Introduction

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BACKGROUND

The oil palm (*Elaeis guineensis*) has now been established on about 5.5 M ha of land in Southeast Asia. Due to its large demand for nutrients and the size of the area planted, the crop is now one of the largest consumers of mineral fertilizer nutrients in Southeast Asia. Because of its geological nature, Southeast Asia is able to supply almost all its requirements for nitrogen (N), by utilizing abundant deposits of natural gas to manufacture N fertilizers, but most of its requirements for phosphorus (P), and all its potassium (K) requirements as well as part of its requirement for magnesium (Mg) fertilizers must be imported.

The use of mineral fertilizer nutrients in Southeast Asia increased from about 250,000 M t NPK fertilizer nutrients in 1980 to more than 1,500,000 M t in 2000. The oil palm accounts for a large part of the increase in nutrient consumption. Only a small proportion of total nutrient uptake is exported in palm and kernel oils, the economic products of oil palm, and thus there is considerable scope to recycle nutrients contained in crop residues or provide nutrients to other cropping systems in the form of compost manufactured from palm oil mill effluent (POME) and empty fruit bunches (EFB) (Redshaw, this volume).

Much knowledge and know-how has accumulated over the past thirty years through the work of research and development departments in the leading plantation houses as well as practical planters. Our aim in updating this bulletin (Ng, 1972; von Uexküll and Fairhurst, 1991) is to provide scientists, advisers, consultants, managers and growers with ‘state of the art’ knowledge on issues relating to nutrient management in oil palm.

VEGETABLE OIL SUPPLY AND DEMAND

Growth in world population and economic development are two factors that drive the increasing global demand for vegetable oils. *Per capita* consumption of oils and fats is smaller than levels recommended by the Food and Agriculture Organization in many developing countries (Figure 1) where population growth and increasing incomes will result in further growth in the demand for vegetable oils in the 21st century.

Nevertheless, the supply of oils and fats to the world’s increasing population has improved continuously over the past twenty years. Almost all of the growth in production has been contributed by vegetable oils whilst the production of animal oils and fats has stagnated during the same period (Figure 2).

Between 1994 and 2001 the production of palm and kernel oil increased by 63% and 54% respectively: a larger increase than for any other vegetable oil (Table 1). The annual rate of increase in production during this period was greater for oil palm (>7%) compared with soybean (6%). Palm and kernel oils represent almost 28% of total vegetable oil production and are well-positioned to become the largest sources of vegetable oil in the 21st century (Table 1).

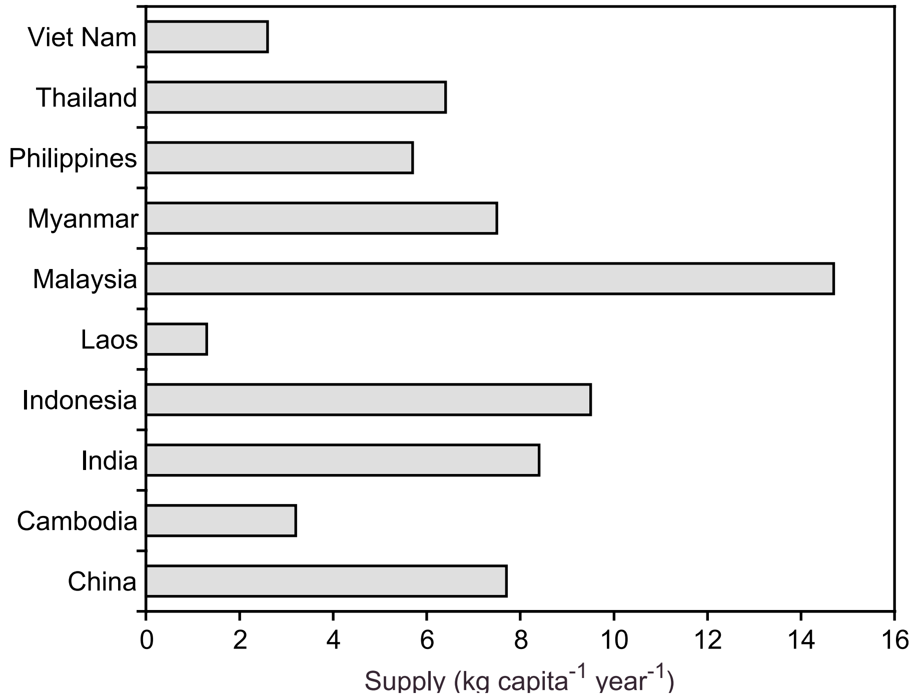

Figure 1. Vegetable oil supply in selected countries in Asia in 2002 (FAO, 2002).

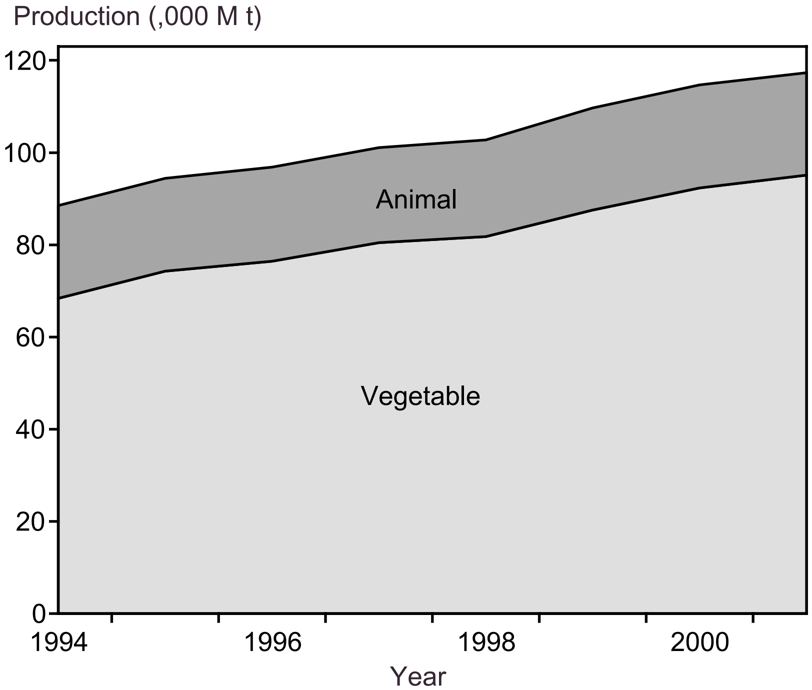

Figure 2. Global production of vegetable oils and animal fats (Oil World Annual 1998, 1999, 2000, 2001; Oil World Weekly, 2002).

Table 1. Production of vegetable oils (1994–2001) (Oil World Annual 1998, 1999, 2000, 2001; Oil World Weekly [22 March & 5 April 2002], MPOB [data on Malaysia]).

Vegetable oil	1994	1995	1996	1997	1998	1999	2000	2001	% of total (2001)	Increase 1994 - 2001
Palm oil	14,304	15,210	16,282	17,903	16,919	20,631	21,825	23,355	24.6	63
Palm kernel oil	1,861	1,945	2,083	2,230	2,168	2,557	2,688	2,872	3.0	54
Soyabean oil	18,684	20,404	20,322	21,052	24,038	24,809	25,546	27,779	29.2	49
Cottonseed oil	3,566	3,905	4,119	4,047	4,043	3,822	3,852	4,006	4.2	12
Groundnut oil	4,309	4,423	4,563	4,521	4,502	4,694	4,573	5,073	5.3	18
Sunflower oil	7,391	8,556	9,006	9,165	8,439	9,308	9,677	8,223	8.6	11
Rapeseed oil	9,970	10,955	11,479	11,830	12,229	13,066	14,467	13,725	14.4	38
Corn oil	1,675	1,855	1,834	1,858	1,880	1,938	1,968	1,962	2.1	17
Coconut oil	3,015	3,350	2,867	3,301	3,107	2,388	3,272	3,539	3.7	17
Olive oil	1,900	1,888	2,042	2,701	2,588	2,461	2,545	2,690	2.8	42
Castor oil	446	483	479	442	441	442	494	515	0.5	15
Sesame oil	616	589	668	723	736	726	715	751	0.8	22
Linseed oil	636	701	666	691	694	730	698	621	0.7	-2
Total	68,373	74,264	76,410	80,464	81,784	87,572	92,320	95,111	100.0	39

AREA EXPANSION AND PRODUCTIVITY

The cultivated oil palm originated from West Africa, but Southeast Asia has now become the largest producer of palm oil (Table 2). The most significant increases in production during the past seven years have occurred in Malaysia (8.5% per annum) and Indonesia (16.9% per annum) which together account for more than 80% of world production (Table 2).

In spite of large rates of growth in production in some countries in Latin America, the area planted is small compared to Southeast Asia, and the position of Malaysia as the world-market leader in palm oil is only likely to be challenged by Indonesia in the near future. Indonesia's palm oil production doubled in only seven years from 1994 to 2001 (Table 2), which may be explained by the country's favorable climatic and soil conditions and the large reserves of suitable land that were available for oil palm development during this period.

Most of the area planted in Southeast Asia can be found concentrated in a band between 10º N and 10º S of the equator due to the crop's particular climatic requirements (Figure 3). Oil palm is cultivated successfully beyond these agroecological boundaries in Thailand, where the major production constraint is low and poorly distributed rainfall (Paramananthan, this volume). The largest centres of production, however, are located in Peninsular Malaysia, and the islands of Sumatra, Borneo and Papua New Guinea.

Whilst palm oil prices have shown a continuous decline in real terms over the past thirty years (Fry, 2002) the recent large expansion in palm oil production is partly explained by the favorable prices for vegetable oil during the 1990s (Figure 4). When presented in real prices, however, palm oil prices have been in continuous decline since 1950 (Figure 5). Perhaps the most important reason for the rapid expansion of oil palm and its strong position among other vegetable oil crops is found in the characteristics of the plant itself. Oil palm has an unsurpassed ability to intercept and transform solar energy into vegetable oil and in this respect can truly be considered a 'gift of nature' (Breure, this volume). This becomes evident when current vegetable oil production and the planted area of major vegetable oil crops is compared.

Soybean, oil palm, oil seed rape and sunflower together account for about 81% of the world's vegetable oil, and occupy about 87 M ha. Oil palm contributes 33% of total vegetable oil production but occupies only 8% (6.6 M ha) of the total area planted to these four crops (Figure 6). By contrast, soybean produces 35% of the world's vegetable oil but accounts for 63% (55 M ha) of the land planted to vegetable oil crops. Thus, oil palm uses land more efficiently than any of the other vegetable oil crops. Even at present average oil yields in Southeast Asia of 3.3 t ha^{-1}, oil palm exceeds present yields of other major oil crops and requires only 0.3 ha to produce 1 t oil, compared to oil seed rape (0.75 ha), sunflower (1.57 ha) and soybean (2.17 ha) (Figure 7).

Breeders have continuously improved yield potential of oil palm by using selected superior dura and pisifera parents to produce tenera palms in conventional breeding programs, and tissue culture to multiply individual elite palms to produce 'clonal palms' (Ng *et al*., this volume) (Table 3).

It seems unlikely that yields of more than 11 t oil ha^{-1} will be achieved in large scale commercial plantations (Breure, this volume) but well-managed plantations using conventional modern planting materials have achieved oil yields of 6.0–6.5 t ha^{-1}, and yields of >14 t oil ha^{-1} have been reached with some small scale plantings of clonal palms (Ng *et al*., this volume). Thus, there appears to be tremendous potential to further increase palm oil production without expanding the area planted.

At current average yields in Malaysia of 3.6 t oil ha^{-1} under present management practices, oil palm outperforms the other major oil crops with regard to the efficient use of inputs. The input:output ratios for oil seed rape and soybean are about 1:3.0 and 1:2.5 respectively, whilst the energy output from oil palm is 9.5 times the energy inputs required for production (Wood and Corley, 1991).

Table 2. World distribution of palm oil production (1994–2001) (Oil World Annual 2001, 2000, 1999, 1998 & Oil World Weekly (22 March & 5 April 2002), MPOB [data on Malaysia]).

Country	1994	1995	1996	1997	1998	1999	2000	2001	% total (2001)	% annual increase
Malaysia	7,403	7,221	8,386	9,069	8,319	10,554	10,842	11,804	50.5	8.5
Indonesia	3,421	4,008	4,540	5,380	5,100	6,250	7,000	7,480	32.0	16.9
Nigeria	645	640	670	680	690	720	740	750	3.2	2.3
Colombia	323	353	410	441	424	501	524	547	2.3	9.9
Cote D'Ivoire	310	300	280	260	275	282	266	275	1.2	-1.6
Thailand	297	316	375	390	405	495	525	535	2.3	11.4
Papua New Guinea	223	225	272	275	215	264	336	325	1.4	6.5
Equador	162	178	188	203	200	230	238	240	1.0	6.9
Costa Rica	84	90	109	119	115	110	113	123	0.5	6.6
Honduras	80	76	76	77	88	80	78	94	0.4	2.5
Brazil	54	71	80	80	89	93	97	110	0.5	14.8
Venezuela	21	34	45	54	54	68	81	84	0.4	42.9
Guatemala	16	22	36	50	47	52	58	70	0.3	48.2
Others	1,265	1,676	815	825	898	932	927	918	3.9	-3.9
Total	14,304	15,210	16,282	17,903	16,919	20,631	21,825	23,355	100.0	9.0

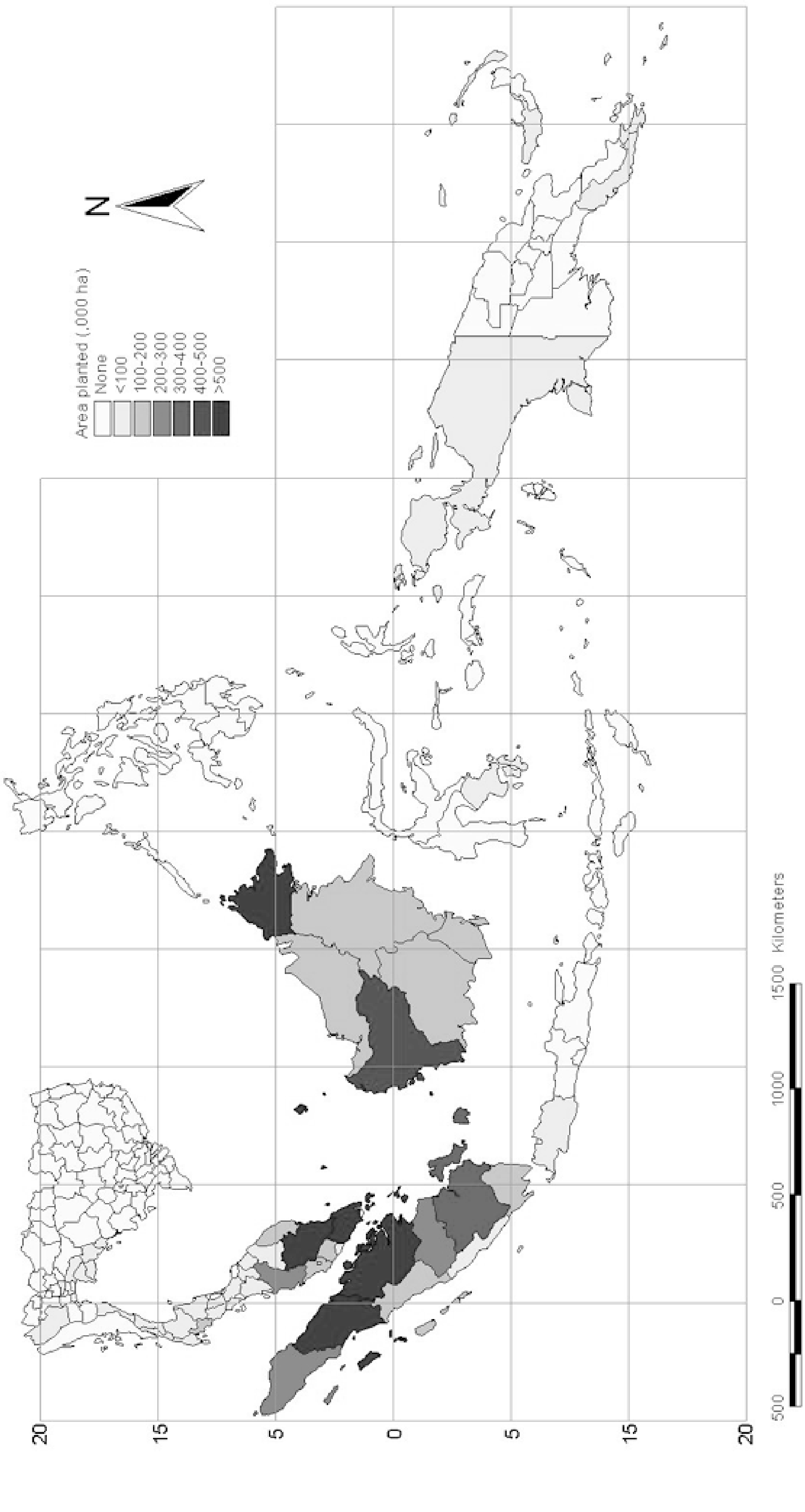

Figure 3. Distribution of the area planted to oil palm in the four major centers of production in Southeast Asia.

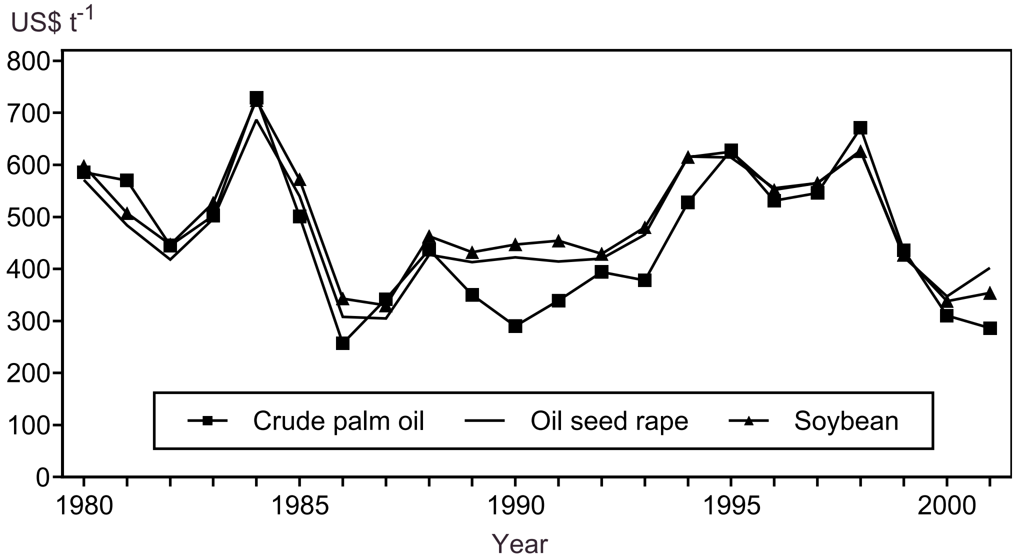

Figure 4. Price of crude palm oil (CPO), rapeseed oil and soybean oil (Oil World Annual 1998, 1999, 2000, 2001; Oil World Weekly 2002).

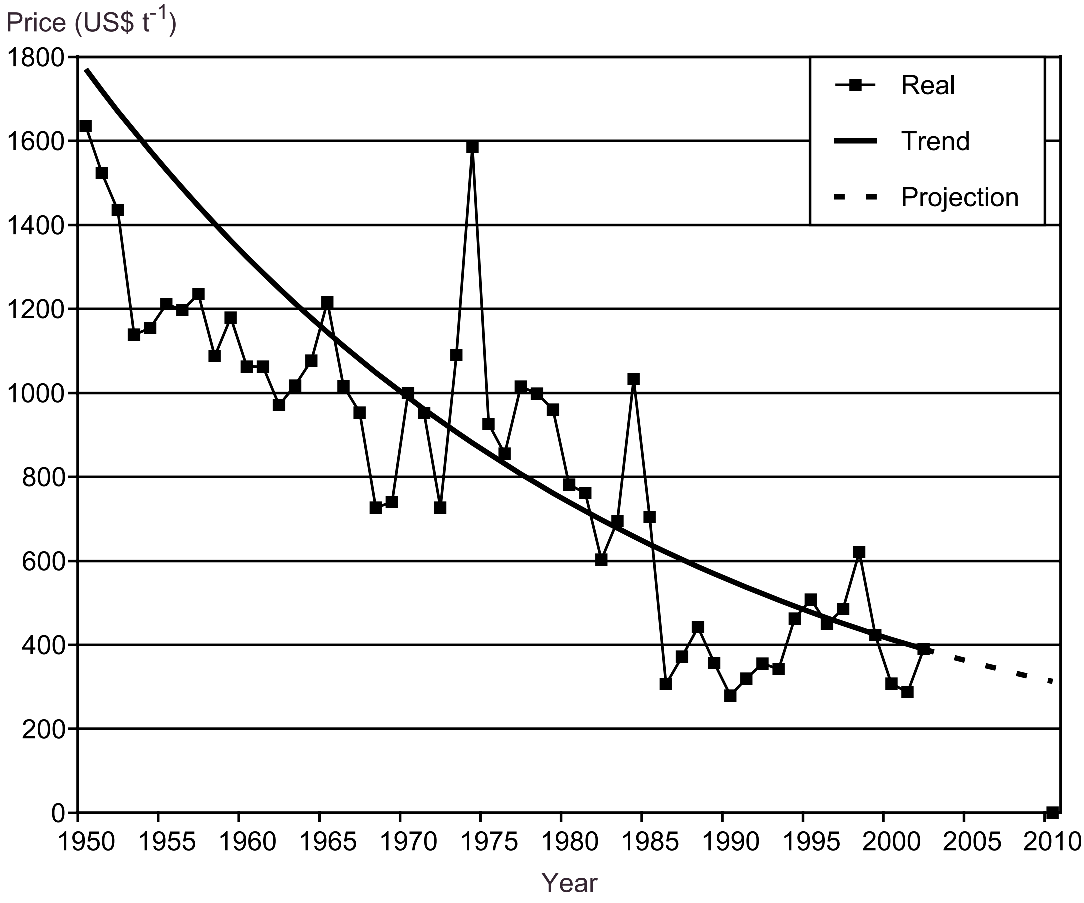

Figure 5. Price development of crude palm oil (CPO) since 1950s and projected until 2010. The jump in real prices in 1975 is attributed to the first OPEC oil price rise that affected the price of all commodities (Fry, J., pers. comm.).

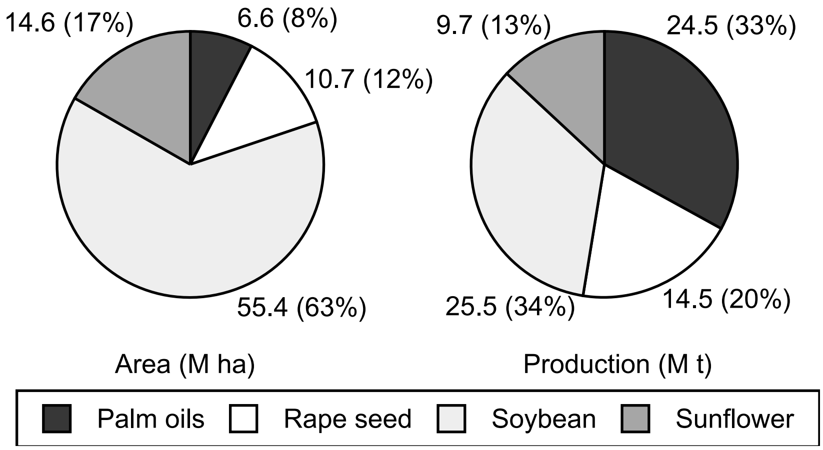

Figure 6. Global area planted (M ha) and production (M t) of major vegetable oil crops (Chan, 2002).

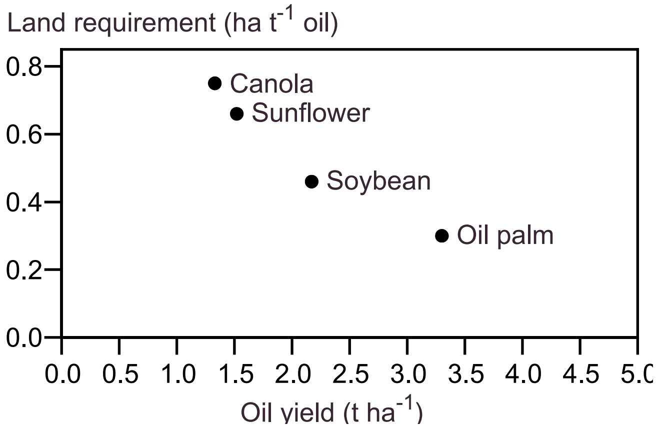

Figure 7. Land area required to produce 1 t oil and oil yields for major vegetable oil crops.

Table 3. Yield performance of oil palms reported by various planting material producers in Malaysia (Jalani, 1999; Ng et al., 1999).

Planting material	Year planted	FFB yield ($t\ ha^{-1}\ yr^{-1}$)	Oil to bunch (%)	Oil yield ($t\ ha^{-1}\ yr^{-1}$)	Source
AGK 19 (clone)	1993	46.6	30.0	14.0	Ng et al., 1999
D x D x Nigeria	1991	36.1	31.9	11.5	Jalani, 1999
D x D x Yangambi	1991	34.8	31.1	10.8	Chin & Shuhaimi, 2000
D x D x Yangambi	1988	35.1	26.0	9.5	Sharma & Tan, 1996
D x D x AVROS	1979	34.5	25.8	8.9	Lee & Toh, 1991
D x D x DY-AVROS	1979	33.3	25.8	8.6	Lee & Toh, 1991
D x D x AVROS	1970	31.6	24.2	7.6	Lee & Toh, 1991
D x D x AVROS	1964	31.0	23.5	7.3	Lee & Toh, 1991
D x D x AVROS	1968	31.1	22.1	6.9	Lee & Toh, 1991
D x D x CI/UA C/SP	1962	22.6	21.9	4.9	Lee & Toh, 1991

Table 4. Estimated amount of carbon fixed by Malaysian oil palm plantations in 2000 (Chan, 2002).

Age groups (years)	Standing biomass (t ha^{-1})	Carbon (t ha^{-1})	Planted area (10^3 ha)	Total carbon fixed (10^3 t)
1 - 3	14.5	5.80	434.9	2.2522
4 - 8	40.3	16.12	1061.6	17.113
9 - 13	70.8	28.32	581.0	16.455
14 - 18	93.4	37.36	570.9	21.327
19 - 24	113.2	45.28	466.1	21.104
>25	104.5	41.00	262.3	10.753
Total	-	-	3376.7	89.274

ECOLOGICAL ASPECTS OF PRODUCTION

By making optimal use of natural growth factors (sunlight, moisture) and production inputs (fertilizers and other agrochemicals) (Goh *et al.*, this volume), the oil palm is the ideal crop plant to convert photosynthetically active radiation (PAR) into biomass (Breure, this volume). During this process the crop assimilates large amounts of carbon dioxide (CO_2) from and releases oxygen (O_2) to the atmosphere. A productive oil palm stand thus 'fixes' large amounts of carbon (C) (Table 4).

The amount of carbon fixed in the biomass of tropical rainforests, the natural land cover in Southeast Asia, is larger than oil palm due to the much longer life cycle of tropical forests. However, undisturbed tropical rainforests are generally found in a steady state where there is a balance between the accumulation and decomposition of above- and below-ground biomass. Thus, the net fixation of CO_2, which is caused by *incremental* biomass production, is larger in a vigorously growing oil palm plantation compared with tropical and temperate forests (Figure 8). The 6.6 M ha of oil palm in Southeast Asia may thus make a considerable contribution to reducing greenhouse gases.

When planted together with legume cover crops, the oil palm simulates the rainforest itself by:

- protecting the soil from erosion by providing permanent groundcover,
- constantly renewing the supply of surface organic matter in recycled crop residues and litter provided by legume cover plants, and
- maintaining low soil temperatures.

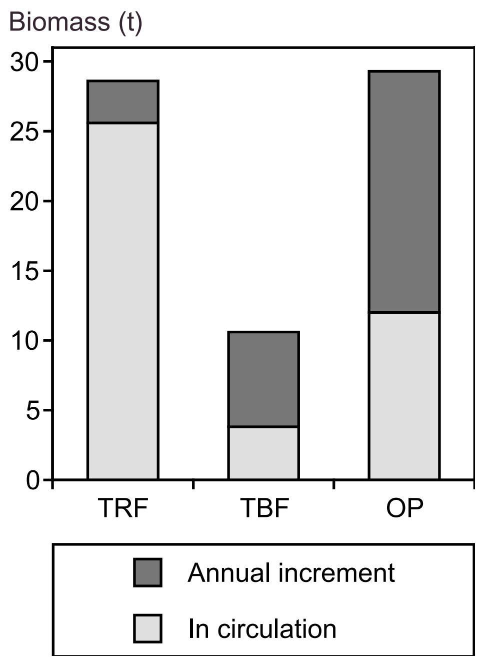

Figure 8. Net annual biomass production for tropical rainforest, temperate beech forest and oil palm (Härdter et al., 1997).

When proper management techniques are used the oil palm can be considered a very sustainable cropping system, as evidenced by some of the plantations in North Sumatra, Indonesia, where four crop cycles have been completed without detriment to the natural resource base.

FUTURE DEVELOPMENTS

Further expansion in the area planted to vegetable oil crops is constrained by the requirement to preserve remaining wilderness land (forest, wetlands) and the scarcity of land not already occupied by farmers and indigenous people. Thus, as with other crops, there is a need to search for the most efficient means of production and high levels of productivity, whilst minimizing potential negative impacts on the wider environment. Where large yields of oil palm are obtained, land is 'spared' for other uses since much more land is required to produce equivalent amounts of oil from other vegetable oil crops.

Progress in terms of productivity gains in Southeast Asia over the past two decades has been rather limited. By contrast to most other agricultural commodities, average yields have mostly stagnated over the past twenty years and increased production of palm oil is mainly accounted for by expansion in the area planted (Figure 9). As mentioned above, the area under harvest in Malaysia and Indonesia has increased dramatically over the past twenty years, whilst growth in Thailand and Papua New Guinea has only been moderate. In terms of oil yields, however, only Thailand has achieved a substantial increase in average yields whilst yields stagnated in Malaysia and Indonesia and even decreased in PNG (Figure 9). What are the reasons for this development? The oil palm industry in Thailand, located at the boundary of the favorable agroecological zone for oil palm (10º north and south of the equator), was compelled to improve productivity to compete with its neighbors in the south where the potential yield is greater. The stagnation in

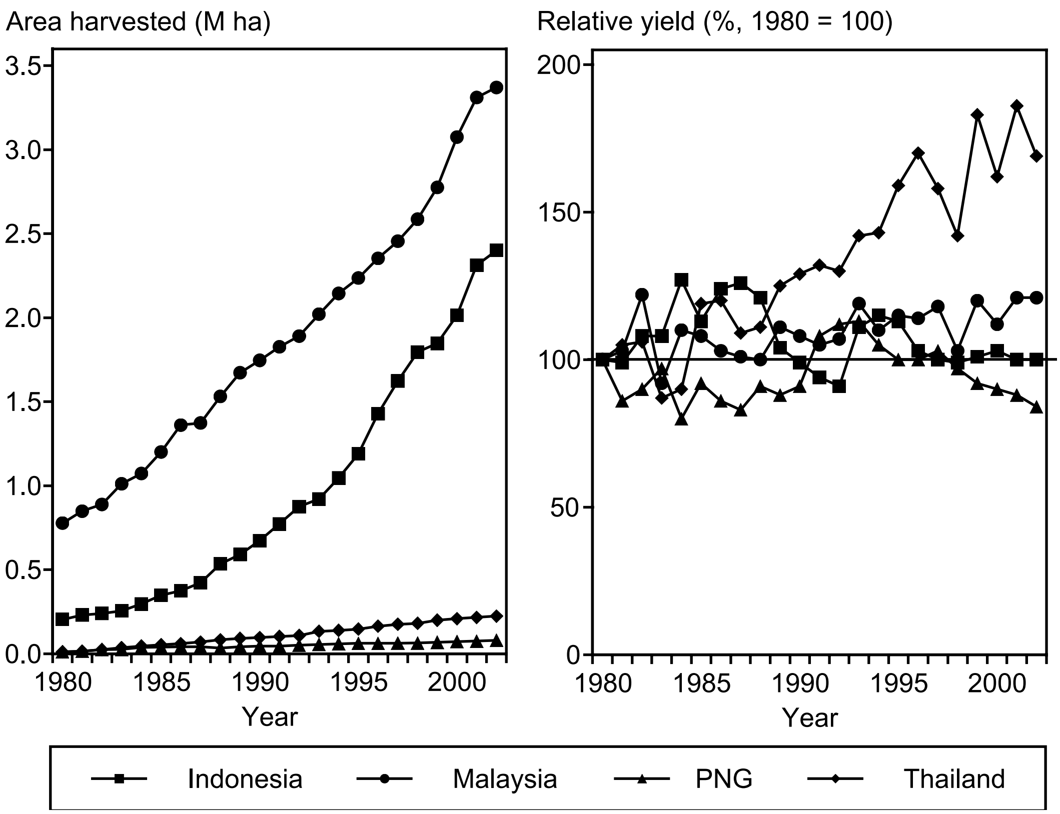

Figure 9. Area harvested and relative yield (1980=100) in four major oil palm producing conutries in Southeast Asia between 1980 and 2001.

yields in Malaysia and Indonesia may be due to expansion into areas with less fertile soils, and the relatively large proportion of young mature plantations.

Close cooperation is required between planters and their partners in research end development to improve and broaden the implementation of existing technologies that have the potential to increase productivity in the oil palm industry. Plantation houses must focus on developing a working environment in plantations so that high quality graduates can be attracted, and new entrants must also be provided with the skills and training required to contribute to the development of highly productive plantations

Some of the important technical challenges faced by the oil palm industry include the following:

- Careful land selection based on strict evaluation procedures and regulations, avoiding expansion into marginal land and areas with important ecological functions;
- Use of high quality planting material for the establishment of new plantations and the replanting of existing areas;
- Meticulous attention to each detail of field management in land preparation, planting and mature palm upkeep;
- Site-specific and precise nutrient management techniques that ensure the maintenance of soil fertility in the long run and efficient use of costly mineral fertilizers.

If the oil palm is to retain or improve upon its position as a leading source of vegetable oil, greater attention must be given to achieving larger yields by closing the gap between potential and currently attained yields (Fairhurst *et al.*, this volume) (see Table 3).

Environmentalists have created a powerful lobby against oil palm, claiming that the crop contributes to rainforest destruction and the alienation of indigenous people from their land. It is therefore timely for the industry to provide more evidence that the oil palm can indeed contribute to the world's growing demand for vegetable oil with high levels of productivity on already established plantations. The oil palm has also the potential to contribute indirectly to conservation efforts by sparing wilderness land for other uses. At the same time, whether grown by smallholders or in plantations, the oil palm can provide gainful and secure employment to indigenous people eager to remove themselves from the poor living conditions so prevalent in the islands of Sumatra and Borneo.

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