kernels (Table 1.6), despite large local consumption. The palm groves were scattered over an area in which shifting cultivation was the predominant agricultural system. In south-eastern Nigeria, the practice of shifting cultivation (Nye and Greenland, 1960) became very intense due to a high population, so the forest fallow period was short and few high trees grew. As the palms were protected and unshaded, they were productive (Andah, 1993), if the soil fertility was sufficient.

The palm groves form an interesting and unique agricultural ecosystem (Zeven, 1965, 1967, 1968, 1972). The Brazilian groves are similar (Hartley, 1988). The types of grove range from secondary forest with a few oil palms to dense groves with an almost pure stand of palms, with arable crops between them. Sometimes farmers deliberately thin out dense groves to allow in more light and get larger yields of food crops, and eventual exhaustion of the soil may lead to derived savannah with a few isolated palms. Hartley (1988) quoted yields of palm groves ranging from 1.6 to 3.1 t of fruit per hectare per year, very poor by modern plantation standards.

Improving the groves has frequently been suggested. However, the problems of organisation, ownership and the need for investment in fertiliser and improved planting material have usually prevented much success (Sparnaaij, 1958). Improved palms planted under the old ones grow very slowly, and the decrease in the commercial value of the groves has reduced interest in such research (Hartley, 1988).

According to Omoti (2004), there are now just over 3 Mha of groves, with 2.1 Mha in Nigeria, 0.5 Mha in Cameroons and 0.3 Mha in Benin.

1.2.3 Early trade

The oil palm industry was largely centred on Africa until World War II. The Portuguese founded a fort at Elmina in Ghana in 1482 and reached Benin City in 1492, but the commercial opportunities and the Portuguese interest were small. Other countries also built forts and settlements along the coast, especially after the West African slave trade started in 1562. Palm oil was used only as food for the slaves.

After 1807, when the slave trade was banned, alternative commerce developed, first with ivory and timber. In 1790, only 130 t of palm oil was imported to England, and the name first appeared in 1804. Trade restrictions, the small number of traders, the diseases in West Africa and poor access to the interior for the European traders prevented any major developments, but fluctuating trade continued until the 1830s. After that, the British government deliberately encouraged the oil palm trade (Stilliard, 1938). The palm oil trade finally took off in the 1850s, palm oil was exported from the Benin River, Bonny and the Calabar River in growing amounts, and the whole area became known as the 'Oil Rivers' (Stilliard, 1938; Dike, 1956).

The early expatriate traders remained in their ships, the control of all trade on land lay with local middlemen, and the quality of oil was therefore very variable. Later, land-based trading posts were established, and the quality improved. The trade was around 12,000 t/year in the 1830s, reached 30,000 t in the 1860s and 87,000 t by 1911. The improved communications and security in southern Nigeria encouraged the farmers to increase the supply of oil (Njoku, 1983). The palm groves would supply local needs for oil and palm wine, and the leaves would be used for palm thatch. Where local needs used up most of the palm oil, the kernels were still saleable.

The oil palm trade also depended upon the developing Industrial Revolution in Europe during the nineteenth century (Henderson and Osborne, 2000). Soap was first made from the oil in Europe as early as 1589; after the 1830s, almost all soap in Britain was made from palm oil. Later, it was used for candles, composed largely of palmitic acid, and to produce lighting gas. By the middle of the nineteenth century, major new uses were being invented rapidly, such as lubricants for the railways and as a flux in the tinplate industry for canned foods. Margarine was developed, and glycerol (glycerine) from palm oil had numerous uses. Prices in the 1860s were around £40/t, in real terms far higher than the present world price (Dike, 1956). Henderson and Osborne (2000) support the case that this explosion of demand for palm oil helped to end the slave trade in West Africa.

The demand for palm kernel oil also increased sharply. Exports of kernels started in 1832, the kernels being produced by African women who cracked the nuts by hand. Exports from British territories in West Africa were 157,000 t by 1905 and 232,000 t by 1911, valued at £3,400,000. The export of kernels was much larger than that of oil because of the large local consumption of the latter. The export of both oil and kernels increased gradually to a maximum before and after World War II but declined in the decades afterwards. (For further details, see Hartley, 1988.)

The palm groves now contribute little to world trade in palm products. The groves themselves are shrinking, as the land is taken for other purposes (Omoti, 2004). Although there are still over 2 Mha of groves in Nigeria, that country now imports large amounts of palm oil (Table 1.11) (see Section 1.4.4.1).

Gerritsma and Wessel (1997) covered much the same historical ground as above but told from the point of view of the successful 'domestication' of a wild plant, a process that they considered is still continuing in terms of increasing yield and more sustainable methods of establishment and cultivation.

1.3 DEVELOPMENT OF THE OIL PALM PLANTATION INDUSTRY

Brief descriptions of the development of the industry are given by Berger and Martin (2000) and Byerlee *et al*. (in press).

1.3.1 The African plantation industry

An unsuccessful plantation was established in Gabon in 1870 (Berger and Martin, 2000). Subsequently, plantings were made in the Belgian Congo, various French territories and Nigeria, before or shortly after World War I. Most activity was in the Congo, including encouraging the planting of palms by local farmers. Lord Leverhulme's concessions had extensive plantations with palm oil mills that also took fruit from local farmers. This led to a steady increase in the exports of palm oil (Table 1.1) and kernels (Table 1.6).

The important scientific relationship between the thick-shelled *dura* and the more desirable *tenera* type of oil palms was first discovered in the Congo (Section 6.1.5), which gave a great impetus to the plantation developments there and later to the whole world oil palm industry. Political changes and intermittent violence have damaged the Congolese industry, but it may still have a great future. The most successful African plantations in the latter part of the twentieth century were in the Ivory Coast, with excellent research supported from France.

Small-scale palm oil extraction as used by small- and medium-sized oil palm farms (smallholders) in Africa was and remains important where industrial plantations with mills are not available (FAO, 2002; Section 15.4.2). The quality of the oil is very dependent upon the extractive system and the degree of care that is applied.

Table 1.1 Exports of palm oil (thousand tonnes/annum) from the main producing countries

Country	1909–1913	1924–1931	1932–1939	1940–1945	1946–1953	1954–1961	1962–1969	1970–1977	1978–1981	1982–1985	1986–1989	1990–1993	1994–1997	1998–2000
Angola	2	4	4	5	12	11	15	11	–	–	–	–	–	–
Benin	13	15	18	8	9	14	11	7	4	3	na	na	na	na
Cameroon	–	–	–	–	–	–	–	–	–	–	24	20	22	15
Congo	2	25	58	74	119	158	124	71	7	8	–	–	–	–
Ivory Coast	6	7	18	8	9	14	1	67	71	57	88	155	110	92
Nigeria	83	126	132	132	156	180	81	9	–	–	–	–	–	–
Sierra Leone	9	4	3	1	2	–	–	–	–	–	–	–	–	–
Brazil	–	–	–	–	–	–	–	–	–	–	4	6	24	21
Colombia	–	–	–	–	–	–	–	–	–	–	0	4	31	87
Costa Rica	–	–	–	–	–	–	–	–	–	–	4	20	52	83
Ecuador	–	–	–	–	–	–	–	–	–	–	0	6	21	26
Indonesia	–	28	161	82	77	122	140	294	366	376	838	1590	2216	3154
Malaysia	–	2	31	26	46	73	188	887	2042	2996	4595	5946	7129	8754
PNG	–	–	–	–	–	–	–	10	35	104	122	183	248	268
Thailand	–	–	–	–	–	–	–	–	–	4	5	1	27	61

na, not available.

Some of the early methods were still in use in Ghana in 1993 (Berger, pers. comm., 2001). There was for a long time no local kernel crushing industry, and kernels formed a separate export trade. Later, African countries obtained crushing plants, and by the 1970s, African countries were exporting over 100,000 t of palm kernel oil annually (Table 1.9).

1.3.2 The Deli palm

The establishment of oil palm plantations in South East Asia started with little or no direct connection with the West African groves, though information from Africa was used in Asia from an early time. The earliest record of the introduction of oil palms into South East Asia was of four seedlings planted in the Buitenzorg (now Bogor) Botanic Gardens in 1848 in Java in the then Dutch East Indies. Two of these were from the Amsterdam botanic gardens, but their origin is not known. The other two were from 'Bourbon or Mauritius' in the Indian Ocean, Bourbon being on Reunion island. The palms from these four seedlings were all quite similar, so it is likely they were all from related seeds brought from Africa, possibly from a single parent palm (see Hartley, 1988; Gerritsma and Wessel, 1997; Pamin, 1998). After transfer of the progeny of these palms to Sumatra in 1875, they became the foundation stock for the South East Asian industry, though other selections have been introduced later (see Chapter 6).

In Indonesia, the seeds from the four palms initially planted at Bogor were distributed widely. They were originally used mainly as ornamentals, but experimental plots were established as early as 1860, and Pamin (1998) suggests that the possible economic exploitation of the palm was always kept in view. One plot was at Deli in Sumatra, from which the name for this material was taken. The main reason for the lack of large-scale economic use for over 60 years from the first introduction was probably the lack of large-scale extraction methods and uncertainty as to the economic return that could be expected. The rapidly increasing market for the oil towards the end of the nineteenth century (see Section 1.2.3) was an incentive for seeking a more efficient production system than the African groves.

1.3.3 The Asian plantation industry

In the *Kew Bulletin* of 1877 it was reported that a trial planting was established on the island of Labuan, off the coast of what is now Sabah (K. Berger, pers. comm., 2001). The palms were provided from Ghana, and there was a long correspondence about the seed and the properties of the fruit and the oil. In 1888, 700 seedlings were growing and producing fruit. However, in 1889, the oil palms were replaced by coconuts. No attempt appears to have been made to extract any oil. Another trial plot was planted in Sabah in the 1880s, but the origin of the material is not known. Seed from this plot was planted at Mostyn Estate in 1957 (Tully, 2003), and this planting may still exist.

The first large plantation in Sumatra was planted with Deli palms in 1911. By 1917, the first plantation in Malaysia was planted in the Kuala Selangor district. The Sumatran industry forged ahead rapidly, with 31,600 ha planted by 1925, when Malaysia only had 3350 ha. By 1938, when the areas were, respectively, 92,000 and 20,000 ha, the Far East Asian plantation industry was fully established and was producing as much oil as the African industry (Table 1.1). The extraction problem had been largely solved, with both centrifuge and press machinery operating in large mills. World War II and subsequent disturbances then set the whole industry back a long way.

1.3.4 The oil palm in America

A brief general history of development in the Americas was given by Richardson (1995). The first plantation was established by the United Fruit Company in 1943 in Honduras, followed by another in Costa Rica. Development has continued but at a rather slow pace compared with the rapid expansion in Asia. The availability of land is good in principle (Table 1.8), but in the absence of clear targets or strong direction at government level, no momentum developed. The American *E. oleifera* palm has aroused much interest, and its use in palm breeding is widespread, but its yields are very small. At present, the industries in Colombia and Ecuador are the largest within America. A full list is in Table 1.4.

1.4 DEVELOPMENT OF THE INDUSTRY SINCE 1950

1.4.1 General

The oil palm is but one of a series of plants that yield vegetable oils to commerce. The others are competitors of palm oil at various levels, though each has its own special characteristics. Palm oil is probably one of the most flexible in its application, and it is now the largest source of vegetable oil (Table 1.2). The world's total

Table 1.2 World production of edible oils and fats (Mt/year) and producing areas in 2012

Year	Palm oil	Palm kernel oil	Soya bean oil	Rapeseed oil	Sunflower oil	Coconut oil	Other vegetable oils	Animal oils and fats	Total
1960	1.26	0.42	3.33	1.10	1.79	–	8.95	11.18	28.0
1970	1.74	0.38	6.48	1.83	3.49	–	10.01	14.46	38.4
1980	4.55	0.64	13.32	3.53	5.04	–	11.17	18.26	56.5
1990	11.01	1.45	16.10	8.16	7.87	–	15.02	20.20	79.8
2000	21.12	2.64	25.21	14.40	9.60	3.28	13.63	21.57	111.7
2001	24.07	2.94	27.78	13.76	8.17	3.52	15.64	21.74	117.7
2002	25.55	3.03	29.76	13.36	7.61	3.11	15.96	22.35	120.9
2003	28.44	3.31	31.15	12.71	8.92	3.27	15.18	22.61	125.8
2004	31.25	3.58	30.66	15.07	9.43	3.04	15.99	23.23	132.4
2005	34.11	3.95	33.53	16.29	9.83	3.15	16.90	23.58	141.2
2006	37.42	4.21	35.16	18.45	11.29	3.22	16.47	23.88	150.2
2007	39.02	4.48	37.28	18.74	10.92	3.20	16.52	24.16	154.2
2008	43.55	4.89	36.81	20.04	10.84	3.18	16.52	24.26	160.1
2009	45.48	5.11	36.08	21.82	13.08	3.24	16.22	24.25	165.3
2010	46.07	5.11	40.20	24.04	12.54	3.61	16.61	24.39	172.6
2011	50.79	5.55	41.57	23.78	13.06	2.98	17.32	25.09	180.2
2012	53.66	5.92	41.71	24.48	14.80	3.24	17.39	25.17	186.4
2013	56.09	6.23	42.68	25.08	13.90	3.34	–	–	–
Producing area (Mha)									
2012/2013	14.8	–	108.8	34.8	25.5	9.8	69.9	–	263.6

Source: ISTA Mielke GmbH, Oil World Annual 2013 and Oil World Data Bank.

production of oil palm products is difficult to assess accurately, as much produce is harvested from groves and smallholder plots and is used for the farmer's domestic purposes or local trade. Worldwide production rose from 2.2 Mt of palm oil and 1.2 Mt of kernels in 1972 to 53.6 Mt of oil and 5.9 Mt of kernel oil in 2012 (Oil World, 2013).

The Asian industry had to make a fresh start after World War II. The independence struggle in Indonesia meant that Malaysia leapt forward in comparison, despite the communist emergency between 1948 and 1957, and by 1970, it was well ahead in total planted area. A key commercial change was the shift in the 1960s from Deli *dura* palms to *tenera* palms, which meant that new plantings gave a 30% increase in yield. The Malaysian oil palm area grew in a roughly linear fashion (Fig. 1.2) until the end of the twentieth century.

Indonesian production grew relatively slowly until the late 1980s but thereafter grew rapidly (Figs 1.2 and 1.3). Yield per hectare of the Indonesian plantations caught up with the Malaysian level in about 1981 and remained roughly the same until the difficult years after 1997 (Mielke, 1998). Total production exceeded that from Malaysia from 2006 onwards (Fig. 1.3). These two countries have been jointly dominant since the 1970s, and they probably will remain so for some time to come (Mielke, S., 1998, 2001; Mielke, T., 2000).

Malaysia and Indonesia have built up an enormous base of experience, both in the actual production of palm oil and palm kernel oil and in the ancillary upstream and downstream industries such as plant breeding, plant tissue culture, agricultural machinery and agrochemicals, oil fractionation and oleochemicals. They now also have social unity, good management, very efficient supply chains and a reputation as reliable partners in trade. The smaller tropical Asian and American countries are following the route pioneered by these two countries, and this path should now also be followed by the African industry.

The African industry still supplies a large part of the domestic demand for oil, and the surplus of kernels has allowed these and kernel oil to continue as a substantial export trade. The American oil palm industry has grown steadily and has become established in many Central and South American countries (Table 1.1), but it is in several ways different from the Asian industry. A large part of the production is used locally, and exports are rather small. South America has several

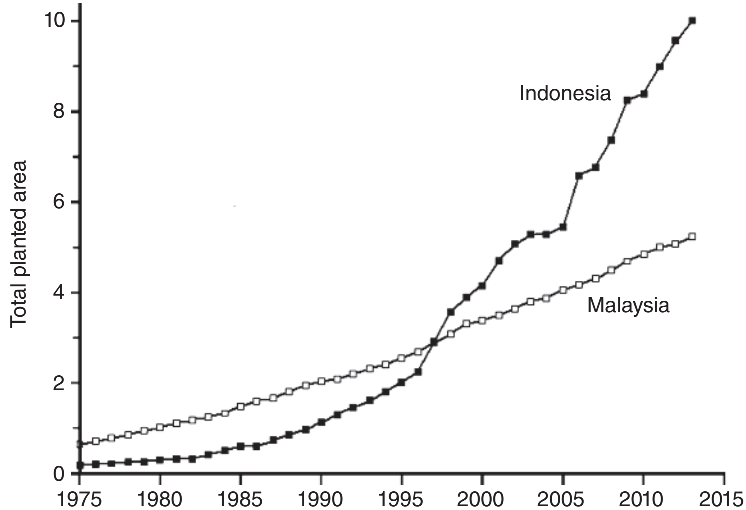

Fig. 1.2 Increase in mature oil palm area from 1973 to 2010, in Indonesia and Malaysia (ISTA Mielke GmbH, Oil World Annual 2013 and Oil World Data Bank).

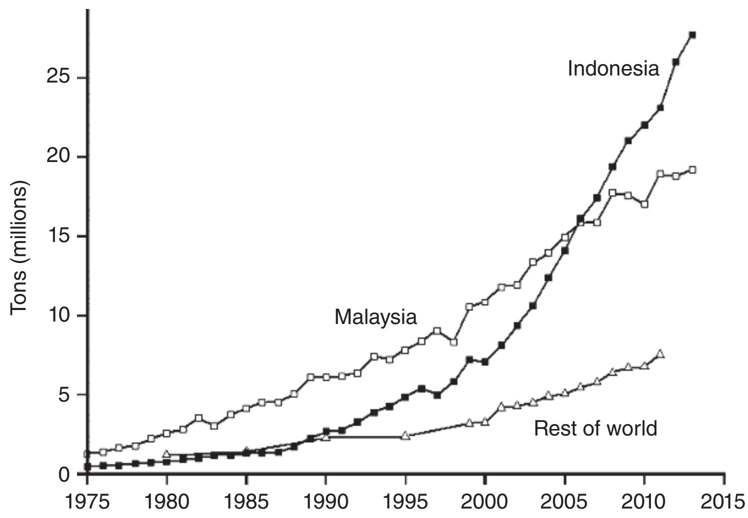

Fig. 1.3 Production of palm oil (million tonnes) from 1973 to 2010 in Indonesia, Malaysia and the rest of the world (ISTA Mielke GmbH, Oil World Annual 2013 and Oil World Data Bank).

serious diseases of the oil palm that are not found elsewhere (see Chapter 13). South American production will probably grow more rapidly in future, as will that of other parts of equatorial South East Asia (Thailand, Papua New Guinea), but it must be some time before the joint dominance of Malaysia and Indonesia is seriously challenged.

1.4.2 Price structures and competitiveness

1.4.2.1 *Changes in the past*

The fluctuations in commodity prices over short periods are difficult to predict or to explain. A clearer picture is presented by the real inflation-adjusted

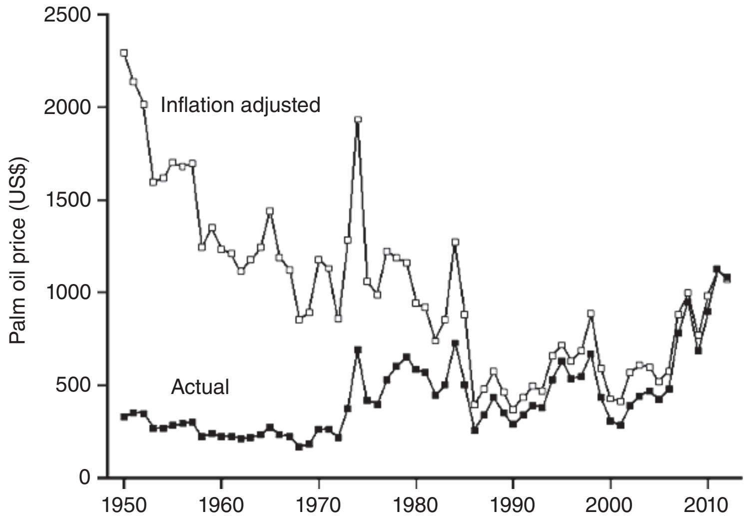

Fig. 1.4 Palm oil prices, actual and adjusted for inflation (to 2011 US$) (data from Fry, pers. comm., 2012).

prices for oil products in the world markets over a long period. Despite the rapidly growing world population, agricultural research and development has more than kept pace with it since World War II, leading to decreasing prices for most major crops. From 1950 to the 1990s, there was a clear, downward trend in the inflation-adjusted price for palm oil (Fry, 1998). In the second half of the twentieth century, inflation-adjusted market prices for all agricultural commodities declined at 1.5–3.5% per year. Palm oil declined at 3% (Fig. 1.4), soya bean oil at 3.1% and coconut oil at 2.9%. Prices rose with petroleum prices in the 1970s but fluctuated after 1981, when the weevil *Elaeidobius kamerunicus* was introduced to the Far East. Since 2000, prices have risen considerably; one reason has been the use of food commodities for biofuel production, but there are other factors as well (see Section 18.3.3).

Fry (2012) showed that there was a close relationship between vegetable oil prices and the petroleum price (see Fig. 18.1). Because of biofuel demand, the petroleum price sets an effective minimum for vegetable oils; if the palm oil price falls below this minimum, it becomes economic to use it for biodiesel even without subsidies, so demand increases and prices stabilise. Between 2007 and 2012, the average premium for palm oil over 'Brent crude' petroleum was about US$270/t (Fry, 2012).

1.4.2.2 *Competition between regions*

A successful global industry does not guarantee success for each individual producer or country. The trend towards lower real prices will put pressure on countries with high costs per tonne of oil, which will depend closely on cost of land, wage rates, yields per hectare and costs of cultivation and fertilisation. The structure of the palm, and the way in which the fruit bunch is presented on the tree, make it difficult to mechanise harvesting (see Section 11.5.6). Even though other processes are being mechanised rapidly in the Asian industry, it is likely that oil palms will always demand a relatively high labour input. This may lead to the progressive migration of the industry away from high-wage producers to countries that can offer the right environment with lower wages. This cannot occur very rapidly because the perennial palm requires large semi-permanent investments in land, roads and mills, and new developments are both costly and time demanding. However, the way in which new planting in Indonesia has expanded (Fig. 1.2) is a good example of this development process that must encourage others.

In Indonesia, there is now pressure to avoid deforestation and to restrict oil palm planting to already cleared land (Chapter 19). At some point, this must start to limit expansion, and Indonesia will probably also meet the problems of increasing wages. Rising prices for oil palm products may make higher wage rates more acceptable, though countries with a low-cost structure will always have an advantage. Currently, the third largest producer is Thailand (Table 1.4), where oil palm is primarily a smallholder crop (Table 1.9). However, many smallholders employ contractors for harvesting, so they are not immune from wage rises. South America has high wage rates, and it may be that most of its production will continue to be used internally. The next country with rising production for the international market is Papua New Guinea, although wage rates there are not particularly low. The Congo has had successful plantations in the past, but it may be some time before it is sufficiently politically stable that investors are prepared to move in. Ultimately, all countries with the equatorial climate are potential oil palm producers.

1.4.2.3 *Competition between products*

The comparative growth of the production of most of the major vegetable oils is shown in Table 1.2. Palm oil production overtook soya bean oil in 2004, and it seems that it will remain ahead in the foreseeable future. For soya bean, the main value of the product is in the press cake that is used for animal feed. The crushers are therefore able to sell the oil at low prices if the protein feed price is high, and in general, they have the advantages of a more diversified main market. Fry (2012) pointed out that the rate of expansion of soya bean will be driven by the expansion in demand for meal, rather than for vegetable oil. Biofuel and oleochemical uses have increased the demand for oil more rapidly than that for meal, so that palm has overtaken soya bean as the major oil (Table 1.2).

The great advantage of palm oil is that the yield of oil per hectare is much larger than that for any other major oil crop (Table 1.3), thus cutting the costs of land and operations per unit of product. Davidson (1993) neatly summarised the competitive situation of the oil palm industry: 'the oil palm is six to seven times more labour demanding than major competitors, but it can produce anything up to ten times more oil per unit area' (see also Murphy, 2009).

Palm oil's disadvantages are the high labour requirement and inflexibility: production of a perennial plant cannot be changed as rapidly as that of an annual farm crop. From 1 year to the next, a soya bean farmer can switch between soya bean and maize, depending on expected prices.

Higher yielding new oil palm material is becoming available, with over 10 t oil/ha in prospect (see Chapter 6). Other crops will of course increase their yields; annual crops can be improved by breeding faster than perennials, but it is hard to see any of them seriously challenging the oil palm in this respect. The competitive position depends on the relative costs of labour (Tan, 1988; Gan and Ho, 1994) and of land, but the oil palm is the most efficient oil-accumulating plant.

Mechanisation is given much attention later in this book (see Sections 11.2 and 11.5.8), because that is one aspect in which the oil palm lags behind the combine-harvested main oil crops. Stringfellow (2000) queried whether the technological changes that continue to sweep through most of the other oil crops may have missed the oil palm industry, arguing from the relative constancy of OER and yield levels that had persisted for nearly 20 years in Malaysia. In contrast, the yields per unit area of the arable oil crops had risen steadily. Table 1.3 shows that since then, yields of all four major oil crops have increased; sunflower and rapeseed yields have increased by more than palm oil, but soya bean, palm oil's most important competitor, shows a very similar increase to palm oil.

Increasing world demand almost certainly means that the global oil palm industry will remain successful and expanding, for as far ahead as world population continues to increase, probably until 2050 at the earliest (Corley, 2009a). However, there may be periods of crisis induced by low prices, and the competition between different palm oil producers may be intense. The palm oil industry cannot afford to be complacent during the occasional upswings in the price and needs to have strategies ready to meet periods of low prices (Basiron, 2000; Tayeb Dolmat and Tarmizi Mohamad, 2001).

1.4.3 Single-country developments: Asia

The world oil palm industry is very complex, and it is not possible to give a detailed discussion about the state of the industry in each individual country. This and the next two sections give notes on the more important producers: production of palm oil and palm kernels, planted areas and yields are listed in Table 1.4, and production and exports of palm oil since 2001 are given in Table 1.5. Palm kernel and kernel oil exports are given in Table 1.6. The main reason for the shrinkage of the trade in kernels (Table 1.6) is that these are now largely crushed in their country of origin, and kernel oil is exported (Table 1.9).

1.4.3.1 *Indonesia*

An area of 110,000 ha planted was achieved in 1940, but following World War II and the independence struggles, the Sumatran plantations were slowly brought back into good condition, and further planting was very slow. By 1956, the planted area had increased by only 15% over the pre-war area, and yields per hectare were low.

In the late 1960s, the tree crop area in Indonesia was organised into large estate groups (Perusahaan Negara Perkebunan, or PNPs) under public ownership. Seven

Table 1.3 Yields of major oil crops (t/ha of oil, from Oil World, 2012

	United States		Argentina		Brazil		EU		Malaysia		Indonesia		World		Increase (%)
	2001	2011	2001	2011	2001	2011	2001	2011	2001	2011	2001	2011	2001	2011	2001–11
Soya bean oil	0.46	0.53	0.48	0.48	0.51	0.56	0.59	0.54	–	–	–	–	0.42	0.46	9.5
Rapeseed oil	0.57	0.73	0.70	0.69	0.65	0.57	1.13	1.13	–	–	–	–	0.57	0.70	21.8
Sunflower oil	0.60	0.66	0.65	0.84	0.66	0.50	0.70	0.75	–	–	–	–	0.47	0.56	18.6
Palm oil	–	–	–	–	2.62	2.50	–	–	3.87	4.42	3.26	3.96	3.36	3.72	10.7
Palm kernel oil	–	–	–	–	0.29	0.34	–	–	0.50	0.50	0.33	0.42	0.41	0.42	2.4

Source: ISTA Mielke GmbH, Oil World Annual 2013 and Oil World Data Bank.
Note: Palm oil and kernel oil yields based on mature hectarage, not total area (Soya bean, rapeseed and sunflower seed yields converted to oil yield assuming 18.1%, 37.8% and 40% oil content, respectively)

Table 1.4 Palm oil and palm kernel production, mature area and yield, 2012

Country	Mature area (kha)	Palm oil production (kt/year)	Yield (t/ha.year)	Palm kernel oil production (kt/year)	Yield (t/ha.year)
Angola	–	48	–	8.3	–
Benin	29[a]	53	1.58	15.0	0.52
Cameroon	124	245	1.98	26.1	0.21
Côte d'Ivoire	265	420	1.58	42.3	0.16
Dem. Rep. of Congo	7[a]	14	2.00	2.5	0.36
Ghana	370[a]	420	1.14	47.3	0.13
Nigeria	457	940	2.06	111.1	0.24
Sierra Leone	–	57	–	–	–
Africa total	1,252	2,197	1.75	252.6	0.20
Costa Rica	63	260	4.13	23.0	0.36
Dominican Rep.	15[a]	45	3.00	5.0	0.33
Guatemala	62[a]	310	5.00	27.9	0.45
Honduras	110	395	3.59	42.1	0.38
Mexico	35[a]	75	2.14	8.2	0.23
Nicaragua	4[a]	12	3.00	1.4	0.35
Panama	–	32	–	–	–
Central America total	289	1,129	3.91	107.6	0.37
Brazil	113	310	2.74	39.2	0.35
Colombia	300	967	3.22	84.7	0.28
Ecuador	215	540	2.51	38.9	0.18
Peru	50[a]	130	2.60	19.8	0.40
Venezuela	35[a]	55	1.57	8.8	0.25
South America total	713	2,002	2.81	191.4	0.27
India	80	96	1.15	8.5	0.11
Indonesia	6,500	26,900	4.14	2919.2	0.45
Malaysia	4,360	18,785	4.31	2164.0	0.50
Papua New Guinea	143	530	3.71	44.3	0.31
Philippines	40[a]	98	2.45	11.0	0.28
Solomon Islands	15[a]	33	2.20	5.4	0.36
Thailand	645	1,600	2.48	148.7	0.23
Asia and Oceania total	11,783	48,042	4.07	5301.1	0.45
Other countries	–	295	–	71.0	–
Total	14,224	53,665	3.77	5923.6	0.42

Source: ISTA Mielke GmbH, Oil World Annual 2013 and Oil World Data Bank.
Note: Total area includes countries for which no individual figure is given. Palm grove areas are not included
[a] Area figures in Oil World Annual 2013 are for palm kernels; assumed same for palm oil.

of these held 90,000 ha in 1971 in Sumatra and another 36,000 ha was held by private companies. During the early 1970s, there were large capital injections by the World Bank and the Asian Development Bank into the PNPs, and by 1985, the planted area was over 500,000 ha (Taniputra *et al.*, 1988). Smallholder schemes also started, and Indonesia has supported its smallholder sector strongly, including guaranteed support prices for FFB supplied by smallholders. The distribution of the various forms of ownership of oil palms is given in Table 1.7. By 1991, the private estate sector was the largest, but the other forms were still substantial. Recently, much foreign capital has been invested in the Indonesian industry, a large fraction of it from Malaysia.

During and after the 1980s, the industry made great strides (Lubis *et al.*, 1993). The policy background favoured foreign investment during the 1990s (Zainal Abidin, 1998; Jacquemard and Jannot, 1999b). From 1980, the planted area increased fivefold in 11 years and over sixfold in the next 20 years (Table 1.7). This included moving into new areas such as Kalimantan

Table 1.5 Production and exports from palm oil-producing countries (thousand tonnes/annum)

(a) Africa

Country		2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Angola	Prodn	49	50	49	51	53	54	55	46	55	57	50	48	
	Export	–	–	8	4	8	6	12	20	13	14	25	24	
Benin	Prodn	36	32	32	34	36	38	40	42	44	46	46	53	
	Export	16	15	32	32	24	160	198	210	215	209	144	165	
Cameroon	Prodn	138	144	142	146	154	160	216	226	238	250	254	245	
	Export	11	4	8	24	21	21	12	10	6	4	5	10	
Dem. Rep. of Congo	Prodn	96	97	98	99	100	102	16	7	8	10	12	14	
	Export	–	–	–	–	–	0	0	0	0	0	0	0	
Ghana	Prodn	108	108	108	114	117	121	337	379	421	401	420	420	
	Export	19	35	65	65	81	87	80	85	60	70	82	100	
Côte d'Ivoire	Prodn	205	240	240	270	320	330	289	302	358	360	410	420	
	Export	74	65	78	109	122	109	89	96	191	201	254	278	255
Nigeria	Prodn	770	775	785	790	800	815	825	840	870	885	930	940	960
	Export	8	5	10	5	10	9	15	25	10	13	12	18	
Sierra Leone	Prodn	42	43	44	44	44	45	46	48	50	52	54	57	
	Export	–	–	–	–	–	–	–	–	–	–	–	–	

(b) Central and South America

Country		2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Costa Rica	Prodn	150	145	155	180	210	198	200	198	206	227	242	260	
	Export	73	80	106	123	147	128	138	131	135	142	173	206	
Dominican Republic	Prodn	26	25	27	28	29	31	32	35	38	41	44	45	
	Export	–	–	–	–	–	–	–	–	–	–	–	–	
Guatemala	Prodn	70	86	85	87	92	125	130	185	180	182	248	310	
	Export	49	58	58	67	64	109	110	160	148	154	217	268	340
Honduras	Prodn	122	126	140	170	180	195	265	278	280	275	320	395	
	Export	56	57	110	108	120	132	153	180	168	156	206	269	310
Mexico	Prodn	35	38	42	41	43	50	57	62	65	68	73	75	
	Export	–	–	–	–	–	0	0	0	0	0	0	0	
Nicaragua	Prodn	8	8	8	8	9	9	9	10	11	13	13	12	
	Export	–	–	–	–	–	–	1	7	14	14	20	16	
Panama	Prodn	12	12	12	13	13	14	14	15	16	20	28	32	
	Export	6	6	4	6	7	8	3	3	4	7	17	19	

(*Continued*)

Table 1.5 (*Continued*)

(b) Central and South America

Country		2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Brazil	Prodn	110	118	129	142	160	170	190	210	240	250	270	310	
	Export	29	7	1	14	45	25	2	4	25	16	46	65	
Colombia	Prodn	548	528	527	632	661	711	733	778	802	753	941	967	1042
	Export	90	85	115	214	224	214	316	310	214	90	159	180	210
Ecuador	Prodn	228	238	262	279	319	345	396	418	429	380	495	540	500
	Export	32	32	44	57	102	113	172	171	181	146	250	276	210
Peru	Prodn	37	30	27	28	29	32	34	59	65	70	87	130	
	Export	6	7	6	0	0	0	0	0	0	0	0	0	
Venezuela	Prodn	74	55	41	61	63	65	70	89	84	75	60	55	
	Export	–	–	–	–	–	0	0	0	0	0	0	0	

(c) Asia and Oceania

Country		2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
India	Prodn	29	34	41	47	47	49	54	70	80	83	92	96	
	Export	27	6	9	19	8	14	na	15	18	17	31	40	
Indonesia	Prodn	8,080	9,370	10,600	12,380	14,100	16,080	17,420	19,400	21,200	22,300	24,300	26,900	28,300
	Export	4,940	6,490	7,370	8,996	10,436	12,540	12,650	14,612	16,938	16,450	17,070	19,094	20,970
Malaysia	Prodn	11,804	11,908	13,354	13,974	14,961	15,881	15,823	17,735	17,566	16,993	18,912	18,785	19,215
	Export	10,733	10,886	12,216	12,582	13,438	14,404	13,747	15,412	15,881	16,664	17,993	17,575	18,122
Philippines	Prodn	55	56	59	60	61	68	75	82	90	92	87	98	
	Export	5	12	12	0	1	1	8	1	2	8	7	27	
Thailand	Prodn	625	600	690	735	700	850	1,050	1,300	1,310	1,380	1,530	1,600	1,910
	Export	180	100	162	166	116	232	289	373	133	133	391	304	560
Papua New Guinea	Prodn	329	316	325	345	310	365	382	465	478	500	560	530	
	Export	328	324	327	339	295	363	368	446	470	486	572	540	545
Solomon Islands	Prodn	36	34	33	34	35	36	37	22	25	29	32	33	
	Export	35	32	32	32	33	34	35	22	25	29	32	33	
Other countries	Prodn	177	184	187	194	201	213	229	249	268	279	282	295	
(worldwide)	Export	64	56	43	43	43	49	68	100	110	104	110	116	
World total	Prodn	23,999	25,400	28,242	30,986	33,847	37,202	39,024	43,550	45,477	46,071	50,792	53,665	56,087
	Export	16,781	18,362	20,808	23,005	25,345	28,758	28,466	33,831	36,178	37,144	38,657	41,363	43,603

Source: ISTA Mielke GmbH, Oil World Annual 2013 and Oil World Data Bank.

Table 1.6 Exports of palm kernels oil from selected countries

(a) Palm kernels (thousand tonnes/year)

Country	1909–1913	1924–1931	1932–1939	1940–1945	1946–1953	1954–1961	1962–1969	1970–1977	1978–1981	1982–1985	1986–1989	1990–1993	1994–1997	1998–2001	2002	2007–2009	2010–2012
Angola	6	7	6	7	12	10	15	6	–	–	–	–	–	–	–	–	–
Benin	35	40	73	49	67	52	24	4	–	–	–	–	–	–	–	–	–
Cameroon	–	–	–	–	–	–	–	–	–	10	2	2	2	0	–	–	–
Congo	7	72	72	46	77	39	4	–	–	–	–	–	–	–	–	–	–
Guinea-Bissau	–	–	–	–	–	–	–	–	–	4	6	3	1	2	–	–	–
Indonesia	–	2	34	8	22	37	36	38	24	11	1	0	1	0	6	30	7
Ivory Coast	6	12	73	49	67	52	11	25	9	7	3	6	3	1	5	4	2
Liberia	–	–	–	4	14	12	12	4	–	–	–	–	–	–	–	–	–
Malaysia	–	–	6	3	8	18	26	22	26	45	0	–	–	–	–	–	–
Nigeria	175	260	318	319	360	439	313	199	90	41	83	20	4	8	6	4	5
Papua New Guinea	–	–	–	–	–	–	–	–	–	–	14	21	22	3	0	11	26
Sierra Leone	48	67	74	43	69	59	27	35	10	10	–	–	–	–	–	–	–

(b) Palm kernel oil (thousand tonnes/year)

Country	1940–1945	1946–1953	1954–1961	1962–1969	1970–1977	1978–1981	1982–1985	1986–1989	1990–1993	1994–1997	1998–2001	2002	2007–2009	2010–2012
Benin	–	–	–	12	16	8	8	5	2	4	4	5	7	7
Colombia	–	–	–	–	–	–	–	–	0	4	14	17	33	43
Costa Rica	–	–	–	–	–	–	–	–	2	6	6	10	12	14
Dem. Rep. of Congo	2	14	48	41	36	18	15	8	3	4	2	1	1	0
Indonesia	–	–	–	–	8	4	26	96	198	374	543	738	1478	1631
Ivory Coast	–	–	–	–	2	9	14	14	16	14	16	6	15	17
Malaysia	–	–	–	–	69	199	380	564	577	451	545	660	1075	1141
Nigeria	–	–	–	17	28	40	24	6	13	22	3	0	2	5
PNG	–	–	–	–	–	–	–	4	8	14	28	35	35	40
Philippines	–	–	–	–	–	–	–	1	6	2	2	2	3	3
Thailand	–	–	–	–	–	–	–	0	0	0	27	60	88	73
Other countries														86

Source: ISTA Mielke GmbH, Oil World Annual 2013 and Oil World Data Bank.

Table 1.7 The development of the Indonesian oil palm area (thousand ha)

Year	Government	Private	Smallholders	Total
1969	84.1	34.9	–	119.0
1975	120.9	67.9	1.3	190.1
1979	176.4	81.4	3.1	260.9
1980	199.5	88.8	6.2	294.5
1991	376.1	552.6	347.5	1276.2
1994	411.4	796.0	585.1	1792.5
1996	441.2	1028.4	757.3	2226.8
1998	489.8	1494.5	892.0	2876.3
2000	588.1	2403.2	1166.8	4158.1
2002	631.6	2627.1	1808.4	5067.1
2004	675.0	2821.7	2220.3	5717.0
2006	692.2	3056.2	2536.5	6285.0
2008	626.7	3825.1	2881.9	7333.7
2010	658.4	4374.4	3077.6	8110.4

Source: After Pamin (1998), BPS-Statistics and Directorate General of Estates, Indonesia.

and Sulawesi. Domestic consumption of palm oil increased, reaching 60% of oil production in 1997, but with the rapid increase in production since then, over 70% is now exported (Table 1.5).

The industry suffered setbacks from the financial crisis in 1998 and the political instability that followed it, but in the last decade, the mature area has doubled to 6.5 Mha in 2012 (Oil World, 2013). The haste and excitement engendered by the oil palm boom occasionally resulted in poor planning, and it appears that the practical needs for suitable soils and efficient palm planting were often ignored in favour of financial issues (Jacquemard and Jannot, 1999a). The outcome of this turbulent period, when the El Niño weather perturbations and forest fires (Sargeant, 2001) also caused much concern and low yields, seems to have been largely overcome. Indonesia's massive resources of land and labour suggest that it will remain the predominant world producer in the medium term.

A major consideration in the past few years has been the growing international protest at the felling of forest for development. The oil palm expansion has been one, though not the largest, factor in the damage done to Indonesia's forests in recent decades (Casson, 2000; Jacquemard and Jannot, 1999b) (see Chapter 19). It is essential that better control be exerted over the further development of forest and peat lands (Sargeant, 2001). Casson (2000) noted that some companies got concessions in Kalimantan and Irian Jaya ostensibly for oil palm development but mainly to get access to timber. They were therefore only interested in land carrying good forest (called 'production forest') and would not develop degraded land.

Casson (2000) and others have recommended that development be directed to degraded land rather than to prime 'production forest'. It has been shown that areas overgrown by lalang (*Imperata cylindrica*) after food cropping can be converted into productive oil palm plantations, which is desirable in both environmental and economic terms (Zulnerlin and Fatah Ibrahim, 1999; Rötheli, 2008; Fairhurst and McLaughlin, 2009).

1.4.3.2 *Malaysia*

Rehabilitation after World War II was more rapid than in Indonesia, and by 1947, the industry was already in full operation. Following the introduction of the *tenera*, expansion was rapid in the 1960s, often on land that had earlier carried rubber or coconuts. The prospects of higher yields and profits with oil palms and the advantages of diversification were recognised, but areas of primary forest were also used. A total of nearly 1 Mha was reached in 1980 (Fig. 1.2), and the Malaysian industry had become a major supporter of that country's economy. Ownership of the plantations was originally in the hands of expatriates, mostly British companies, but almost all were later bought out by Malaysian interests.

Most of the planting in forested areas was done by federal and state agencies including government-sponsored settlement schemes (see Section 1.5.3). Estate planting tended to be more on old estate land, where rubber was steadily replaced by oil palms. The infrastructure of the industry was greatly expanded, with the aim of adding value to exports, and by 1980, there were 147 plantation oil mills. Local refineries were set up, and 42 refineries were processing 9000 t of oil per day (Wood and Beattie, 1981). This downstream movement in the industry has since extended to fractionation (Section 16.3.3), and in 2011, crude palm oil (CPO) made up only 20% of exports (www.mpob.gov.my). An oleochemical industry has also developed, with over 2 Mt exported in 2011.

The oil extraction mills initially caused a major river pollution problem, and the industry had to develop reliable methods of effluent disposal (Ma, 1999a). Another environmental problem is that some steep sites have suffered erosion, particularly where forests were first logged over before development as plantations. The increasing use of marginal land, particularly steep land, may be a cause of problems in the future, especially as field mechanisation becomes more established (see Chapters 9 and 11). Environmental and other aspects of plantation operations are now tightly regulated in Malaysia. Gan (2007) listed over 60 Acts of Parliament governing the industry, together with additional legislation by individual states.

A labour shortage has grown during the last three decades, owing to the many opportunities for jobs in newly developing industry. It is difficult for plantations to meet the wage rates now available in other industries, and they have become dangerously dependent on short-term immigrants from Indonesia, Bangladesh, the Philippines and elsewhere.

Following the collapse of a cocoa boom and establishment of the benefits of weevil pollination (Sections 2.2.2.5 and 5.5.3.1), interest shifted to East Malaysia in the 1990s. By 2010, there were 1.4 Mha in Sabah and 0.9 Mha in Sarawak, 48% of the total area in Malaysia (www.mpob.gov.my). The soil in Sabah is fertile, and the best plantings between 1985 and 1989 gave peak yields of 40 t/ha FFB (Goh *et al.*, 1994b).

Difficulty in finding sites for further expansion and suitable labour in Malaysia has led the Malaysian industry to look for investment opportunities in other countries (Guerts, 2000). Several Malaysian companies have joint ventures in Indonesia. Kuruvilla and Mohandas (1997) outlined many of the problems of setting up a large-scale (12,000 ha) plantation in central Kalimantan, which demanded co-ordinated action by many players. There is investment in Papua New Guinea, Brazil, the Philippines, Colombia, Guyana and Honduras and in African countries such as Liberia, the Congo, Nigeria and Ghana.

At present, the industry is extremely successful, and Davidson (1993) estimated that the Unilever plantations in Malaysia had increased yields per hectare by 315% and labour productivity by 419% over the period 1951–1991. The largest improvement in productivity was obtained in the oil palm mill, rather than in the field. According to Mohd Noor *et al.* (2005), the real cost of production continued to fall between 1994 and 2003, despite rising costs of harvesting and fruit collection.

This improvement in yields seemed to have slowed since the 1980s, and there was a period up to about 2000 when the oil extraction ratio (OER) and yield of Malaysian oil palms appeared to make little or no improvement (Tinker, 2000a). Over several years, the largest oil yields in very good conditions were 7 or 8 t/ha, but the national average has seldom gone above 4 t/ha (Fig. 1.5a). In a highly developed agricultural industry, it is reasonable to expect a national mean yield of about half that of the most outstanding fields. The potential 'yield gap' was the subject of discussion in 2000 (Tinker, 2000a; Jalani *et al.*, 2001). Figure 1.5b shows a clear decline in OER from 1989 to around 1995, followed by a rise from 2000 to 2011. After the introduction of the pollinating weevil in 1983, there was a step change in kernel extraction from improved fruit set, which has been maintained since then (Fig. 1.5c). This was not related to the decrease in OER, which did not occur until several years later. There has been some improvement over the last decade. Mean FFB yield has increased slightly from 18.5 t/ha in the 1990s to 19.2 t/ha in 2007–2011 (Fig. 1.5d). Oil extraction ratio has improved since 2000 but in 2011 was only back to the 1975–1980 level of 20.4% and still below the Indonesian average of about 22%. As a result, oil yield has improved from 3.5 to 3.9 t/ha. Yields in Sabah are above the national average, with FFB of 21.8 t/ha, OER of 21.1% and oil yields of 4.6 t/ha (means for 2007–2011, from www.mpob.gov.my).

1.4.3.3 *Other Asian countries*

The most important new palm oil producers are Thailand and Papua New Guinea. The palm oil industry in Thailand is growing rapidly, with a planted area up from 110,000 ha in 1988 to 645,000 ha in 2012, producing 1.6 Mt of palm oil (Table 1.4). About half of this was used for edible purposes, and in 2011, almost 400,000 t was converted to biodiesel, with the balance being exported. Eighty per cent of production is by smallholders with less than 8 ha of palms, and almost all expansion has been by replacing other crops, particularly rubber. The climate is less favourable than that of Peninsular Malaysia, so yield per hectare is lower (Table 1.4) and costs are probably higher. Where water supplies allow, irrigation is profitable (Palat *et al.*, 2000; 2008; Corley and Palat, 2013).

Papua New Guinea is now a significant producer, with an output of 530,000 t oil in 2012, all of which was exported (Table 1.5). The climate and soils are very suitable, although the rainfall is very high in some areas, with around 5000 mm rain/year. The country also has a smallholders' development scheme (see Sections 1.5.3), which has been highly effective. There has been a strong emphasis on sustainability in recent years, and an important development was the export of certified sustainable and 'identity preserved' oil to Europe starting in 2011 (Vis *et al.*, 2012). The oil palm area is expanding, but Nelson *et al.* (2013) showed that there have been many instances of companies clearing forest ostensibly for plantations, but actually for the timber, with no intention of planting palms.

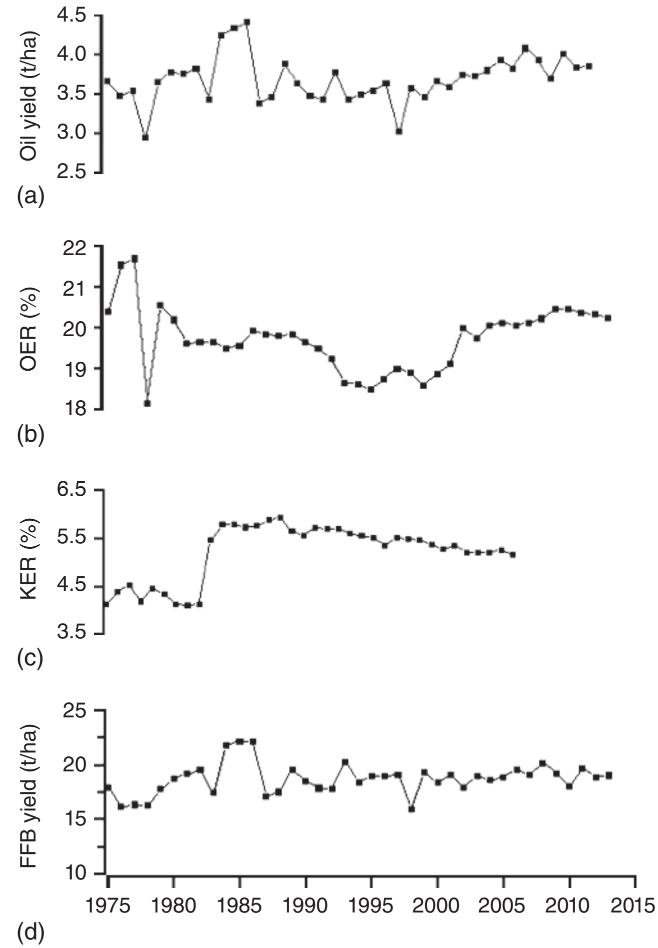

Fig. 1.5 (a) Annual mean oil yields, Malaysia (based on total area, including immature). (b) Annual mean oil extraction ratio. (c) Annual mean kernel extraction ratio. (d) Annual mean FFB yield (data from Malaysian Palm Oil Board – www.mpob.gov.my).

There is developing interest in growing oil palms in India, probably encouraged by the very large imports in recent years. According to Rethinam (1998), oil palms were imported to the Calcutta botanic gardens in 1848 (at the same time as to Bogor – Section 1.3.2), but in most of India, the climate is not favourable and the crop did not develop until the late twentieth century.

A good summary by Kochu Babu (2005) brought the story up to date. The first planting was in 1971 on the mainland in Andhra Pradesh, and in 1973, on the Nicobar and Andaman islands, which have a rather wetter climate. Kallarackal *et al*. (2004) studied the water needs of the palm when grown in areas with a marked dry season, none of which could carry a purely rain-fed crop of oil palms. These regions (Andhra Pradesh, Karnataka and Maharashtra) have substantial reserves of groundwater so irrigation in the dry season is possible (Carr, 2011), but yields remain low (Table 1.4), and it is not clear how large a part of the present planted area of 80,000 ha is presently irrigated.

1.4.4 Africa

Africa is the original home of the oil palm, but the industry there has been through a very difficult period. There are now signs of development, by local smallholders/grove owners, by estate planting and national and international schemes. The groves are diminishing and are being felled in some states to make way for plantations or other developments. There is considerable planting extant or planned by international or other-national bodies (Minal and Mokmin

Bahari, 2011). So long as palm oil prices remain high, these projects should be profitable, and there is a large local demand which is at present met by imports from the Far East. Palm oil-producing countries alone imported over 1.1 Mt in 2012, and sub-Saharan Africa has net imports of between 3 and 4 Mt/year (Oil World, 2013).

Production costs are much higher in Africa than in Malaysia and Indonesia. Corley (2012a) stated that costs per hectare were quite similar in Indonesia and several African countries, but yields were lower because of climatic limitations in Africa, and costs per tonne were thus much higher. Byerlee *et al*. (in press) quoted costs of $364/t and $300/t for Malaysia and Indonesia respectively, while according to Gold *et al*. (2012), costs in Nigeria range from $540 to $830/t. Hawkins (2012) quoted a cost of $488/t for West Africa, including cost of finance, depreciation and overheads. His costs for Indonesia were much higher than the $200/t quoted by Corley (2012a) but at $405/t still below African costs. Even with shipping costs of about $85/t added, it can be cheaper to import palm oil from Indonesia than to produce it in Africa.

1.4.4.1 *Nigeria*

The early development of the industry in Nigeria is described in Section 1.2.3. Nigeria lost its position as the largest producer of palm oil to the Congo in 1962; now, its palm oil output is only about 5% of the Malaysian output (Table 1.4), although Nigerian production may be under-recorded. All the oil produced is consumed within the country, and it seems likely that the Nigerian industry will remain solely a supplier to the internal market. Over 850,000 t of oil were imported to meet internal demand in 2012 (Table 1.11), and according to Oil World (2012), there are probably additional illegal imports. Kernel production is around 240,000 t (Table 1.4), with negligible exports (Table 1.6).

There are four reasons for this change from exporter to importer. First, the Nigerian population grew rapidly, and its demand for palm oil grew even more as diets improved. Secondly, the price offered to the farmer for palm oil by the marketing boards was for long periods very low, sometimes little more than half the export price (Ataga, 1986; Hartley, 1988). This was equivalent to a heavy tax on the farmers, and it discouraged production. Thirdly, internal strife and government mismanagement were serious impediments to the industry. Finally, because of the low prices, Nigeria fell woefully behind the Asian producers in developing modern plantations and techniques (see Section 1.3.1). Even now, the total mature planted area is only around 460,000 ha (Oil World, 2013), but this may not include all smallholders. The area of palm groves is uncertain; according to Omoti (2004), there were 2.1 Mha, but Gold *et al*. (2012) stated that the area is decreasing and quoted a figure of 1.7 Mha from a later report by Omoti (2009). According to Omoti (2004, 2009), the groves gave an average yield of about 0.3 t oil/ha.year; 95,000 ha of estates yielded an average of 1.9 t/ha.year, and 150,000 ha of smallholdings yielded 1 t/ha.year. By 2009, Omoti gave a figure of 204,000 ha for smallholdings.

Before this period of decline, there was considerable improvement in the quality of the oil produced, in terms of free fatty acid (FFA) content. This had always been very high, and some ethnic groups in West Africa actually preferred this. However, with a sharp price differential for quality, almost all Nigerian oil reached a grade of 3.5% FFA by 1963.

Ugbah and Nwawe (2008) stated that growing of oil palms in Nigeria was increasing. Most of the action seems to have been with smallholders (Vermeulen and Goad, 2006; Ugbah and Nwawe, 2008). A target of planting 250,000 ha per annum has been published.

Many development schemes, some with external funding by international bodies (Minal and Mokmin Bahari, 2011), have been launched for state-owned plantations and for smallholder developments over the past few decades, but few of these have met their targets. It has been difficult for private estates to be set up because of the complex land tenure systems, the low returns and the difficulties of management. The national state schemes began to be privatised after the 1986 reforms, and serious efforts were made to get improved planting material to the farmers. Omereji (1995) recommended that the main emphasis in expansion should be placed on the smallholder sector because of the poor results of estate developments in the past, but this seems doubtful, as several efficient estates did operate in the past.

Traditional methods of extraction (see Section 15.4.2) are still being used to a significant extent (Ilechie and Omoti, 2001), but there is interest in producing small semi-mechanised systems of extraction. NIFOR has developed a small-scale processing equipment in various sizes that meets the requirements of small estates, smallholders and farmers of wild palms and can be constructed largely from local components (Section 15.4.4).

1.4.4.2 *Democratic Republic of Congo*

By 1959, the Congo had made great advances, with 147,000 ha in industrial plantations and nearly 100,000 ha planted by local farmers. Production in that year was 240,000 t, of which three-quarters was exported (Hartley, 1988). The best yields were 3 t oil/ha, which was outstanding for Africa and good even for the Malaysian industry at that time. This high standard was a result of the excellent work of the Institut National pour l'Étude Agronomique du Congo Belge (INEAC), whose activity declined greatly in later years. As in Nigeria, the increasing local population consumed a steadily greater amount of the oil produced, and political unrest and failure diminished production. Cheyns and Rafflegeau (2005) quoted palm oil production of 191,000 t in 2004, but output was estimated at only 14,000 t in 2012, and there were no exports (Oil World, 2013).

1.4.4.3 *The Ivory Coast*

This country has benefited from the work of the French organisation Institut de Recherches pour les Huiles et Oléagineux (IRHO), now reorganised as part of Centre de Cooperation Internationale en Recherche Agronomique pour le Développement (CIRAD). The country has a moderately suitable climate but with the typical West African dry season. The development of modern plantations started in the 1960s (Anon., 1983) and was operated by the Société d'État pour le Développement du Palmier à Huile (Sodepalm) and by Palmindustrie, in a mode that involved local people as both owners and workers. Both of these organisations were eventually privatised. There are extensive smallholdings, responsible for 60% of national FFB production in 2001 (Cheyns and Rafflegeau, 2005). In 2012, there was a total of 265,000 ha (Table 1.4), producing 420,000 t of oil, of which more than half was exported (Table 1.5).

Cheyns and Rafflegeau (2005) described plantings on a 15-year cycle, with palm wine as the main product, palm oil being secondary.

1.4.4.4 *The Cameroons*

The Cameroon Development Corporation planted a considerable area in the Cameroons, as did Unilever in West Cameroon (Courade, 1978) and Société Camerounaise de Palmeraies (SOCAPALM) in East Cameroon. Apart from direct planting, an outgrowers' scheme was started by SOCAPALM (van der Belt, 1981). Current production is about 250,000 t, almost of all of which is consumed within the country (Table 1.5). The rainfall gradient across Cameroon is not as sharp as in the more westerly African states, so the climate is more suitable for palms. Detailed studies of the Cameroons have been published by Bakoumé and collaborators (Bakoumé and Mahbob, 2005; Bakoumé *et al.*, 2006a). The Cameroons has semi-natural groves, as in the rest of West Africa, and many smallholders, but a mature area of only 120,000 ha (Table 1.4) in some 25 Mha of potential interest. The organised plantation companies have not expanded in recent years, but smallholders, with more than half the planted area (Table 1.9), are often highly motivated. Expansion of the crop is possible, but technical assistance and improved capacity of palm oil mills are essential.

1.4.4.5 *Other West African countries*

Palm oil and kernels are produced in several other West African countries. Benin has a very marginal climate for oil palms, with a well-defined and intense dry season and relatively low rainfall. Interest in oil palms first arose because of the extensive palm groves in the south of the country (Hartley, 1988). The yield levels are low, and despite attempts to build up a plantation industry, the oil output is very small. In recent years, Benin has become a large importer of oil, which is then re-exported (Table 1.5; Oil World, 2012), probably to Nigeria (Minal and Mokmin Bahari, 2011). In 2010, exports were over 200,000 t, although local production was less than 50,000 t.

Ghana has 370,000 ha of palms; there are several established plantations with associated smallholder schemes, but smallholders have 90% of the total planted area (Hawkins, 2012). Production in 2012 was 420,000 t, of which about 100,000 t were exported (Table 1.5).

Other countries in West Africa such as Sierra Leone and Liberia produce small amount but require imports to satisfy their needs. There is at present some foreign investment in developing oil palm plantations and rehabilitating older plantings, and some of these projects may be successful.

1.4.5 America

South and Central America are considered to be prime areas for oil palm expansion (Anon., 1999) (Table 1.8). However, several diseases that are not encountered elsewhere in the world can be very serious in the Americas (Gomez *et al.*, 1996) (see Chapter 13). *E. oleifera* × *E. guineensis* hybrids have been planted in some countries, as these seem resistant to the diseases (Chapters 6 and 13).

Development is proceeding steadily, without the massive increases seen in Malaysia and Indonesia, but

Table 1.8 Oil palm structure in South America, in thousand hectares

Country	Planted		Increase (%)	Potential
	2006	2013		
Bolivia	0	–	–	120
Brazil	77.9	194.6	150	30,000
Colombia	303.7	475.8	57	1,750
Costa Rica	48.4	76.0	57	90
Dominican Republic	8.3	11.4	37	15
Ecuador	212.8	295.6	39	340
Guatemala	45.6	129.5	184	100
Guyana	1.1	–	–	50
Honduras	84.5	136.4	61	282
Mexico	24.1	90.4	275	200
Nicaragua	10.9	22.4	106	150
Panama	6.8	19.5	187	20
Peru	18.7	50.0	167	2,250
Venezuela	49.5	45.5	−8	125
Surinam	1.7	–	–	10
Total	**892.0**	**1547.1**	**73**	**35,502**

Source: ASD, Costa Rica (2007), and R. Escobar and F. Peralta, pers. comm. (2014).

there are now over 1.5 Mha in Latin America, and the attendance of 1700 people at an oil palm conference in Colombia in 2012 showed the level of interest in the crop.

1.4.5.1 *Brazil*

Brazil has the largest potential area that could be used for oil palms (Table 1.8), as the whole of the Amazon basin has an equatorial climate and is or was covered by rainforest (Ooi *et al*., 1982). There has been discussion about whether very extensive clearance of the Amazon forest, as has occurred in recent decades, could lead to a substantial change in the local climate (Tinker *et al*., 1996). There is some evidence that a change from forest to grassland or other low-growing crops might cause such a change, because it alters evapotranspiration. General considerations suggest that the climatic conditions with mature palms would be much more like those with high forest than with grassland or arable agriculture, which is the objective of much clearing. Clearance followed by establishment of oil palm plantations is probably one of the safest ways of developing this large area, if it is to be developed. Progress has been slow; in 2012, Brazil produced 310,000 t of oil, from 110,000 mature ha, although plans for increasing production have been made over a number of years (e.g. Nascimento *et al*., 1982). Pinheiro do Prado and Block (2012) mentioned a target of 1 Mha by 2014, all to be planted on degraded land or pasture, and quoted a study by Embrapa showing that 58 Mha were suitable for oil palm. They stated that 'Few economic options [other than oil palm cultivation] offer guaranteed permanent income for the Amazon population without environmental destruction'. Villela *et al*. (2014) quoted a government report showing that there were 29 Mha of deforested land in the 'Legal Amazon' area suitable for oil palm, but Lambin *et al*. (2013) noted that labour supply would be a major constraint and that only 7–12 Mha could realistically be considered.

1.4.5.2 *Colombia*

Colombia is the largest producer in South America, with a total area of 404,000 ha in 2010 (Fedepalma, 2011) and a further 65,000 ha planted by 2013 (Table 1.8). The plantations are widely spread over its regions; the largest area is in the Llanos Orientales in the eastern part of the country, followed by the north and central zones and a smaller area on the Pacific coast (Fedepalma, 2011). The best yields are in the central zone. The industry was set back for many years by serious internal unrest, but at the time of writing, the security situation is much improved.

Current production is over 900,000 t (Table 1.4). Exports were over 300,000 t in 2007 and 2008 (Table 1.5) but have since diminished because of increasing local demand for biodiesel production; over 400,000 t were used for biodiesel in 2011 (L.E. Betancourt, pers. comm., 2012). The widespread occurrence of bud rot or fatal yellowing (Section 13.5.2) has probably slowed the rate of expansion, and there is much interest in hybrids between *E. guineensis* and *E. oleifera* (Sections 2.4 and 6.5.1.6), which appear to be resistant to fatal yellowing. By 2012, over 20,000 ha of hybrids had been planted in Colombia (I. Ochoa, pers. comm., 2013).

The estimate of 1.8 Mha of potential oil palm land for Colombia (Table 1.8) appears very conservative. Corley (2009a) noted that most plantations in Colombia have replaced grassland and that there are over 40 Mha of permanent pasture in the country, though not all will have a suitable climate.

1.4.5.3 *Costa Rica*

Development has been steady; there were 30,000 ha of plantations in 1996 (Umaña, 1998), increasing to 76,000 ha in 2013, producing 260,000 t of palm oil. The areas of oil palm production are mainly on the alluvial plains on the Pacific coast, in the Quepos and Coto regions, where the soils are fertile and suitable for the oil palm, though the rainfall is very high. Despite its relatively small area, the industry in Costa Rica has a high profile because of the ASD research programme and in particular the production and worldwide sale of 30 M oil palm seeds per year (Kushairi and Rajanaidu, 2009).

1.4.5.4 *Ecuador*

Early in the 1980s, there were great expectations for oil palm development in the Oriente, but later, the outbreak of bud rot or fatal yellowing disease prevented further expansion, and the planted area has remained at about 15,000 ha. In the north-west region, plantations have increased greatly to a total of 190,000 ha in 2005 and nearly 300,000 ha in 2013 (Table 1.8). Yields are lower than in Colombia (Table 1.4).

1.4.5.5 *Other South and Central American countries*

The oil palm was originally introduced to Honduras in 1927, but did not develop widely until the 1950s and 1960s. The oil palm industry is now growing steadily, and Honduras is one of the larger growers in Latin America, with nearly 140,000 ha in 2013 (Table 1.8).

Several other countries have the necessary climate in South and Central America, and nearly all these have some oil palm plantings (Tables 1.5 and 1.8). Guatemala has 130,000 ha, with average yields from the mature area of over 4 t/ha. Venezuela had 22,000 ha of palms planted by 1996, producing 43,000 t which was used within the country, meeting 13% of total needs for fats and oils (Carrero, 1998). This had increased to 50,000 ha in 2006 but reduced to 45,000 ha in 2013; in 2011, only 55,000 t of oil were produced. Peru has large territories in the Amazon plain, but only about 50,000 ha planted, producing 130,000 t.

Expansion in Mexico is very rapid, with 90,000 ha in 2013, of which 32,000 ha were immature. In 2011, 75,000 t of oil were produced.

1.5 DEVELOPMENT METHODS

1.5.1 Main mechanisms of oil palm development

The first distinction lies between wild or semi-wild and planted palms. The palm groves of West and Central Africa provided the raw material to start a major world industry, with little prior investment. It allowed the markets and applications for use of palm products to be tested and developed, and the growing markets for palm oil during the nineteenth century led to the development of the modern plantation industry. Demand grew with the wealth of the developed countries, and it became logical to cultivate the oil palm leaving little economic place for the wild or semi-wild plant. The decline of the groves was therefore a measure of the growing maturity of the industry.

1.5.2 Plantations

The major distinction in development is between plantations working at the 1000 ha level or above and farmers' plots of a few hectares, farmed alone or in small groups. Apart from their better planting material, plantations have always had advantages over farmers' plots in the production of large amounts of commodity materials, because they are based on tight managerial control of routine tasks carried out efficiently (Webster, 1983). There may be an advantage for those smallholder crops that require careful and detailed attention, such as rubber or cocoa, where smallholders may achieve higher yields because of their personal attention. However, there is nothing of this nature in the oil palm, where maintenance and harvesting activities are usually physically demanding but basically fairly simple procedures. Regular fertilising, maintenance and above all harvesting are essential to produce high yields and high quality, and this is suited to the plantation system. In addition, there is the essential need for a mill to extract the oil and kernels from the bunches, and a plantation and mill can be designed to work together.

A tendency to lean towards either estates or smallholders seems to have been avoided in South and Central America, and instead, there have been more privately owned medium-sized holdings with small locally designed mills. In Colombia, 47% of mills in 2010 had a capacity of less than 15 t FFB/h, and the average was 21 t/h (Fedepalma, 2011), compared to an average of about 33 t/h in Malaysia. These small estates have become progressively more successful, perhaps questioning the view that oil palm plantations give great economies of scale.

1.5.3 Smallholders

Despite the emphasis on the establishment of plantations in Asia, smallholders have operated from an early time in the industry and play a significant part today.

Table 1.9 Area of smallholdings (including government schemes) in some producing countries

Country	Year	Smallholder area (ha)	Smallholders as % total
Malaysia	2011	1,962,000	40
Indonesia	2010	3,078,000	38
Thailand	2011	590,000	80
Papua New Guinea	2010	54,800	40
Nigeria	2003	260,000	61
Ghana	2012	300,000	89
Cameroons	2012	135,000	71
Ivory Coast	2012	160,000	80

Sources: mpob.gov.my; Omoti (2004); Hawkins (2012); I. Orrel, pers. comm. (2012); J.H. Clendon, pers. comm. (2012); Table 1.7.

Table 1.9 shows the proportion of smallholdings in some producing countries. Vermeulen and Goad (2006) distinguished smallholders supported by the government or a private sector organisation, independent smallholders, collective landowner schemes where land is rented out to grow oil palm and landowner mini-estates. They showed that smallholder yields were lower than estate yields, with 'scheme' smallholders outyielding independent smallholders. In both Malaysia and Indonesia, scheme smallholders achieved 90% of estate yields, but independents averaged 79% in Malaysia and only 57% in Indonesia. In PNG, smallholders, most of whom are in schemes, averaged only 68% of estate yields (I. Orrell, pers. comm., 2011). In the Ivory Coast, smallholder yields were 72% of estate yields, and in Cameroons, 77% (Cheyns and Rafflegeau, 2005).

The most common problems were differences over land tenure, access to urgent capital needs, getting good technical or market information, striking a good balance between food security and the cash crop and coping with normal market (price) risks. In the Ivory Coast, a policy of promoting co-operatives has strengthened the smallholder sector (Cheyns and Rafflegeau, 2005).

A particular problem for smallholders is the extraction of the oil. If there are large mills as part of plantations nearby, the best solution is to sell fruit to the mill. If the smallholders themselves engage in oil extraction, then the smaller machinery that might be used is described in Section 15.4.4.

Although many farmers maintain their plots well, the average standard of efficiency and accuracy will almost always be below that of plantations, giving lower yield and quality. Quality of planting material may be very poor: a survey of smallholdings in Cameroons showed a ratio of 26 *dura*/52 *tenera*/22 *pisifera*, indicating that open-pollinated *tenera* seed had been used (Ngoko *et al*., 2004). The *pisiferas* may be felled for palm wine production. Irregular harvesting or delayed transport of fruit to the mill by a significant fraction of farmers will produce bulked oil of substandard quality.

There has always been pressure for oil palm cultivation by smallholders, partly from the would-be farmers seeking a better life, partly from politicians who see this as a desirable way of finding work for young men and building stable rural communities. This driving force is shown by a quotation from a Malayan government working party in 1955: 'there is a very real need for planned and co-ordinated development of land so as to ensure that economic development goes hand in hand with social development' (Shamsul Bahrin and Lee, 1988). From this sprang the Federal Land Development Authority (Felda), which is a good example of successful land settlement and development. The total areas of land developed in Malaysia by the state and private sectors up to 2001 are shown in Table 1.10. The schemes vary but Felda preferred a minimum size of 1800 ha for 400 families, that is, about 4 ha per family, plus residential and infrastructure areas. The maximum size was around 2600 ha for 600 families: above this the commuting distance became too large, and if families were dispersed, it became difficult to provide essential services such as schools. The more recent Felda schemes were larger, as increasing wealth allowed the purchase of motorcycles, giving workers greater mobility. The first Felda schemes were for rubber, but with oil palms, a central oil mill is also essential, so a reasonable area is 4000 ha. The basic facts that make a reasonably sized oil palm plantation efficient also make themselves felt in smallholder schemes, and thinking within Felda appeared to be in favour of still larger contiguous blocks of land for oil palms.

Felda land was held in co-operative ownership (Shamsul Bahrin and Lee, 1988, p. 53), so that all had a stake in the land, but individual parcels were not distributed until the settlers had shown their competence in cultivation. Later settlers were given title to their individual plots, and this system caused a feeling of ownership and responsibility in the settlers. Later, Felda adopted a share ownership system, in which settlers received wages for their work, shares in the whole enterprise equivalent to 4 ha and dividends on this. Ultimately, settlers were given their share certificates and titles to their house plot.

Table 1.10 Land development targets and achievements in Malaysia, by agency, 1971–2001 (hectares)

Programme	Second plan (1971–1975)		Third plan (1976–1980)		Fourth plan (1981–1985)		Total areas, 2001	
	Target	Achieved	Target	Achieved	Target	Achieved	All crops	Oil palm
Felda	121,408	161,900	202,347	206,819	161,600	161,600	804,000	641,810
FELCRA	40,470	23,576	20,235	27,134	41,100	31,100	175,300	115,320
RISDA	60,705	19,122	40,470	12,341	9,770	9,770	na	na
State	136,504	143,667	97,127	146,466	217,200	158,000	116,190	66,300
Independent smallholders	na	na	na	na	na	na	1,880,900	617,300
Joint venture/ private sector	90,045	55,502	44,516	64,545	100,000	57,100	2,240,800	2,058,000
Total	449,132	403,767	404,695	457,305	529,670	417,570		

Source: From Shamsul Bahrin and Lee (1988) and Ministry of Agriculture, Malaysia.
na, not available.

From about 1980 onwards, Felda extended its operations to Sabah, and in 1985, Felda schemes were producing 986,800 t of oil. By the early 1990s, rural poverty had diminished, and intake of new settlers stopped (www.perdana.org.my). In 2011, Felda had a total of 90,500 settlers on 723,000 ha of oil palms and 22,000 on 88,000 ha of other crops (Mohd Nor Kailany, 2011).

In 1996, Felda Holdings was established, with the aim of covering all aspects of the palm oil business. By 2010, Felda Holdings had over 50 subsidiaries, with all settlers receiving an annual dividend. In 2007, Felda Global Ventures was set up to operate as the commercial arm of Felda for overseas investments. Felda Global Ventures was floated as a public company on the Kuala Lumpur stock market in 2012, with a small proportion of shares reserved for settlers (though commentators differed in their views as to how generously settlers were treated).

Indonesia has also had a rapid expansion of smallholder schemes (see Table 1.7). The nucleus estate and smallholders or 'plasma' approach has been widely adopted. Under this system, a company develops and plants land, some of which forms the nucleus estate, while the remainder is allocated to smallholders or returned to them if the land was acquired from them initially. The smallholders sell their fruit to the central mill and pay for their holding by deductions from the resulting income. In principle, this system works well, but there have been many examples where land was acquired for the scheme without 'free, prior and informed consent' of the previous landowners, leading to long-running disputes. This is discussed further in Section 19.4.1.

In the Ivory Coast, the nucleus estate approach has been followed, with mills capable of taking greater inputs than expected from the estate alone. Smallholdings are grouped around this mill. It was found in practice that the estate has to be relatively large because of the risk that smallholders would not supply bunches to the mill consistently (Hartley, 1988). In Benin, co-operatives for smallholders were set up (Adje and Adjadi, 2001). Nigeria has a smallholder sector that appears to be stronger than the estate sector (Omereji, 1995), but this is not reliant upon large estate mills. Plantation companies in Ghana have also established smallholder schemes.

In Papua New Guinea, the first smallholder scheme was set up in 1968 in West New Britain as the Hoskins oil palm scheme (King *et al.*, 1998). Each settler received 6 ha of land and undertook to plant 4 ha with palms within 2 years of taking over the block and to remain there for 7 years. The farmers were responsible for all planting and normal upkeep and maintenance. Harvested fruit was picked up by estate lorry for transport to the mill. The management company, New Britain Palm Oil Ltd, produces seedlings, sets up experiments, runs the estate and advises the farmers.

In the 1970s, 6 ha was considered sufficient for a typical family of 6, but by 2000, the average population per block had expanded to 13 people of 3 generations. It was initially considered that the smallholders should be discouraged from seeking outside income, but with the increase in population, this is clearly impracticable, and an additional outside income is essential (Koczberski and Curry, 2005).

In recent developments in PNG, companies have leased land from customary owners for a period of

20–40 years and planted palms, with the land and associated infrastructure to be handed back to the owners at the end of that period (Koczberski *et al*., 2001).

In the Philippines, there is an outgrower scheme grouped around nucleus estates, with about one-quarter of the total area managed by smallholders. Brito (2010) described company-supported smallholder projects in Brazil.

Many smallholders have benefited from the large cash returns from the cultivation of oil palms, despite some examples of conflict. Härdter *et al*. (1997) argued that when done properly, intensive oil palm cropping was a sustainable system, giving a better income than most alternatives, and should be encouraged.

1.5.4 Research

Taking a wild and naturally reproduced plant into mass planting raises many questions of planting, seed treatment, diseases and so on, and these must have been dealt with by the early pioneers, probably with help from botanical gardens and agricultural services in Indonesia and Malaysia. The first organised professional research on oil palm cultivation was in 1916 at the research station of Algemene Vereniging van Rubberplanters ter Oostkust van Sumatra (AVROS) at Medan in Sumatra [now the Indonesian Oil Palm Research Institute (IOPRI)]. As the name shows, the initial interest was in rubber, but oil palms began to be investigated quite soon, and a very positive report on this was made in 1922 (Pamin, 1998). AVROS *pisiferas* are still widely used in current seed production (Pamin, 1998).

In the 1930s, work started in the then Belgian Congo at Yangambi, at Institut National pour l'Étude Agronomique du Congo Belge (INEAC). An important discovery was the relationship between *tenera*, *dura* and *pisifera* palms (Section 6.1.5).

The West African Institute for Oil Palm Research was set up in Benin City, Nigeria, shortly after World War II. This is now the Nigerian Institute for Oil Palm Research. Later research facilities were set up in the Ivory Coast at La Mé, and in Benin.

In Malaysia, research was for a number of years largely pursued by the individual private companies, and their contribution proved to be vital (Chew *et al*., 1998) and continues today. The Department of Agriculture had a small programme, but in 1971, a public research programme was set up under the Malaysian Agricultural Research and Development Institute (MARDI) and then taken over in 1980 by the Palm Oil Research Institute of Malaysia (PORIM), which became the Malaysian Palm Oil Board in 2000.

In Colombia, the palm growers' federation, Fedepalma set up a research centre, Cenipalma, in the early 1990s. In Brazil, research has been undertaken by Empresa Brasileira de Pesquisa Agropecuária (EMBRAPA), Brasil, for many years. The ASD research programme in Costa Rica has already been mentioned.

In Ecuador, in the early 1960s, the Instituto Nacional de Investigaciones Agropecuarias (INIAP) established an oil palm research station, in the north-west region near La Concordia. This is close to the first oil palm plantation in Ecuador, which was planted in 1953 with open-pollinated Deli *dura* seed from Lancetilla.

In Papua New Guinea, the PNG Oil Palm Research Association was set up by the oil palm industry. Thus most countries that are seriously involved with oil palm culture have national research organisations of some form.

Research has produced many valuable advances for the industry in the past. It will be even more important in the future because of the intensely competitive nature of the international agricultural industry and the rapid strides being made in research into other crops. The advantages of annual crops over perennial crops in a research race have been outlined by Tinker (2000a), and the oil palm industry will have to ensure that its research strategy is correct if it is to hold its present strong position.

Chew (2001) discussed the needs for research in Malaysia, in both the public and the estate sector. He considered that more effort should be put into determining the most useful research programmes and that these needed a proper balance of basic, strategic and applied research. Currently, the basic research on biotechnology and related subjects receives much attention, work on clonal palms and plant breeding is well supported, and simple applied work is done because of pressing needs to solve specific problems on estates. However, more strategic work on agronomy is needed, and Chew (2001) considered that the most important issues were to obtain more data sets and proper analyses of estate yields and costs, climate and soil resources and best agronomic practices. These could establish benchmarks for palm and labour productivity. Wood (2007) considered that monitoring of harvesting and oil extraction, investigation of shorter planting cycles and understanding of *Ganoderma* disease were particularly important.

A particular feature of the past two decades has been the rise in environmental consciousness in the oil palm industry (Gurmit, 1999; Chan, 2000b). The development of methods of integrated pest management started in the 1960s (Chapter 14), many years in advance of most other major crops. A successful research programme has been the prevention of pollution from oil mills, particularly river pollution. The most emotive issue has been the loss of old high forest (Casson, 2000) and of wetlands (Sargeant, 2001) to planting with oil palms. Both ecosystems have high biodiversity and are particularly sensitive. The use of forest land for oil palm is discussed further in Chapter 19.

1.5.5 Environmental and social aspects

The degree to which a new oil palm plantation would replicate the environmental benefits that were lost when the original forest was cut down has been a growing issue in the last few decades (Chapter 19). Henson (2003) followed others in listing the main benefits of forest as a large carbon store, maintenance of the good structure of the soil and its plant nutrients, a continuing cycling of these elements between forest and soil, and the very much richer biodiversity in a natural forest than in a plantation. He concluded that a well-managed plantation can replicate most of the valuable properties of forest but that the biodiversity issue may always cause problems. Forest clearing will also result in large emissions of greenhouse gases (see Section 17.2.3). The amount of carbon in a hectare of oil palms averages around 35 t, which is exceeded by all but severely degraded secondary forest (Section 17.2.3.2).

These environmental issues have become increasingly important, modifying the usual commercial and technical factors that drive the development of any industry. In particular, retail customers will always be sensitive to suggestions that a particular crop is damaging either health or the environment (Vis *et al.*, 2001) (see Chapters 16 and 19). The industry will be expected, like all others, to safeguard the land and the forests, prevent pollution of water and land and care for biodiversity (Gurmit, 1999; Gurmit *et al.*, 2009). The human health questions have already affected palm oil acceptability for decades, and if genetically modified oil is produced, it may meet resistance in Europe.

The social effects of the 'expanding frontier' of oil palm culture in SE Asia depend upon the degree to which traditional landholding structures are affected (Fold and Hirsch, 2009). Curry and Koczberski (2009) explained the situation in PNG, where customary land rights may appear to have been transferred for oil palm planting, but the land rights and the security of land tenure remain embedded in social relationships. In both Indonesian Outer Islands and East Malaysia (McCarthy and Cramb, 2009), there has been a shift away from state-led policies which encouraged the conversion of whole landscapes into oil palm land, ignoring the indigenous forms of agriculture and land tenure while creating reserves of 'state' or 'idle' customary land. These papers (Fold and Hirsch, 2009) give some idea of the complexity of government policy for land use (see also Chapter 19).

1.6 TRADE IN AND USE OF OIL PALM PRODUCTS

1.6.1 Trade in oil palm products

The main importers of palm oil in 2012 are listed in Table 1.11. The European Union (EU) was for decades the main importer; originally, the United Kingdom was the largest market, but the Netherlands and Germany have now become more important.

There have been three periods in which countries outside Europe have imported palm products on a large scale, one of which is still continuing. First, the United States imported up to 20% of the world supply of palm oil in the years before World War I. This import continued until 1937, when it peaked at 183,000 t. After this, it declined sharply to 30,000 t. More recently, US imports have increased again to about 1 Mt in 2012 (Table 1.11), but this was only about 6% of total domestic oil disappearance. There are well-known reasons for the past relatively low imports (see Sections 1.6.3 and 16.4).

The most striking change in trade has been the growth since the 1970s in importation of palm oil into countries with large and increasingly wealthy populations, such as China, India and Pakistan. These three countries consumed 30% of the world's palm oil in 2012. Otherwise, most countries use palm oil to a significant extent.

The main importers of palm kernels and kernel oil are listed in Table 1.12. Historically, the United States bought large amounts of palm kernels, up to 90% of world supply in 1937. A smaller but still substantial import continued into the 1960s. This was ascribed by Hartley (1988) to the US Public Law 480 and other aid programmes, which for a period made it cheaper for US manufacturers to buy vegetable oils from foreign than from US sources. Today, the United States imports about 300,000 t of palm kernel oil per year (Table 1.12).

Almost all palm kernels are now crushed in the country of origin, and exports of kernels are negligible (Table 1.12). The main exports are from Papua New Guinea and Thailand, and the only significant importer

Table 1.11 Main importers of palm oil, 2012 (thousand tonnes/annum)

Country	Imports	Imports as % world production	Exports	Net imports
Netherlands	2,663	5.0	63	2600
Italy	951	1.8	17	934
Germany	818	1.5	30	788
Spain	516	1.0	1	515
United Kingdom	550	1.0	0	550
Other EU	812	1.5	12	800
Other Europe and CIS	998	1.9	47	951
Europe, total	7,308	13.6	170	7,138
Nigeria	870	1.6	18	852
Egypt	691	1.3	142	549
Kenya	436	0.8	57	379
South Africa	402	0.8	2	400
Benin	200	0.4	165	35
Other Africa	2,739	5.1	549	2,190
Africa, total	5,338	10.0	933	4,405
United States	991	1.8	89	902
Mexico	461	0.9	–	461
Brazil	244	0.4	65	179
Other Americas	552	1.0	1,215	−663
Americas, total	2,248	4.2	1,369	879
India	7,809	14.6	40	7,769
China	6,447	12.0	–	6,447
Pakistan	2,240	4.2	46	2,194
Malaysia	1,269	2.4	17,576	−16,307
Bangladesh	1,013	1.9	–	1013
Singapore	844	1.6	88	756
Iran	740	1.4	–	740
Vietnam	598	1.1	1	597
Japan	577	1.1	–	577
Myanmar	509	1.0	–	509
Turkey	437	0.8	–	437
United Arab Emirates	405	0.8	330	75
Philippines	371	0.7	27	344
Other Asia, Oceania	2,198	4.1	20,140	−17,942
Asia, total	25,457	47.4	38,348	−12,891
Other countries	1012	1.9	100	912

Source: ISTA Mielke GmbH, Oil World Annual 2013 and Oil World Data Bank.

Table 1.12 Main importers and exporters of palm kernels and kernel oil, 2012 (thousand tonnes/year)

Country	Palm kernels		Palm kernel oil	
	Imports	Exports	Imports	Exports
Germany	–	–	268.2	4.0
Netherlands	–	–	185.0	10.0
Spain	–	–	30.5	–
United Kingdom	1.6	–	27.5	–
Other EU	0.1	–	94.0	–
Other Europe and CIS	–	–	102.6	0.2
Europe, total	1.7	–	707.8	14.2
Egypt	–	–	27.7	–
South Africa	–	–	35.6	–
Côte d'Ivoire	–	2.0	–	17.2
Ghana	4.0	–	–	–
Nigeria	12.0	4.5	1.4	3.0
Benin	–	–	–	7.1
Other Africa	–	–	30.2	2.7
Africa, total	16.0	6.5	94.9	30.0
United States	–	–	256.7	8.2
Brazil	–	–	166.3	–
Mexico	–	–	82.6	–
Colombia	–	–	1.3	49.5
Other Americas	–	–	11.3	78.4
Americas, total	–	–	518.2	136.1
Malaysia	50.3	–	440.7	1084.5
China	–	–	485.7	–
India	–	–	181.0	3.0
Japan	–	–	88.9	–
Turkey	–	–	84.2	–
Thailand	–	13.2	106.2	72.6
Indonesia	–	7.4	0.6	1669.4
Papua New Guinea	–	28.0	–	38.3
Solomon Islands	–	7.6	–	–
Other Asia, Oceania	–	–	149.5	9.4
Asia, total	50.3	56.2	1536.8	2966.5
Other countries	7.2	12.0	183.8	9.0

Source: ISTA Mielke GmbH, Oil World Annual 2013 and Oil World Data Bank.

is Malaysia. The main importer of kernel oil is still the EU, followed by Malaysia, China and the United States. These account for over 30% of world production; the rest is taken by a long list of other nations (Table 1.12).

1.6.2 Uses of oil palm products

The interchangeability of oils has steadily increased with lipid technology, and the oil used for a particular purpose often depends on the current price and availability. There have always been both food product uses and technical uses, but the latter have changed progressively. The lower quality oil is used for non-edible purposes, such as soaps, resins, candles, glycerol, fatty acids, inks, polishing liquids and cosmetics.

1.6.2.1 *Edible uses*

Palm oil is used largely for food products. Refining and fractionation (see Section 16.3.3) are now often done in the producing countries. Malaysia has been at the forefront of this and now exports a wide range of different products, including CPO, neutralised palm oil, refined bleached and deodorised (RBD) palm oil, palm olein, palm stearin, palm kernel oil and palm kernel cake or meal, palm fatty acid distillate (PFAD), biodiesel and a variety of oleochemicals and finished products (www.mpob.gov.my; Berger, 2010). Palm oil is well suited to use as cooking fats and deep-frying oil, and it appears in bakery products, potato crisps and other snacks, ice creams, imitation cream and other dairy products and margarine (Berger, 2010), The high-melting-point stearin fraction is used for shortenings, vanaspati and bakery fats, whereas olein, which has a lower melting point, is used for cooking oils, margarine and salad oils. Genetically modified palm oil with an increased oleic acid content may become available in time (Parveez *et al*., 2003) and will make palm oil still more flexible for use in foodstuffs and more competitive with other edible oils. However, it does not seem likely to change its uses fundamentally.

A recent development in food crop production is the popularity of 'organic foods', which has some links to the general concept of sustainability. The organic movement is now almost worldwide and is taking up to several per cent of the total food market in some developed countries. Most scientific assessments of food from organic crops conclude that there is no advantage over the conventional methods used by developed agriculture (Tinker, 2000b, 2001). Nevertheless, organic food usually commands a significant price premium over the conventional product. Organic palm oil is now produced in Brazil, Colombia and Ghana. Ahmad Borhan *et al*. (2004) reviewed the feasibility of organic production in Malaysia. They quoted premiums for other organic vegetable oils compared to non-organic oils of 32–114% at that time.

1.6.2.2 *Non-edible uses*

Many compounds are now produced from palm oil and are known collectively as oleochemicals. Most of these are molecules with different fatty acid chains attached to various simple functional groups, such as acids, amines or alcohols, and include sulphonated methyl esters, polyols and polyurethanes (for general reviews, see Basiron and Salmiah, 1994; Pamin, 1998; Miyawaki, 1998; Berger, 2010; Zahariah and Mohd Suria, 2012). In addition, several minor constituents of palm oil can be extracted and used separately, such as carotene, vitamin E and sterols.

Palms produce up to 40 t/ha of dry matter per year, of which less than 10 t is extracted as oil and kernels. The remaining biomass (meaning any organic plant product) can in theory be used for paper, building board and many other purposes, including as a solid fuel (see Section 18.1.1) (Basiron and Salmiah, 1994; Jalani *et al*., 1999). The removal of all this dry matter may change the palm ecosystem and the soil composition, but at present, this does not appear to be a serious difficulty. There is much research on palm biomass, but it is not yet used on a large scale.

Palm biodiesel is made by forming methyl esters of the fatty acids in palm oil (see Chapter 18). Its properties make it analogous to diesel fuel, and cars and buses have been successfully operated with it. Although a relatively small amount of palm oil actually goes to produce biodiesel (Chapter 18), the interchangeability of oils means that if rapeseed oil is used for biodiesel, it can be replaced in the edible market by palm oil. In fact, the flexibility of palm oil use is one of its most valuable qualities. Fluctuations in the price of petroleum make it difficult to predict the future for biodiesel, and a major constraint is the campaign to stop the felling of tropical forest for planting oil palms (Chapter 19).

1.6.3 The conflict over 'tropical oils'

The 1980s and 1990s were marked by a strong publicity conflict over the use of what have been called 'tropical oils' in the United States. A campaign was launched by the soya bean interests in the Unites States (Berger, 1981; Enig, 1998) to counter competition from palm oil and coconut oil. The latter product has decreased in importance in international commerce, so that palm oil was in practice the main target. There is no doubt that the campaign had considerable success, as shown by the small imports of palm oil into the United States for many years. The basis for this campaign was the claim that unsaturated fats and oils were 'much more healthy' than saturated fats. The evidence that *trans*-acids produced by hydrogenation of liquid oils are probably more harmful than saturated fats has largely reversed this (Section 16.4).

1.6.4 The future

The future of the palm oil market must be considered secure (Carter *et al*. 2007), based on its cheapness, high yields, well-defined markets as a fuel and as food, practical plantation systems and large information store. It is now a mature crop, but still with the potential for great expansion, based on the exploitation of the large gene store from the past, and the many new developments based on existing science. Corley (2009a) estimated that there would be a demand for at least 93 Mt of palm oil for edible use alone by 2050 and perhaps much more if soya bean production does not expand.

The high yields from oil palms are attributable to the fact that it is an equatorial crop, with a 12-month growing season, but this is also its major disadvantage, as the ideal climate is the same as for tropical rainforest (Fig. 1.1). Expansion of the oil palm crop therefore implies cutting down rainforest or succeeding vegetation with consequent loss of biodiversity, and this is the basis for the opposition to area expansion (see Chapter 19).

Area expansion in Malaysia is now very slow, with no high conservation value forest (see Chapter 19) being felled for oil palms and with a government undertaking to maintain 50% of the country under forest. The main issue at present is therefore in Indonesia. There is strong pressure to plant oil palms in degraded forestlands, including grassland, instead of rainforest. Fitzherbert *et al*. (2008) have given a penetrating review of the biodiversity question, and there is no doubt that oil palm plantations do not have the same biodiversity as high forest. However, the overwhelming advantage in productivity per hectare of palm oil over other edible oils (Tables 1.2 and 1.3) greatly reduces the total land area needed for any given production level.

In terms of poverty reduction and food security, the oil palm can be very important, and this is recognised in the African nations. A report by the Nigerian think tank, Initiative for Public Policy Analysis (Ayodele, 2010), has urged that placing too strict environmental or social rules on the funding of oil palm cultivation may prevent this major driver of poverty reduction and national development from making reasonable advances in national wealth.

The decade since Edition 4 of this book was completed has seen massive growth in production and use of palm oil. The main markets for palm products have expanded, with China, India and Pakistan becoming major importers and consumers (Table 1.11). There are new uses for palm oil as a chemical feedstock and a substitute (biofuel) for fossil fuels. The latter is driven by the concern over the consequences of climate change (Chapter 17). The extent to which this new demand will grow is still uncertain, but it could be very large, depending on the prices of competing fuels.