

CAN THE SUSTAINABILITY OF OIL PALMS BE IMPROVED?

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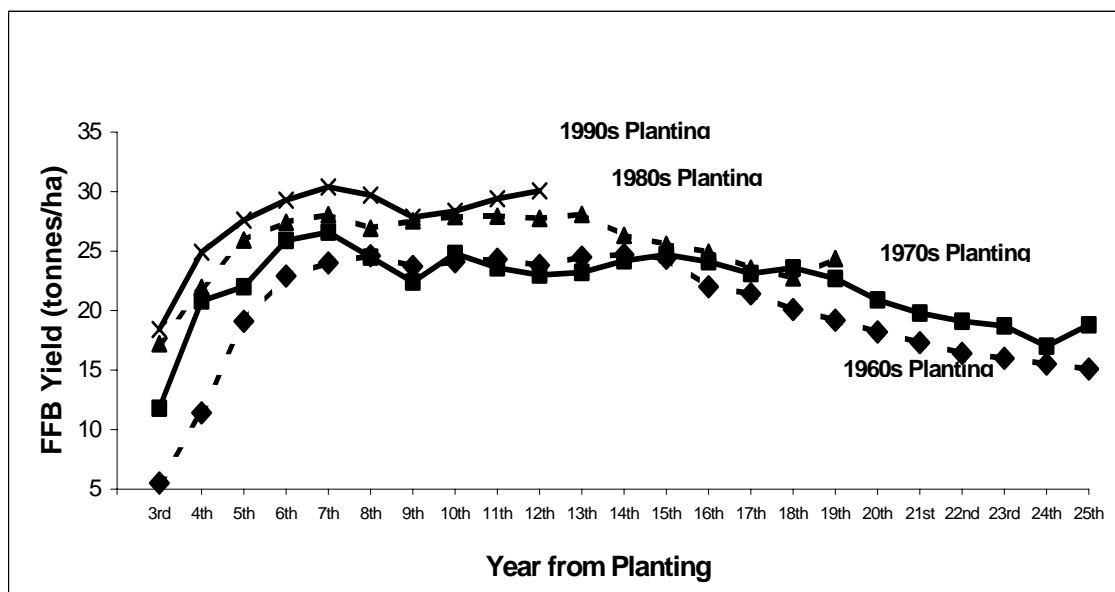
Abstract

The sustainability of oil palm plantations has attracted much attention recently. In this paper, the Unilever scoring system is outlined. There are two main areas for improvement: despite over 40 years of research, pest control does not always follow IPM principles, and nutrient recycling is inefficient, with less than 20% of the nutrients applied being exported in oil and kernels. Field application of EFB and effluent is still considered mainly as a waste disposal operation; these materials should be applied at lower rates to larger areas in the field than is usual. Palm trunks contain large quantities of nutrients, which should be recycled after replanting. If left in situ, nutrients will be released much more rapidly than the young palms can take them up, so distribution of trunk chippings to mature fields should be considered. This would be expensive, but the saving in fertiliser costs could be considerable.

Introduction

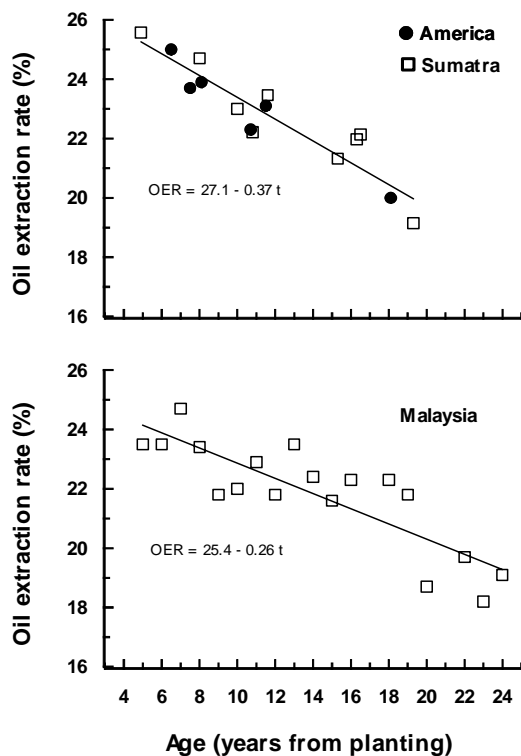
There has been much discussion about sustainable palm oil in recent years, with Unilever publishing a set of sustainability criteria in 2001 (Vis et al, 2001), Migros paying a premium for palm oil which meets another set of criteria, and recently the formation of a Roundtable on Sustainable Palm Oil (RSPO), which is drafting yet another set of criteria. All this suggests that there is a problem with sustainability of oil palm plantations, but that is not so. Well-managed oil palms, in common with most perennial tree crops, are inherently sustainable. Plantations established in the early part of the 20th Century are still in existence, and yields are still increasing. As an example, Figure 1 shows that yields at United Plantations, in Malaysia, are rising steadily.

Figure 1 Yields from plantings in successive decades
(data by courtesy of United Plantations Bhd)



Plantings in the 1960s had peak yields of about 25 t FFB/ha, reached in the 8th year after planting; 1990s plantings reached that level in the 4th year, and peaked at over 30 t/ha. Oil extraction ratios have also been rising steadily in many countries (Figure 2), and oil yields of over 7 t/ha.yr are now regularly achieved.

Figure 2 OER in relation to age of plantings
From Corley & Tinker, 2003



Why, therefore, is there this sudden emphasis on sustainable palm oil? I see two reasons: first, growers want to emphasise that oil palm *is* sustainable. Unilever has a large project on sustainable agriculture, covering several different crops; when this project started in 1998, Unilever Plantations Group arranged for oil palm and tea to be included, with the intention of demonstrating that these crops are more sustainable than many others. The second reason is not so positive: oil palms grow in the tropics, where the climax vegetation is forest, and expansion of the crop into forested areas, particularly in Indonesia, is causing widespread alarm. Oil palm has been targeted as a major problem by NGOs concerned with the environment. It is not really the sustainability of the crop itself which is at issue here, but more the sustainability of land management. To many, oil palms planted in place of forest are ‘unsustainable’, regardless of how they are managed.

It is, of course, easy to say that oil palms are sustainable, but what do we mean by this? The simplest definition of sustainability is that it involves “meeting the needs of the present without compromising the ability of future generations to meet their own needs” (WCED, 1987). The definition of sustainable agriculture adopted by Unilever states that it “is productive, competitive and efficient while at the same time protecting and improving the natural environment and conditions of the local communities”. Well-managed oil palm plantations appear to meet these definitions, except that most plantations were established in place of forest. Destroying forest to plant palms has an irreversible effect for future generations, and does not ‘improve the natural environment’. It is this which concerns the NGOs, and there are those who believe that any deforestation is unacceptable, and who argue that ‘sustainable development’ is a

contradiction in terms. Robinson (2004) reviews this contradiction in detail. I think we must accept that ‘meeting the needs of the present’ requires agriculture, and that agriculture can only take place at the expense of the natural environment. I think it is also true that for future generations to ‘meet their own needs’, it is not necessary to preserve every square metre of the remaining natural environment. Thus I believe that sustainable development is a valid concept. The Brundtland report argued that ecological sustainability cannot be achieved if the problem of poverty is not dealt with. Oil palms have a clear role in reducing poverty in rural communities in the tropics.

It is important to define boundaries when discussing sustainability. As pointed out by Dibb (2004), the world will not run out of phosphorus, nor of potassium, nitrogen or any other nutrient element. As readily usable sources are exhausted, they will become more expensive to obtain, and will require more energy for extraction, but within the boundaries of the planet, total quantities will not change.

The only resources which cannot be replaced are fossil fuels and biodiversity. Soil is formed at rates of the order of 1 mm/10 years, or 1 ton/ha.yr (but varying greatly with parent rock, climate, terrain, vegetation type and management, and other factors). Strictly, therefore, soil is a renewable resource, but the rate of formation is very slow, and for practical purposes any measurable erosion is too much. Pollution is a major concern; in terms of long-term sustainability, pollution may destroy biodiversity, which may be irreplaceable. Greenhouse gas emissions are also a form of pollution.

To achieve true sustainability, therefore, as opposed to meeting one or another set of possibly arbitrary criteria, we must minimise fossil fuel use and soil loss, protect biodiversity, and avoid damaging pollution.

Measuring sustainability

I have stated that well-managed oil palms are sustainable, but what about less well-managed plantations? This is where indicators become necessary. A great deal of work has been published on this subject, and there are almost as many published indicator systems as there are definitions of sustainability. One approach is simply to define best practice; failure to implement this would then imply that the plantation was not sustainable. This is essentially the approach adopted by the RSPO (see www.sustainable-palmoil.org). There are two problems with this approach: it does not allow easily for development or improvement, and it is not clear how to treat a plantation which meets most, but not all, of the criteria. Rao (2004) has pointed out many of the faults with the RSPO criteria, and emphasised the need for practical planters to make an input before the criteria are finally adopted.

The Unilever project adopted a different approach, taking the view that it was essential to have quantitative criteria so that developments and improvements would be measurable. Quantitative criteria also allow different degrees of sustainability to exist. There are 10 indicator groups in the Unilever system, under each of which several parameters can be measured. Best practice guidelines based on these indicators have been published (Unilever, 2003), and areas for improvement were highlighted. The indicator groups, and the criteria within each group, are listed in Table 1, together with the relevant draft criteria from RSPO. There is a further section of the RSPO criteria dealing with establishment of new plantations;

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in the Unilever system, this aspect is not covered, but this is not because it is regarded as unimportant; on the contrary, it was agreed that the subject was too important to be treated as

Table 1 Unilever indicators and RSPO criteria for sustainable palm oil

Indicator	Unilever parameter	RSPO criterion	
Soil fertility	Organic matter content	3.1 Maintain and, if appropriate improve, fertility	
	Soil compaction		
	Soil pH and salinity		
Soil loss	Rate of soil erosion	3.2 Minimise and control erosion	
	Percent ground cover	5.2 Avoid use of forest soil	
	Forest soil not used for nursery		
Nutrients	Ratio of nutrient exports to inputs	3.3 Maintain quality and quantity of fresh water 6.1 On and off site impacts assessed and managed	
	Amount of biological N fixation		
	N and P loss to ground water		
Pest management	Extent of adoption of IPM (checklist)	4.1 Effective management with minimal pesticides	
	Pesticide loss to ground water	5.2 Minimise chemical pest control in nursery	
		3.3 Maintain quality and quantity of fresh water	
	Pesticide toxicity	6.1 On and off site impacts assessed and managed	
Operator safety (checklist)	4.2 WHO class 1A/1B pesticides not used; pesticide use to minimise health/environmental risks		
Biodiversity	Crop genetic diversity (checklist)	5.1 Planting material of highest quality available	
	Biodiversity within estate and 'footprint' (checklist)	7.1 Understanding of species in and round estate	
		7.2 Plan to conserve and restore biodiversity in and round estate to be developed and implemented	
Product value	Profit per unit product	2.1 Planning aims at long-term economic viability	
	Prices relative to commodity index	2.2 High productivity and quality of produce 2.3 Plantation and mill procedures documented 8.4 Strategies to reduce pollution to be developed	
	Quality (contamination, complaints - checklist)		
	Solid waste disposal (checklist)		
Energy	Energy use per unit product	8.2 Energy efficiency maximised	
	Proportion of renewable energy	8.2 Fossil fuel use minimised	
	Greenhouse gas emissions	6.1 On and off site impacts assessed and managed	
	Polluting gas emissions	8.2 Minimise all emissions, including GH gases	
		8.4 Strategies to reduce pollution to be developed	
Water	Field water management / irrigation (checklist)	6.1 On and off site impacts assessed and managed 8.1 Waste minimised, disposed of responsibly 8.4 Strategies to reduce pollution to be developed 3.3 Maintain quality and quantity of fresh water	
	Factory water use per ton of product		
	Renewability of water sources (checklist)		
	BOD and COD of effluent		
Social and human capital	Employee turnover rate	10.1 Acceptable pay and conditions	
	Grievance procedures (checklist)	9.3 Documented grievance system implemented	
	Housing, welfare, medical facilities (checklist)	1.1 Compliance with applicable laws & regulations	
	Land tenure (checklist)	1.2 Right to use land / customary rights of others	
	Relations with local community (checklist)	9.2 Effective communication and consultation with local communities	
	Relations with suppliers and market (checklists)	12.1 Deal fairly with smallholders / local businesses	
	Relations with government (checklists)		
	Health, nutrition and safety of workers	11.1 Health and safety programmes	
	Training (days per worker)	13.1 Staff and workers adequately trained	
	Education of workers' children (checklist)	10.2 No child labour, except in family enterprises	
	Company contributes to savings or pension plan	9.1 Social impact assessment required	
	Local economy	Proportion of goods and services sourced locally	12.2 Contribute to local development where possible
		Money spent locally	
Contribution to national economy (money, added value)			

just one among 10 indicator clusters, and it should be tackled separately. Also the Unilever system aims to describe sustainable agriculture, which presupposes that agriculture exists. Land use and deforestation are parts of the wider subject of sustainable development.

Unilever indicators

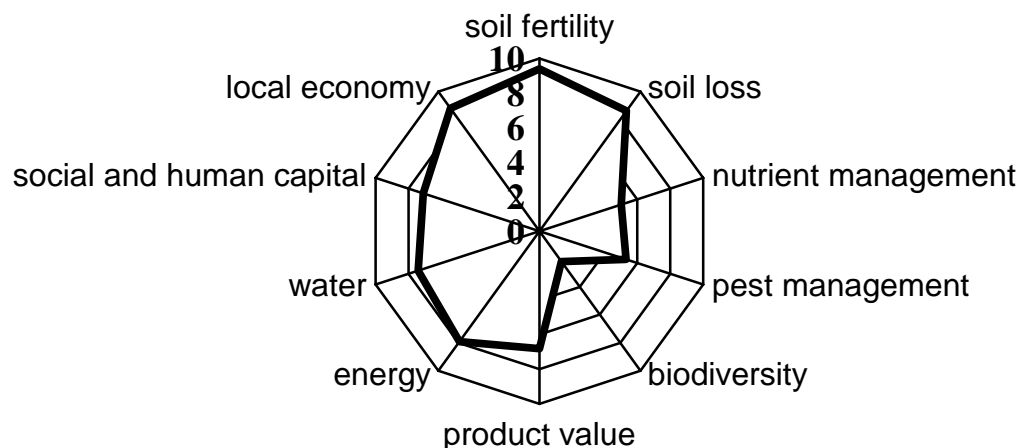
I will briefly discuss each of the Unilever indicators, and the scope for improvement. An attempt was made to choose parameters which met the following criteria:

- Input data should be available, or practicable to collect
- The parameter should be appropriate in all areas where the crop is grown
- The output should be quantitative or semi-quantitative
- The output should be sensitive to change, with alterations in management practice causing changes in values

The most difficult of these requirements was that for a quantitative output, but all the parameters can be scored in some way; for some this is by physical measurement and comparison with a standard or baseline (eg. soil organic matter; N level in ground water; BOD in effluent), but for others quantification is by degree of compliance with a check list (eg. adoption of IPM; renewability of water sources). Figure 3 shows an example of these scores, set out to emphasise where the greatest scope for improvement lies.

Figure 3 Unilever sustainability scores for a typical oil palm estate

The parameters in each indicator cluster are combined to give a total score between 0 (unsustainable) and 10 (fully sustainable)



Soil fertility - Soil organic matter content should be maintained or improved under oil palms; pH is only problematical on particular soils. Salinity could be a problem where irrigation is done in a very dry climate, such as is proposed in parts of India.

Soil compaction could become a limitation with increasing mechanisation (eg. Teo et al, 1996). This can usually be rectified by deep ploughing at the time of replanting (Caliman et al, 1990).

Soil loss - Some erosion is unavoidable. Ideally, the rate of soil loss should not exceed the rate at which soil is formed, but this may be difficult to achieve. Methods of controlling soil movement (mulching, ground cover) and soil loss (terracing, silt pits) are well known, but there is no general agreement as to what slopes require which measures. The Universal Soil Loss Equation, normally used to estimate erosion rates given soil characteristics, slope and rainfall, might be used, with an 'acceptable' erosion figure as input, to estimate tolerable slopes for different soil types.

Nutrients - The main criterion in this cluster is the efficiency of use of supplied nutrients. This is generally low for oil palm, and there is clear scope for improvement, as discussed in more detail below. The other criteria are the amount of biological nitrogen fixation, and nutrient losses to ground water. In most plantations, N-fixation is only significant in the first 3 or 4 years out of 25, as the legumes are shaded out when the canopy closes. *Calapogonium caeruleum* is supposed to survive better under shade, but I have not seen any data on N-fixation under shade by this species; it is possible that it survives, but without fixing much N.

Pest management - In general, oil palms are not subject to major pest problems, and pesticide usage should be very low. The principles of integrated pest management are well understood in the industry, but where a problem does arise, there is still a tendency, even after half a century of IPM research on the crop (Wood, 2002), to spray first, and ask questions later. Some early work has also been forgotten; for example, for control of *Oryctes*, the recommended practice in Malaysia at present is to spray with pyrethroids. Spraying is either prophylactic, or started at infestation levels far below the economic damage threshold. The importance of cover crop in controlling the pest (Wood, 1968) is often played down or ignored, though Kamarudin et al (2003) noted that *Oryctes* was only found where the height of the cover crop was less than 80 cm. The poor score in Figure 3 reflects prophylactic spraying with pyrethroids. The other parameters in this cluster relate to pesticide toxicity, pollution, and operator safety.

Biodiversity - Maintaining genetic diversity of the crop itself is an important issue, included in the Unilever system. For the oil palm industry as a whole, this has been well covered by the prospection work of MPOB.

Biodiversity within the plantation is more difficult; in the Unilever system, there is a score for natural habitat quantity and quality within the plantation, but the problem with this is that biodiversity has no intrinsic value in agriculture (apart from pest control, which is dealt with under that indicator cluster), so where should the baseline be set? The biodiversity 'footprint' of the plantation can be estimated, in terms of off-site effects (pollution, illegal hunting and firewood collection, etc). As I have noted above, forest clearance is regarded as a separate issue in the Unilever system.

Product value - This indicator cluster is intended to cover economic sustainability. The simplest way to measure that is to look at the long-term trend in profitability, though profit is a) strongly influenced by commodity prices, which are outside the control of the plantation, and b) often confidential, and so may not usable as a yardstick. Another criterion is the

vulnerability of the business, assessed by comparing long term product price trends with a commodity index. The argument is that all commodity prices are declining, but provided that the prices a plantation is obtaining are not declining faster than average, the plantation should be able to remain in business.

Product quality is also dealt with here, in terms of residues and contamination, and also of complaints from customers.

Energy - Oil palm is a net producer of energy, but fossil fuels are usually used for transport, and domestic electricity supplies may also be imported from a national grid. Estates could be entirely self sufficient, if better use was made of the potential energy available. Husain et al (2003) have pointed out that there are much more efficient boilers available than those used in palm oil mills, but with a surplus of free fuel, there is little incentive towards greater efficiency. Quah and Gillies (1981) obtained about 5.46 GJ/ha.yr as usable biogas energy (after losses) from tank digestion of effluent; this should be sufficient to meet the energy requirement for transport and other engine use (irrigation, drainage, earth moving, roads, replanting) of about 5.14 GJ/ha.yr (Wood and Corley, 1993). There is also unused energy in other mill by-products: the calorific value of fibre and shell is about 49 GJ/ha.yr, of which only half is used for milling (Wood and Corley, 1993). The surplus could, and sometimes does, provide electricity for domestic use, or for export to the national grid. There is a further 26 GJ in EFB, but that has a high moisture content, so is difficult to burn, and is probably best returned to the field for nutrient recycling and mulch.

One of the Unilever parameters is greenhouse gas emissions. The gas from effluent digestion is about 60% methane, which is an important greenhouse gas. Burning the gas as fuel would convert the methane back to CO₂, which would be 'greenhouse neutral', as the plant material was derived from atmospheric CO₂ by photosynthesis.

Water - The main requirements are that water should not be polluted with mill effluent, and should not be extracted at the expense of downstream users. The latter point is particularly important if irrigation is done. Effluent treatment standards are now very high in the major palm oil producing countries.

Social and human capital - This cluster covers relations between the company and workers, the local community, suppliers and buyers, and government. Traditionally a plantation provided everything for the workers, in terms of services and facilities. This is sometimes seen as paternalistic, but it ensured that on most estates the workers' standard of living was above that of the surrounding population. There is now a trend towards employing workers from outside the estate, so that the large capital costs of providing housing can be avoided. This is understandable, and in terms of the employee's long-term security may actually be preferable to a company house, but it should not be seen as absolving the company of the responsibility to ensure that medical, education and leisure facilities are available. As countries develop, these are increasingly supplied by the state, but the company should ensure that standards are adequate, supplementing the state system if necessary. As an example, providing land, and helping to employ teachers, for state schools may be useful.

Local economy - The requirement here is to support the local economy wherever possible. Do not import goods or services from outside the country, or district, unless it is unavoidable.

Nutrient efficiency

I noted above that nutrients are not a non-renewable resource, so it could be argued that inefficient use does not matter. However, the energy required to mine or fix, transport and apply fertilisers is considerable, even from today's readily accessible sources, and as these sources are used up, the energy costs of extraction will inevitably rise still further. Fertilisers make up nearly 60% of the total energy input to the plantation (Wood and Corley, 1993), and are often also the greatest cost.

The Unilever system compares inputs and exports of nutrients. Nutrient budgets are often constructed using figures for exports in bunches, and data on nutrient content of FFB and its components are summarised in Table 2. There is some variation in the figures from different sources, but nutrient content of FFB is sure to depend at least in part on soil, and on fertiliser history, so variation is to be expected.

Table 2 Nutrient content of bunches

(data from Ng & Thamboo, 1967; Chan, 1999; Ma, 1999; Ng et al, 1999)

Component of FFB	Percent of FFB wt	Dry matter content (%)	Percent in dry matter				Nutrients in FFB (kg/t)							
			N	P	K	Mg	N	P	K	Mg				
Oil	24	24	0	0.02	0	0	0	0.005	0	0				
Kernels	6	80	1.3	0.30	0.43	0.16	0.62	0.14	0.21	0.08				
Shell	6	85	0.3	0.01	0.15	0.02	0.15	0.004	0.07	0.01				
Fibre	13	60	0.3	0.08	1.4	0.13	0.26	0.065	1.1	0.1				
EFB	22	35	0.8	0.09	2.7	0.12	0.6	0.07	2.1	0.09				
Effluent	70	5	percent fresh weight				0.08	0.002	0.23	0.06	0.58	0.014	1.6	0.42
Total nutrients in FFB (from above)							2.2	0.3	5.1	0.7				
Total (Ng & Thamboo, 1967)							2.9	0.5	3.7	0.8				
Total (Ng et al, 1999)							3.3	0.5	4.3	1.1				

In fact, the only products exported from the plantation (as opposed to the individual field) are oil and kernels. Palm oil contains no N or K, and only about 20 g of P per ton. A ton of palm kernels contain about 13, 3 and 4.3 kg of N, P and K respectively (Ng and Thamboo, 1967). With a yield of 6 t/ha.yr of palm oil and 1.5 t of kernels (approximately 30 t FFB/ha) the nutrients exported are equivalent to about 0.7 kg ammonium sulphate, 0.4 kg rock phosphate and 0.1 kg potassium chloride per palm. Typical inputs in Malaysia are at least 3, 1 and 3 kg per palm.yr of these fertilisers, so efficiencies are roughly 23%, 40% and 3%, or an overall 17%.

For NBPOL, N, K and Mg are applied, the last in the form of Kieserite. Magnesium exports are about 1.6 kg/t of kernels (Ng and Thamboo, 1967), or 2.4 kg/ha (0.02 kg/palm) at the yield level mentioned above. Average mature inputs over the last 9 years at NBPOL have been about 1.1 kg N, 0.2 kg K and 0.1 kg Mg per palm. Efficiencies are thus about 15%, 26% and 19% for N, K and Mg. Overall, including P exports, efficiency is about 19%.

If less than 20% of the nutrients supplied are exported, what happens to the rest, and why are the optimal levels determined in trials so much higher than the rates of export? The obvious answer is that nutrients are required for vegetative growth, as well as for bunch production.

However, once the fertility of a plantation has been built up, it should be possible, theoretically at least, to recycle these nutrients so that further inputs are unnecessary. Thus the low efficiency may be at least partly due to poor recycling. Other possibilities include immobilisation in the soil, leaching or run-off losses, and (for urea as an N source) volatilisation, but it is recycling which I shall discuss here. Bunches and vegetative tissues both contain large quantities of nutrients, which need to be recycled.

Recycling from bunches

Most of the nutrients in harvested bunches are found in the mill by-products EFB, mesocarp fibre, and mill effluent (see Table 2).

Fertiliser trials and recycling - The first point to note in relation to recycling of these by-products is that in fertiliser trials, apart from those in which EFB or effluent is a treatment, there is usually no recycling. In conventional fertiliser trials, EFB is not applied as it would interfere with the treatments. Thus the trial will estimate the nutrients required to replace exports in bunches, not just in kernels. Bunches contain about 4 times more N and 20 times more K than that in the kernels alone (Table 2), so optimal nutrient application rates with recycling are likely to be much lower than indicated by most fertiliser trials.

Application rates - EFB and effluent solids are normally put back into the plantation, and this is described as recycling, but the industry started out with a waste disposal problem, and that is still the underlying attitude to these two by-products. Both EFB and effluent are normally spread over relatively small areas, to keep down the costs of disposal. After processing, 30 tons of FFB will give about 7 t EFB, so to recycle the nutrients precisely, 7 t EFB/ha.yr should be applied to the whole mature area, but application rates of up to 50 t/ha to much smaller areas are the norm. Similarly with effluent, 30 tons of FFB will give about 21 t effluent; for field application of the liquid, this is equivalent to about 2 mm of water, but application rates are typically 10 to 100 times greater. Various authors have calculated the fertiliser equivalent of EFB or effluent, and estimated application rates from those figures and the optimum fertiliser rates from trials (eg. Lim et al, 1999), but as noted above, the optimal rates indicated by conventional trials are much too generous where recycling is done.

Nutrient losses - Digested effluent apparently contains only about one third of the nitrogen present in raw effluent (Ng et al, 1999); the rest is presumably volatilised as ammonia. For full recycling, therefore, it would be necessary to apply raw effluent. Early work with raw effluent was abandoned, partly because of the smell, and partly because of the risk of contaminating water courses. However, as already noted, the rates of application in the early trials were far above those required for nutrient recycling, and with lower rates both smell and risk should be reduced.

An alternative to field application of effluent is to compost effluent and EFB (Lord et al, 2002). The water in the effluent is evaporated, which eliminates the risk of run-off into water courses. However, I have not seen any figures on nutrient content of the resulting compost, nor any estimate of losses during composting. If biogas is to be generated (see above) the value of the gas needs to be compared with the value of any nutrients lost in digestion.

The best use for fibre and shell is probably to burn them as fuel, but the nitrogen in these by-products is lost in burning. The other nutrients can be recovered from boiler ash, which should be used as fertiliser rather than as land-fill. A modern mill does not usually need to

use all the fibre and shell for processing; alternative uses, such as making activated charcoal, will increase nutrient exports, and these exports must be costed. The most economic use is probably to generate extra power for domestic use or export to the grid (thus retaining all nutrients except the nitrogen).

Smallholders - Smallholders are at a large disadvantage where nutrients are concerned. The comment was made to me that “at NBPOL fertiliser trials show no responses, although it is obvious that smallholder plots not receiving fertiliser are deficient, at least in nitrogen”. In most situations the smallholder sells bunches, and no attempt is made to return EFB or effluent to smallholdings. In effect, therefore, the smallholder subsidises the fertiliser bill of the company buying his fruit; he exports nutrients, which are then recycled into the company’s plantations. The RSPO criteria state that the company should ‘deal fairly with smallholders’; in terms of nutrients, this would require either that waste products are returned to the smallholding (composting could be useful here), or that the price paid for FFB reflects the nutrient content, as well as the oil content.

Recycling from vegetative tissues

Trunk, leaves and roots all contain large quantities of nutrients. During the life of the plantation, the nutrients in roots and leaves are recycled automatically. Roots die and are replaced on a regular basis, while leaves are pruned, stacked or (preferably) spread, and left to decay. However, problems arise at the time of replanting. Table 3 summarises data on the nutrient contents of vegetative tissues in palms about 25 years old. Total dry weight data are very few, and nutrient contents vary depending on fertiliser application and soil type (Teoh & Chew, 1988), so these figures can only give a rough indication of the quantities of nutrients locked up in the palms.

Table 3 Nutrient content of palms at time of replanting (dry weights from summary in Corley & Tinker, 2002; nutrient percentages from Ng et al, 1968)

Tissue	Dry weight		Percent in dry matter				Total nutrients (kg/ha)*							
	kg/palm		N	P	K	Mg	N	P	K	Mg	N	P	K	Mg
	min	max												
Trunk	300	450	0.5	0.05	1.6	0.15	192	19	614	58	288	29	922	86
Leaves	95	340	1.2	0.11	1.3	0.21	146	13	158	26	522	48	566	91
Roots	60	250	0.3	0.03	0.8	0.07	23	2	61	5	96	10	256	22
Total nutrients in vegetative tissues							361	34	833	89	906	87	1744	199
Teoh & Chew (1988), 19 year-old palms, alluvial soil											-	-	2104	-
Khalid et al (1999a, b), 23 year-old palms, inland soil											642	58	1384	156

* based on 128 palms/ha

After felling, these nutrients are quickly released. Khalid et al (2000) showed that 18 months after felling, 60-70% of N, 85-90% of P and virtually 100% of K had been released from trunk sections. With the chipping and pulverising methods currently advocated in Malaysia, release is probably even more rapid. Khalid and Basri Wahid (2004) advocate using trunk chippings as mulch for the young palms, to improve nutrient recycling, but the young palms cannot take up nutrients at the rate they are released. Estimates of the total nutrient content of 2½ year-old palms are given in Table 4. The amount of nitrogen is 24 - 60% of that available from the old stand, and of potassium only 13 - 33%. The cover crop will also take up some of the nutrients; Han & Chew (1982) recorded a maximum K-content of 223 kg/ha

in the cover crop plus leaf litter, 24 months after planting. This is equivalent to 11 - 27% of the K in the old stand. Thus the K uptake by young palms plus cover crop, over the first 24 months after planting, is equivalent to between 24 and 60% of the K available from the old stand. Han and Chew also found a high nitrogen content in the cover crop (nearly 400 kg/ha), but much of that presumably came from fixation, rather than uptake from the soil.

Table 4 Nutrient content of 2½ year-old palms
(dry weights from Corley & Tinker, 2002; nutrients from Ng et al, 1968)

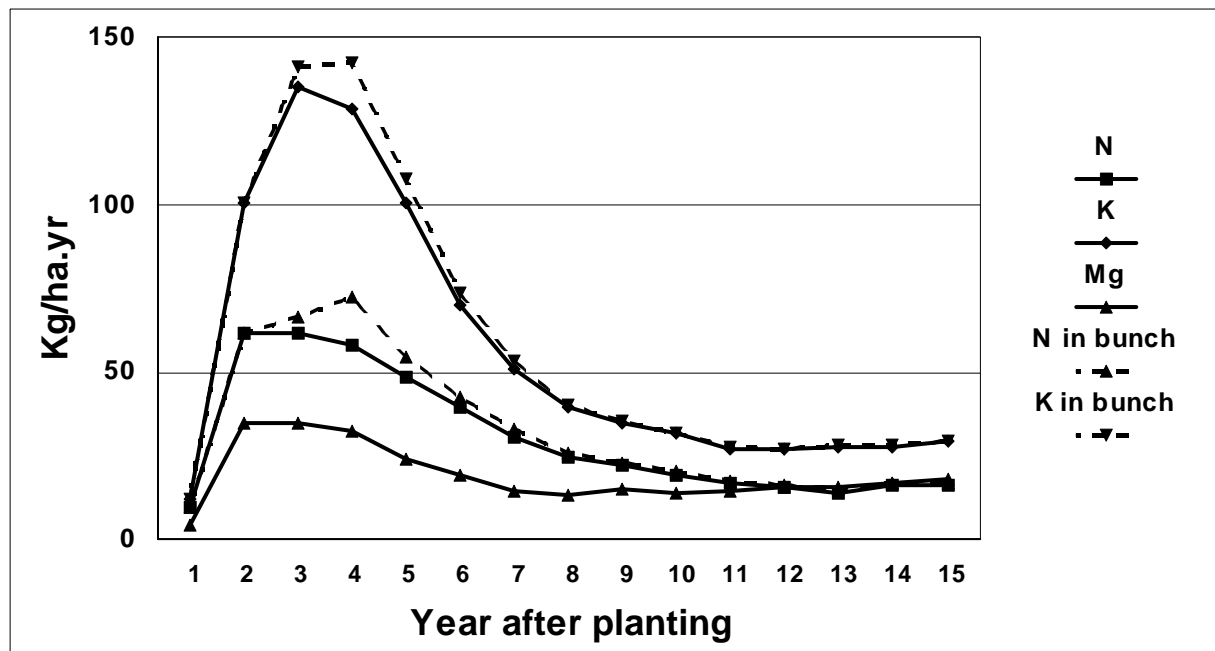
Tissue	Dry weight kg/palm	Percent in dry matter				Total nutrients (kg/ha)*			
		N	P	K	Mg	N	P	K	Mg
Trunk	20	1.0	0.14	2.3	0.22	29	4	66	6
Leaves	105	1.2	0.11	1.2	0.21	180	16	180	32
Roots	17	0.5	0.04	1.2	0.14	12	1	29	3
Total nutrients in vegetative tissues						221	21	275	41

* based on 143 palms/ha

Before deciding how best to recycle the nutrients in the old stand, it is also worth considering the time course of nutrient uptake by the replant. Figure 4 shows annual nutrient uptake into vegetative tissues, based on data from Ng et al (1968) (but adjusted for the fact that their trunk weights included leaf bases). Requirements are greatest in years 2 to 5 or 6 after planting; during that period, the canopy is expanding, with leaves reaching their maximum size by about year 9. Thereafter, the nutrient content of leaves, and probably also roots, remains more or less constant. The only continuing requirement is for trunk growth. The nutrient contents of bunches developing on the palm are also shown in Fig. 4. These are very small relative to vegetative needs, because less than half the annual crop is on the palm at any one time, and most of those bunches are not yet fully developed.

The K contained in leaves and roots is probably sufficient to meet the young palms' requirements over the first 2 or 3 years. As roots, and to a lesser extent leaves, are not easily removed from the replanting site, they are probably best left *in situ*. Leaf petioles can be used to mulch the young palms, while rachises and leaflets, which will decay faster than petioles, can be spread to provide nutrients for the cover crop, and to help control erosion until the cover crop is established.

Figure 4 Annual nutrient requirements of oil palms



We are then left with the trunks. If these are windrowed in the replant, the nutrients will be released in the first 2 years, when they are surplus to requirements. The situation is improved if replanting is done by underplanting. Clendon et al (2004) recommended felling half the old stand before planting the young palms, with the other half felled 2 years after planting. This will spread the nutrient release over the first 4 years, rather than just the first 2 years. However, the K requirement for the first 5 years is still only 25 –50% of that available (more, if cover crop is included, but by the fifth year the covers will be dying back and releasing nutrients).

It would be more efficient to distribute the trunk tissue as fertiliser to fields of older palms. The best way to do this would probably be to chip or pulverise the trunks before transporting them out of the field. Pulverised material could then be spread using a conventional muck spreader. It will be argued that this is too expensive, but if we consider that much of what is currently spent on fertiliser might be saved if nutrients were more effectively recycled, then I think it is worth looking into the possibilities in more detail.

Conclusion

Oil palms are sustainable, but improvements are possible. IPM principles are not universally applied, and the efficiency of nutrient use is very low. Recovery of nutrients in bunches should be improved by extending the areas over which EFB and effluent are applied, with raw effluent being preferable to digested. The nutrients in the old stand are released faster than the young palms can take them up, and could be better utilised either by underplanting, or by distributing trunk tissue as fertiliser to mature palm areas.

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