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BEST-DEVELOPED PRACTICES AND SUSTAINABLE DEVELOPMENT OF THE OIL PALM INDUSTRY

CHAN KOOK WENG*

ABSTRACT

The long-term economic viability of any crop production system is dependent on implementation of its best-developed practices (BDPs). Improperly managed, any resource can pollute the soil, water and air. The growing challenge for agriculture is to find ways to increase crop yields and improve nutrient use efficiency while stabilizing nutrients, replacing those removed in the harvested crop, recycling those in the crop residues and ultimately retaining them in the soil organic matter. Nutrient balance management is the most significant BDP that has evolved to be site-specific and cost-effective in palm oil production. The practice of nutrient balance management is, at the same time, accompanied by protection of the soil, water and air resources. This would result in not only protection from surface runoff and leaching but also in the reduction of gaseous emissions.

The management policies on BDPs now require plantations, firstly, to look at protection of the physical environment such as the air, soil and water. Secondly, to look at the impact of chemical environment such as pesticide usage, nutrient balance and soil organic matter on chemical pesticides in palm oil; and, thirdly, at maintaining the biological environment such as biodiversity, high yielding planting materials and reduced weeds, pests and diseases. There are also a host of other objectives imposed on the palm oil industry that arise from the globalization of its trade. They include challenges such as overall ecosystem protection, food security and sustainability with the aim of slowing down climate change by stabilizing greenhouse gas (GHG) concentrations. This implies using less energy inputs on resources like pesticides and fertilizers.

From this review of the important future challenges, there is no reason why the oil palm production system, using the latest BDPs, cannot sustain its high yield while protecting the environment. As per Article 2 in the United Nations Framework Convention on Climate Change (UNFCCC), the triple requirements of ecosystem protection (ecological), food security (social) and sustainable economic development (economic) can be met. There is now a need for the oil palm industry to demonstrate this inherent strength of high productivity without undue imposition on the limited world resources.

Keywords: best-developed practices, sustainable development, nutrient balance, greenhouse gas (GHG) reduction, climate change.

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INTRODUCTION

The greatest challenge to plantation agriculture is to continually increase its yield per unit land area in order to meet the demand for food by the growing world population that is currently six billion and projected to reach eight billion by 2025. Sustainable

* Malaysian Palm Oil Board,
P. O. Box 10620,
50720 Kuala Lumpur,
Malaysia.
E-mail: chankw@mpob.gov.my

oil palm cultivation dictates that the best agro-management techniques be compiled with a systems approach and be made available to the plantations involved. Such a compilation of the BDPs for implementation must be in accordance with the way nature aspires, provide food for society's needs, and ensure a safe and viable environment, by maintaining the very ecological base on which agricultural production is dependent upon. Progressive agriculture is intrinsic to sustainable development.

Up to now, most of the BDPs have emphasized solutions to one or more of the triple pillars of sustainable development - economic, social and ecological. The time has come for the BDPs to contribute to the stabilization of atmospheric GHG concentrations. This paper draws together a generic selected lists of BDPs from the physical, chemical and biological environments currently in use that can increase yield but yet address the issue of climate change. These BDPs are highly cost-effective, non-capital intensive, and ecologically and culturally sound. They are also easily replicable, up scalable and can be incorporated into the agricultural policies of the plantation with ease.

THE APPROACH

Many individual plantation groups have themselves reported several BDPs that have improved the social, economic and environmental aspects in their local situations. These BDPs have kept the companies profitable and viable. In the early 1990s, the question of how best to introduce these BDPs into other plantations and to make them perform just to well if not better, was examined (Chan, 1993). Since then, the pace of introducing more BDPs has gathered momentum as several new advances in agronomy and management practices have been brought in. Many of these newer BDPs have the potential to make the industry even more competitive (Chan, 1995a). Sustainable agriculture then becomes the clarion call made several years ago (Chan, 1995b) and the oil palm industry soon becomes the champion for the protection of its own environment. In fact, as early as the 1970s, Corley *et al.* (1976) had pointed out that in a developing economy like Malaysia, mechanization, while raising productivity and reducing the input per unit land area, would lead to an increasing dependence on fossil fuels. This has now become an increasingly relevant point in light of the call to the plantations to reduce GHG emissions from the use of fossil fuels. Wood and Corley (1991) subsequently showed that the oil palm industry being highly energy efficient should exploit its energy resources, and even Pauli and Gravitis (1997) had called for zero emission from its fuel sources.

Later, with further developments on the pressure to go for emission reduction targets by developed countries resulting from globalization, the palm oil trade saw several plantation companies coming out with their own guidelines for sustainable production (Rushworth, 2002; Tek and Chandran, 2002; Basri *et al.*, 2002). These groups assembled many valuable good agricultural practices that were not only useful but which had actually the potential to contribute to the well-being and profitability of their plantation operations. Although some of these BDPs may have evolved from the specific social and cultural conditions of individual plantations, their use can nevertheless be expanded to benefit other plantations as well. Very often, the BDPs of a particular plantation can be replicated in another plantation with only some modifications to suit the specific circumstances of the recipient plantation.

The Criteria

For any scientific finding/experience/practice to be classified as a BDP, it must meet one of the following criteria:

- the BDPs must improve on the current position, welfare and quality of life of the people in the individual estates initially, and then over the plantation group subsequently;
- it must be innovative in meeting the socio-economic needs;
- it must be environmentally sound and sustainable;
- it must have a significant impact environmentally, socially and economically over the existing policy; and
- it must provide a solution to an existing problem yet only use local materials and knowledge where possible.

The Reporting of a BDP

For each finding/experience/practice to be qualified as a BDP, there has evolved a common framework in which the information and analysis for reporting a BDP must follow:

- a description of the finding/experience/practice;
- a description of the institution responsible for the BDP;
- statement of the problem addressed or the socio-economic need served by the finding/experience/practice;
- the benefit of the finding/experience/practice over the current performance;
- the problems and obstacles encountered and how they were overcome;
- the possibility of upscaling;
- the significance on policy-changes and the impact on existing policies; and

- the possibilities and scope for transferring or replicating the finding/experience/practice to other companies or countries.

Analysis of BDPs

The analysis of BDPs used in plantation agriculture, as recorded in the many technical agricultural policies of plantation companies, is based on the information provided by the major plantation companies in six sub-sectors. They include many of the best agricultural and processing practices that fitted into a framework. They are compiled from the physical, chemical and biological improvements to the environments when these BDPs are implemented.

- From the physical environment, there are the BDPs which improve on water, the soil, radiation, interception, wind breaks, topographic and terrain modifications.
- From the chemical environment, the BDPs are on providing nutrient balance and maintenance of organic matter to preserve the inherent soil fertility and integrated pest management to reduce pesticide usage.
- From the biological environment, there are BDPs for the improvement in nursery and planting materials, optimum age of field planting, the areas to be planted by each age groups, harvesting operations, improve fuel consumption in mechanization, and use of natural bio-pesticides for control of weeds, pests and diseases.

There are, of course, BDPs that straddle all the three areas, especially those in downstream processing. Here the emphasis is on BDPs that have linkages with all the six sub-sectors. The synergy arising from the linkages of these BDPs is explored. The analysis, done by broadly classifying the BDPs into the six sub-sectors of land use change and conservation, agricultural practices, processing, waste management, transport and mechanization, and energy, is shown in *Table 1* to show the generic practices. This would enhance their usage in all plantations as they may vary slightly in their implementation.

FRAMEWORK FOR SELECTING AND IMPLEMENTING BDPs IN NEW POLICIES AND MEASURES

The process for selecting a BDP for inclusion as a new policy has been honed using a well-trodden path way. Plantation companies use the framework in *Figure 1*.

To include a BDP into a new policy, it is guided by a number of instruments such as economic, fiscal, voluntary, informational, educational, public awareness and research. These instruments are to ensure that each BDP has been well tested to suit initially the local conditions and that the benefit is not only technical but also has socio-economic and environmental importance. They are several steps in proving that a BDP for its usefulness. When a benefit is claimed, the first step is to publish the finding in the company's internal publication/ communication. This is for awareness. It may simultaneously be published in journals or presented in seminars and conferences for technology transfer. The aim is to inform the plantation industry and, at the same time, educate it. Implementation of the finding is voluntary at this stage, especially by other

TABLE 1. CLASSIFICATION OF THE BDPs THAT INCREASE YIELDS AND IMPROVE THE ENVIRONMENT INTO SIX SUB-SECTORS

Land use change and conservation
- Protection and sustainable management of the plantation.
- Conservation of soil, water, air, biodiversity and wildlife.
- Enhancing the carbon sink capacity of the soil and plantation crop.

Agricultural practices
- Practise zero burning and establish a legume ground cover.
- Reduce nutrient runoff, leaching and volatilization.
- Exploit genotype x environment interaction of high yielding materials.
- Improve the environmental performance of energy-intensive nutrients with recycling, and use of bio-pesticides through biological control of weeds, pests and diseases.

Processing
- Promote sustainability with emphasis on improved food quality, safety and rural development.
- Reduce emissions of GHG during the processing of by-products.
- Reduce waste at source from milling and refining.
- Improve efficiency of industrial processing.

Waste management
- Waste minimization and recycling.
- Reduce waste impact on soil, air and subterranean water.
- Capture methane from effluent ponds.

Transport and mechanization
- Improve air quality management.
- Reduce soil compaction from mechanization.
- Reduce fossil energy requirement through use of renewable energy and energy efficiency.

Energy
- Promote energy efficiency in supply and end-use sides.
- Promote the growth of energy sector in the plantations.
- Promote carbon emission trading through carbon credit earned from efficient use of resources in mills.

companies, but for the company discovering the finding, implementation will allow the problems in upscaling and application to another site to be learnt quickly. Modifications are made, either technical or socio-economical or both for better improvement.

Under technical improvement, the potential gains are also examined from the physical, chemical and biological environments. The improvements, listed as A-G, *etc.*, can come from a number of areas such as a yield increase, higher productivity, higher earning, less labour requirement, less soil compaction, *etc.*

Non-technical improvements would have to be assessed under the local conditions of the estate from four angles. They are, firstly, from the management point of view, whether the workers are committed and interested in achieving the goals set for them. Secondly, whether the management has benefited from the new uses of resources of land, capital and labour? Thirdly, does the management need to re-engineer the attitude of the workers? Or are they still sticking to their old ways of doing things? Or do they, finding their needs not satisfied, fail to pitch in to realize the management targets? Fourthly, the re-engineering of attitudes must be done considering the different anthropological backgrounds of the labour force – are they Malaysians, Indonesians, Filipinos or Bangladeshis? Finally, the quality of the commitment of the executive and staff members is also important in motivating the workers.

The framework allows feedback for fine-tuning in order to realize the full potential of the technical improvement. The feedback on socio-economic aspects is whether the finding has been accepted widely as a BDP. Only after a period of testing will the new BDPs, designated X_2 or Y_2, be allowed to replace the old BDPs designated X_1 and Y_1. When the new BDP is finally incorporated into the company policy, it is allowed to be implemented throughout the plantation group. However, further minor modifications may have to be made for the different individual sites, prompting the need for site-specific recommendations for each BDP.

LISTING OF BDPs IN OIL PALM PLANTATIONS

Classifying BDPs in Sub-Sectors 1: Land Use Change and Conservation and 2: Agricultural Practices under the Three Environments of Physical, Chemical and Biological Factors

From the analysis of the BDPs in *Table 1*, the two major sub-sectors of, firstly, land use change, soil and water conservation, and, secondly, agricultural practices, are expanded to show the more important BDPs under the three environments of physical, chemical and biological factors. Soils, for example, can be evaluated on these three factors (Paramananthan *et al.*, 2000). The BDPs are tabulated in following T*ables 2, 3, 4a* and *b*. It is also possible to project the BDPs in a systematic approach based on the various phases of development of the oil palm plantation.

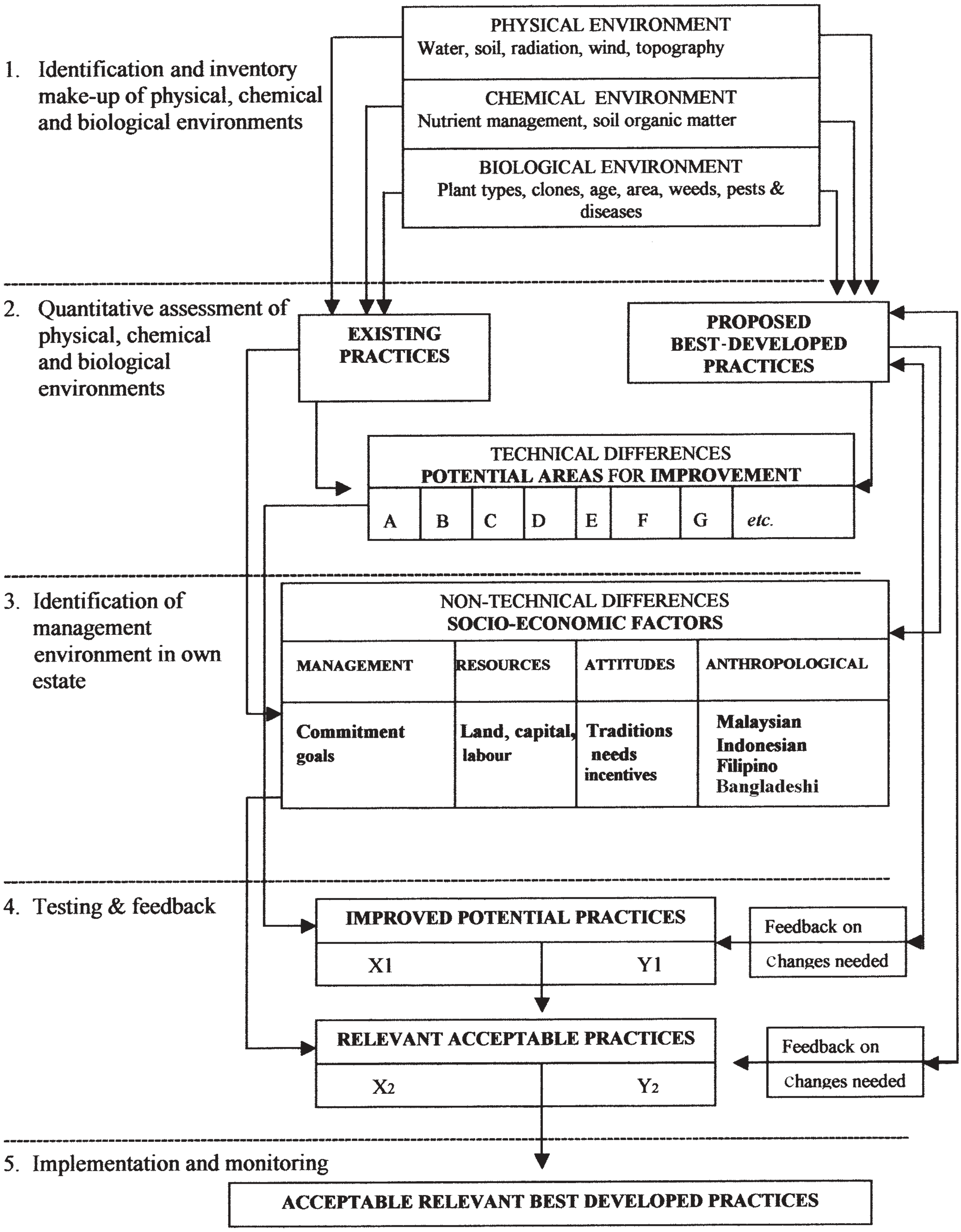
a. Physical environmental factors. In the systems approach for raising yield, the yield-defining physical factors like climate, soils, site environmental variables such as sunshine, rainfall, temperature, incident radiation and the canopy of the palms, are taken together to determine the growth rate and yield. Together, they form the major category of growth-defining factors that are physical in nature but yet must be managed. Some of the BDPs are shown in *Table 2*.

TABLE 2. BDPs FOR SUSTAINABLE DEVELOPMENT UNDER THE PHYSICAL ENVIRONMENT

Planning
- Carry out an Environment Impact Assessment (EIA) prior to development of the plantation or change of planting materials.
- Evaluate the land use change and soils by encompassing the physical, social and financial factors.
- Provide a management plan for biodiversity.

Development
- Conserve forest areas, especially those with high conservation value (HCV).
- Retain buffer zones, *e.g.* wildlife corridors and riparian strips.
- Zero burning of debris to improve the soil health with emphasis on microbial diversity.
- Construct contour terraces in undulating to hilly terrain.
- Establish legume covers for soil protection and for building up of organic matter and soil N.
- Harvest rainfall, minimize runoff, prevent soil erosion, and maintain natural ground cover.
- Drain low lying areas, maintain the water level in peat and acid sulphate soils.

From *Table 2*, the emphasis in planning a plantation is in improving the sustainability of oil palm cultivation. This is done, as shown by the BDPs implemented, by protecting the biodiversity. The BDPs are integrated to conserve the maximum biodiversity within the economic constraint. It is hoped that a model system will evolve in which these groups of BDPs serve as a benchmark for environmentally-friendly planning protocols for a biodiversity action plan to suit the local conditions. A database on the differences in microorganisms, invertebrates and bird, plant and mammalian communities between natural forests and plantations is being compiled for functional agricultural bio-diversity. Samples from forests will provide the baseline targets for assessing the BDPs and improvements will be suggested as more data are obtained and become available.



Source: Adapted from Chan (1993).

Figure 1. A framework for implementing best-developed practices phases.

b. Chemical environmental factors. Besides the soil, moisture and climate as yield-defining factors, the nutrient supply may also be limiting to palm growth and yield. Proper nutrient management has been and continues to be important for high yields. Nutrients which are yield-limiting must be applied at the correct amounts and time (Chan, 1999). The soil must be maintained fertile to keep any nutrient from being limiting. For this, the BDPs for crop balanced nutritional needs are detailed in *Table 3*.

TABLE 3. BDPs FOR SUSTAINABLE DEVELOPMENT UNDER THE CHEMICAL ENVIRONMENT

Immature phase
- Build up the potassium status in the palms prior to the first harvest.

Mature phase
- Manage the ground cover with judicious use of pesticides/IPM for legume purification to ensure persistence.
- Place pruned fronds on the lips of terraces and in between inter-rows to recycle organic matter, conserve moisture and prevent erosion.
- Apply empty fruit bunches at replanting.
- Apply treated POME for nutrient recycling and moisture conservation.
- Practise discriminatory fertilizer application based on the individual nutrient needs of the crop as assessed from soil and foliar analyses and responses from fertilizer trials.
- Integrate precision agriculture to accommodate the soil variability through variable rate technology.
- Maintain a nutrient export/input balance at each site with a yield target of 35 t ha^{-1} yr^{-1} FFB.

Understanding the site-specific optimum nutrient rate, and time and method of application is essential for the improvement of crop yield, quality and profitability while protecting the environment. Soils, when properly managed with the application of mineral fertilizers and recycling of by-products from the plantation like pruned fronds, empty fruit bunches and palm oil mill effluent can increase productivity and enhance sustainability. More importantly, it can increase carbon sequestration and act as sinks when the debris breaks down over four to five years.

With the appropriate BDPs in place, the challenges with both the application of mineral fertilizers and by-product recycling will be to ensure a balanced nutrition in which N, P, K and Mg are at the optimum levels. The organic mulch used must be allowed to decompose so that the nutrients they contain can be released in the inorganic form, the only form usable by crops.

Soil organic matter (SOM) has long been recognized to have a positive effect on the soil structure, tilth, bulk density and moisture holding characteristics. The SOM increases the soil cation exchange capacity (CEC), reduces runoff and erosion losses. The SOM retains a significant amount of P yet reduces P fixation. Excess NO_3^- in the ground water will pose a potential threat to humans, and contamination is more likely in sandy soils without SOM than in clays or clayey loams that drain slowly and allow denitrification to reduce the NO_3^- leaching to the ground water.

As regards air quality, ammonia (NH_3), hydrogen sulphide (H_2S) and other gases like methane from effluent ponds can contribute to the GHGs causing global warming. Carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_20) from nitrogene fertilizers are the most important GHGs associated with agriculture. CO_2 is already reduced with the BDP of zero burning. Efforts are underway to capture the methane as biogas for fuel, while N_2O, arising from the denitrification of all forms of N fertilizers, both inorganic and organic, can be minimized by the proper application of fertilizer and mulch.

The oil palm is a good sequester of CO_2 and the plantation has a great potential to store carbon in both the debris in soil and standing biomass in vegetation. Basically, we need to build up the soil OM level and improve its fertility to produce more yield per unit area. Recent studies have confirmed that improving the OM level will improve the N level, as both organic N and C are highest with soil conservation and recycling of the crop residues. Such BDPs when practised together will result in balanced supply of nutrients through improved soil fertility which should increase the crop yield.

c. Biological environmental factors. The biological factors form the third category of growth and yield. Generally they are the yield-limiting factors. There are two aspects. Firstly, the planting materials set the yield potential. The planting materials should be carefully chosen for particular sites. This is to ensure that the site x environment x nutrient interaction is exploited synergistically to obtain the highest yields. However, each site-specific environment should also be considered for its yield-reducing factors. They include above- and below-ground micro fauna and flora such as pathogens, insects, weeds, pollutants of the air, water, soil, and the extremes in weather caused by haze, cold and high temperatures, and drought associated with the *El Nino* phenomenon. It may well be to consider that some of the weed, pest and disease problems have resulted from disturbance resulting in imbalance where the biodiversity is being reduced. The two aspects of i) setting the yield potential, and ii) yield reduction by the biological environment are detailed in *Tables 4a* and *b*.

TABLE 4a. BEST-DEVELOPED PRACTICES FOR SUSTAINABLE DEVELOPMENT IN THE BIOLOGICAL ENVIRONMENT

i. Yield Potential Setting

Nursery practices

- Use top-soil only from disease-free areas, supplemented where possible with EFB compost or effluent solids mixed with soil and oil palm shell or fibre as mulch in polybags.
- Cull stringently in the pre-nursery stage prior to transplanting into big polybags at three months to ensure that only good healthy palms are planted in the field eventually.

Planting materials and clones

- Plant the right mix of legume covers with correct seeding rates for maximum ground cover, nitrogen fixation, organic matter buildup, soil structure improvement and shade tolerance.
- Maintain a genetically diverse germplasm through conservation of oil palm breeding stock for the industry to meet the changing needs of the future.
- Exploit the potential of genotype x environment x fertilizer interaction synergistically to raise the site-specific yield.
- Breed for higher efficiency and value-addition.

Biodiversity

- Develop a local Biodiversity Plan with actions to be taken in specific areas to conserve and enhance the species and habitat biodiversity, including soil microbial population.
- Conserve biodiversity in the plantation and its surroundings by retaining high conservation value forest, riparian reserves, wildlife corridors and native tree species in hilly areas.
- Avoid pesticide damage to the beneficial flora and fauna, *e.g.* by using alternatives to the second-generation anticoagulants for rat poisoning as they are less harmful to owls.

Biodiversity is defined as the variety in forms including genes, species and the ecosystem. Biodiversity conservation in plantations seeks to maintain the life support systems provided by nature. Biodiversity encompasses all living things, including human beings, and not just rare or threatened species. Thus, human intervention that threatens these life support systems would need to be curtailed to conserve the biodiversity. They would include the establishment of wildlife corridors, riparian strips and high conservation value forests. The soil microbial population is preserved to maintain soil organic matter and fertility. The necessity for agricultural biodiversity preservation in plantations to reduce use of pesticides has been highlighted by Mohd Hashim *et al.* (2000).

Thus, with the BDPs of planting of high yielding oil palm, good nursery management, planting a legume mix and a biodiversity action plan, the plantation should be able to ensure that none of the indigenous species are upset environmentally to become weeds, pests and diseases. The BDPs in *Table 4b* are some further measures to reduce the causes of yield loss.

TABLE 4b. BEST-DEVELOPED PRACTICES FOR SUSTAINABLE DEVELOPMENT UNDER THE BIOLOGICAL ENVIRONMENT

ii. Yield Reducing Factors

Weed management

- Use fibre mulch mats or empty fruit bunches around the bases of young palms immediately after field planting to obviate the need for herbicides for weed control.
- Use only ecologically and medically safe compounds approved by the Pesticides Board, and in accordance with the manufacturers' instructions.
- Avoid the development of weed resistance by alternating the use of different herbicides.
- Reduce herbicide use by not blanket spraying as the resultant bare ground condition is prone to erosion.
- Maintain soft weeds in the inter-rows and epiphytes on the trunks, and plant beneficial plants with nectaries for pest control by predator insects.

Pest and disease management

- Minimize losses from known fungal diseases such as *Ganoderma* with a high standard of field sanitation.
- Do not carry out prophylactic spraying of pesticides but be selective and provide good supervision when using pesticides to avoid eco-balance disruption.
- Practice integrated pest management by using owls to control rats, *Metarhizium* and virus for *rhinoceros* beetle, Bt formulation for leaf-eating pests like the bagworm and nettle caterpillar.

Weed, pest and disease management is best tackled with the integrated pest management (IPM) approach. The aim is to discourage any displaced biodiversity life form from developing into a nuisance, and to keep pesticide use to the minimum to minimize the risk to health and the environment. The objective is to adopt cultural, biological, mechanical and physical methods in lieu of chemical pesticides.

Sub-Sector 3: Harvesting and Processing

Sustainable agriculture must be profitable besides socially acceptable and environmentally sound. After the BDPs for optimizing the yield factors have been implemented, there comes the harvesting of the high yield. The BDPs for harvesting are to obtain the maximum product value. They include the mill practices for efficiency in obtaining high oil and kernel extraction ratios. The BDPs for harvesting and processing are listed in *Table 5*.

TABLE 5. BDPs FOR HARVESTING, PRODUCT QUALITY AND VALUE

Harvesting
- Maintain short-harvesting rounds (at least 30 rounds yr^{-1}) with the minimum ripeness standard and collect all the loose fruits without debris.
- Mechanize field FFB collection to ensure quick transport to the mill to increase productivity and oil quality, and to reduce the physical load on the workers.
- Enforce strict quality control to avoid contamination of the FFB.

Milling
- Ensure high mill efficiency with high oil and kernel extraction ratios.
- Ensure efficient management of the wastes (*Table 6*) from milling, processing and refining.

Product quality and value
- Keep FFA and oxidation to acceptable levels for marketability.
- Process fruits from the field immediately.
- Reduce the backlog of FFB on the ramp.
- Avoid all contamination.

Biofuel and biogas production
- Directly burn palm oil in the boiler to reduce the use of fossil fuel.
- Convert palm oil into biodiesel to replace fossil fuel.
- Capture biogas from the digestion of POME for fuel.
- Determine the GHG emissions saved and convert them into carbon

To obtain the maximum product value, there must be a policy to obtain the optimum amounts of high quality products with the least adverse environmental impact. The BDPs in *Table 5* under processing have been developed taking into account consumer concern for food safety, environmental performance and corporate responsibility. This is further supported by the BDPs on waste management in *Table 6*.

Generally, in processing FFB to refined oil, or in the production of biodiesel and biogas, there are considerable savings possible. The GHG emissions saved from the use of fossil fuels mixed with biofuel can be converted to carbon credits under the Clean Development Mechanism (CDM) of the Kyoto Protocol. The value realized from the carbon credit will strengthen the viability of the production of biodiesel (Choo *et al.*, 2002).

Sub-Sector 4: Waste Management

The GHG emissions reduction from the waste sub-sector can be substantial. There is a need to draw up the GHG profile of the wastes from the oil palm industry as part of a long-term life cycle analysis. The BDPs for incorporation into a policy must have the following objectives – ensure clean air, prevent soil and subterranean water contamination and the production of malodours. The policy will then significantly reduce the GHG emissions. The palm oil industry is distinctly different from other industrial operations in that the oil palm takes in CO_2 and uses solar energy to produce palm oil. No toxic wastes are produced. This must be highlighted in its marketing effort since palm oil wastes are *clean* of only heavy metal contamination.

For sustainable waste management, the following BDPs and activities are implemented - waste minimization, source separation, waste reuse, material recycling, energy recycling *i.e.* incineration to generate electricity, and application of the empty fruit bunches and POME in the field as mulch. The BDPs are listed in *Table 6*.

TABLE 6. BEST-DEVELOPED PRACTICES FOR WASTE MANAGEMENT

BDPs for Efficient Waste Management

Mill waste
- Draw up the GHG profile for the milling of FFB (using the LCA standard).
- Reduce smoke emissions (Clean Air Regulation 1978).
- Treat POME effectively and apply to the field as fertilizer substitute (Environmental Quality (Prescribed Premises) (Crude Palm Oil) Regulations 1977).
- Implement a zero POME discharge system and determine the CH_4 and N_2O emissions saved from the reduced waste treatment.
- Apply empty fruit bunches as mulch for nutrient recycling.
- Capture the biogas instead of discharging it to waste.

Corporate governance
- Formulate a company Environmental Corporate Policy that incorporates the biodiversity action plan outlined earlier.
- Implement environmental management systems such as ISO 14001 EMS.
- Establish an occupational safety and health policy (OSHA, 1994).
- Establish food safety and HACCP policy as per ISO 22000.

Sub-Sector 5: Transport and Mechanization

Transport is a major source of GHG emissions. In the plantation, road transport of FFB is the largest single source of emissions. It is therefore a priority area for intervention. There should be a policy to improve the energy efficiency of the vehicle fleet and the carbon density of the fuel. Further, non-technical measures to switch to less polluting transport modes and planning the traffic flow are important BDPs to consider. The transport policy is linked to air quality management, congestion of lorries at the mills and energy security, *i.e.* to be less dependent on fossil fuels. While transport policies are easily replicable by other estate groups, more innovative and effective measures have to be defined, though presently there has only been limited success in this context. Some measures on transport and mechanization are shown in *Table 7*.

TABLE 7. BEST-DEVELOPED PRACTICES ON TRANSPORT AND MECHANIZATION

Transport
- Encourage more efficient FFB transport like using the returning vehicles to carry EFB to the field.
- Improve the transport efficiency by using larger vehicles.
- Reduce the fossil fuel density by blending with palm biodiesel.
- Use liquefied petroleum gas (LPG) wherever possible as it is a cleaner energy source.
- Reduce unnecessary transport movements with better planning.
- Shift to less polluting transport, *e.g.* buffalo cart for in-field FFB collection.

Mechanization
- Reduce the demand for mechanization by using the buffalo cart for in-field transport and larger vehicles for main road FFB transport.
- Comprehensive transport planning.
- Consider the fuel mix and select suitable vehicle engines for better efficiency.
- Set the new frond piles at replanting on the harvesting paths of the old stand.

Government incentives
- Tax exemption for using biodiesel fuel blends.
- CO_2 tax exemption for the use of natural gas (LPG, biogas).
- Appeal for government incentive for using biogas from the digestion of effluent.
- Tax incentives for the use of low ground pressure tyres for in-field machines.

Mechanization has been another area of concern. The current trend is to increase mechanization even as the vehicles are used less and less efficiently with low load factors. Special attention should be paid to the energy consumption per tonne-km and the fuel mix. The increase in demand for mechanization has gradually eroded the need for non-motorized transport like the buffalo cart, the bicycle and use of harvesting knife, *etc.* Their decline and perhaps subsequent demise has led to higher emissions from mechanization.

Mechanization also presents a Catch-22 situation. It is important for higher efficiency to use larger tractors and trailers, yet the larger the transport the greater potential for damage to the soil, especially in soft clayey areas. It is therefore important that low ground-pressure tyres be used on soft soils.

Sub-Sector 6: Energy

The industry has a great potential to generate surplus electricity from the burning of its mill wastes *viz.* fibre, shell and empty fruit bunches. In addition, there is the biogas from effluent ponds that is at present still largely untapped. The potential energy from the biogas alone should suffice for the mills' requirement thereby freeing the fibre, shell and empty fruit bunches for use in the production of electricity for sale to the national grid.

The government is offering incentives for individual mills to become power suppliers. The mills only have to link their supply to the nearest grid. With this move, CO_2 emission will be reduced considerably from the lower use of fossil fuels to generate the electricity (*Table 8*).

TABLE 8. BEST-DEVELOPED PRACTICES FOR ENERGY AND ENERGY INDUSTRIES

Energy
- Draw up the GHG profile from fuel combustion and compare it to the total emission from the palm oil industry using the LCA approach.
- Break down the GHG emissions into CO_2, CH_4, N_2O by identifying the sources.
- Promote efficient energy supply and use, and also energy security.
- Reduce CO_2 emission by using cleaner gaseous fuels such as LPG instead of diesel in energy production.

Energy industries
- Determine the GHG profile of energy generation by the oil palm industry using LCA.
- Establish the potential electricity that can be generated from the wastes of the oil palm industry.
- Determine the CHP that can be generated from oil palm biomass and adopt a renewable resources portfolio for energy generation and use.
- Encourage consumers to use electricity generated from renewable resources.
- Adopt broader energy reforms such as economic efficiency and consumer choice of energy sources designed to reduce GHGs.
- Use oil palm plantations to sequester CO_2 as a parallel alternative while technologies to improve energy efficiency and reduce GHG emissions are being developed.

AN INTEGRATED APPROACH TO THE IMPLEMENTATION OF BDPs

A refined and integrated approach for the implementation of BDPs is shown in *Figure 1*. A greater emphasis is given to mitigation and adaptation, especially in the six sub-sectors, to enhance the effectiveness of the BDPs. Importance is also attached to new technologies which include those using biomass wastes and biogas to generate electricity, improving the efficiency of boilers, using effluent as fertilizer substitute, obtaining higher energy efficiency from the direct burning of palm oil and conversion of palm oil to biodiesel. The ultimate aim is to reduce GHG emissions and add value to the wastes.

In the future, more BDPs are expected to be developed for the palm oil industry in energy technology, such as improved biomass generation of electricity. In addition to the BDPs for energy generation, there will also be attempts to reduce GHG emission such as capturing CH_4 from effluent ponds, decreasing N_2O production by applying N fertilizers to mulch and reducing CO_2 by carbon sequestration using oil palm plantations.

The BDPs in all the six sub-sectors will be subjected to new and stringent environmental criteria, like ISO 14000 standards, especially EMS and LCA, to monitor their implementation over the whole chain of production (Chan, 2000). Implicit to this will be environmental responsibility and cost-effectiveness although other criteria such as social inclusiveness, employment, human health, safety and welfare will also be examined continuously.

The environmental responsibility will include not only climate change mitigation but also other environmental aspects like air and water pollution. These criteria, when included in the long-term monitoring of the policies adopted, will reduce the emission levels.

In calculating the cost-effectiveness of BDPs, the costs are rarely considered presently by the companies applying the BDPs. It may, therefore, not be possible to do a detailed analysis to arrive at a figure of, say, RM t^{-1} GHG emission saved. Standard methods and procedures need to be developed to calculate the costs of the mitigation. In this way, the monitoring can be done in a more systematic way so that the policies, aimed at energy efficiency, emission reduction and sequestration, can be incorporated into an economic model for calculating the profitability of palm oil production. The use of the GHG standard ISO 14064 for measuring, qualifying and verifying GHG emissions should be expanded.

A database, currently being developed by MPOB, will contain all the information on the BDPs that have been reported and used in key policies and measures to help improve the profitability of the industry. Such sets of BDPs have been proven to have a significant long-term effect on reducing GHG emission besides increasing the FFB yield and reducing costs to improve the industry competitiveness.

As an indication of this type of research, Choo *et al*. (2002) has indicated that biodiesel, besides producing 78% less CO_2, is derived from a renewable energy resource when compared with diesel. Further, the CO_2 from biofuel does not add to the CO_2 accumulation in the atmosphere. Therefore, it does not contribute to global warming unlike the CO_2 from fossil fuels which require plants like the oil palm to sequester it from the atmosphere. The Malaysian oil palm industry in 2000 has been estimated to sequester, through its standing biomass, 90 million tonnes of carbon (Chan, 2002).

BEST-DEVELOPED PRACTICES AND BENCHMARKING

When completed, the database of BDPs will reveal a whole range of operating environments from the wide distribution of estates throughout Malaysia. There will therefore be variations in the results obtained from the same BDPs. The solution is to benchmark the BDPs over all the six sub-sectors as this will allow the value chain methodology to attribute to the BDPs their contributions to the improvements in costs and productivity. Benchmarking is already practised by several plantation companies, notably Boustead (Chow, 2000). In the way it is done, the plantation group is able to identify a particular set of BDPs for a site, so that even in a short time the management will be able to assess the improvement over the old practices.

Thus, the objective of benchmarking is for organizational progress. As the data are collected after implementing a new set of BDPs, the new information will allow the effects to be gauged in a programme of continuous improvement. The benchmark goals set will help the estates to improve their performance and thereby their productivity and profit. With a commitment by management to benchmark the BDPs and analyzing the causes of any shortfall, all the goals are very much more likely to be achieved.

DISCUSSION

Increased emissions of GHGs are the causes of global warming. The oil palm industry has an important role to play because it provides well for the growing demand for food and energy while promoting economic and social development. Nevertheless, it has to contribute to the international efforts to mitigate the risk of climate change. While this poses a fundamental challenge to many nations with their different crops, the oil palm is naturally positive in its contribution.

Recently, the Intergovernmental Panel on Climate Change (IPCC) projected a rise of 1.4ºC to 5.8ºC in the average global surface temperature if GHG emissions are left unabated. The growing demand for food and energy is the main cause of the rise in GHG emissions. Fossil fuels will likely continue to be the primary choice to meet growing energy demand. Thus, oil palm with its high production of oil per unit area and generation of renewable energy from its biomass provides an option for reducing the use of fossil fuels. As the use of oil palm fuel is still small at the moment, the challenge is to significantly increase its use in the future.

There are two approaches to increase the contribution by the oil palm - firstly, to use the biomass directly for energy production, and secondly, to improve significantly the energy efficiency of the whole palm oil industry. This calls for balanced utilization.

Development of new technologies to sequester CO_2 and store it both in the ground and vegetation, using the oil palm as the preferred crop because of its other benefits, is to be encouraged as it offers a significant potential for reducing the net atmospheric CO_2.

The oil palm should now be recognized as a crop that has the potential to reduce GHG emissions and help in stabilizing the net atmospheric GHG concentration. The government should exploit this point in its market promotion by positioning the oil palm as a very environmentally-friendly crop.

Unfortunately, the current focus of the international climate change policy makers is on making the developed countries reduce their GHG emissions. This has caused them to miss the fact that there are possibilities for emission mitigation such as that offered by the planting of oil palm in countries with a suitable climate.

But perhaps this can be incorporated in the longer-term plan of action. In facing the challenge of reducing GHG emissions, an option would be to use the oil palm to sequester CO_2 while providing food and energy for all. The oil palm industry should indeed be considered one of the leaders in the field of net GHG emission removal.

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