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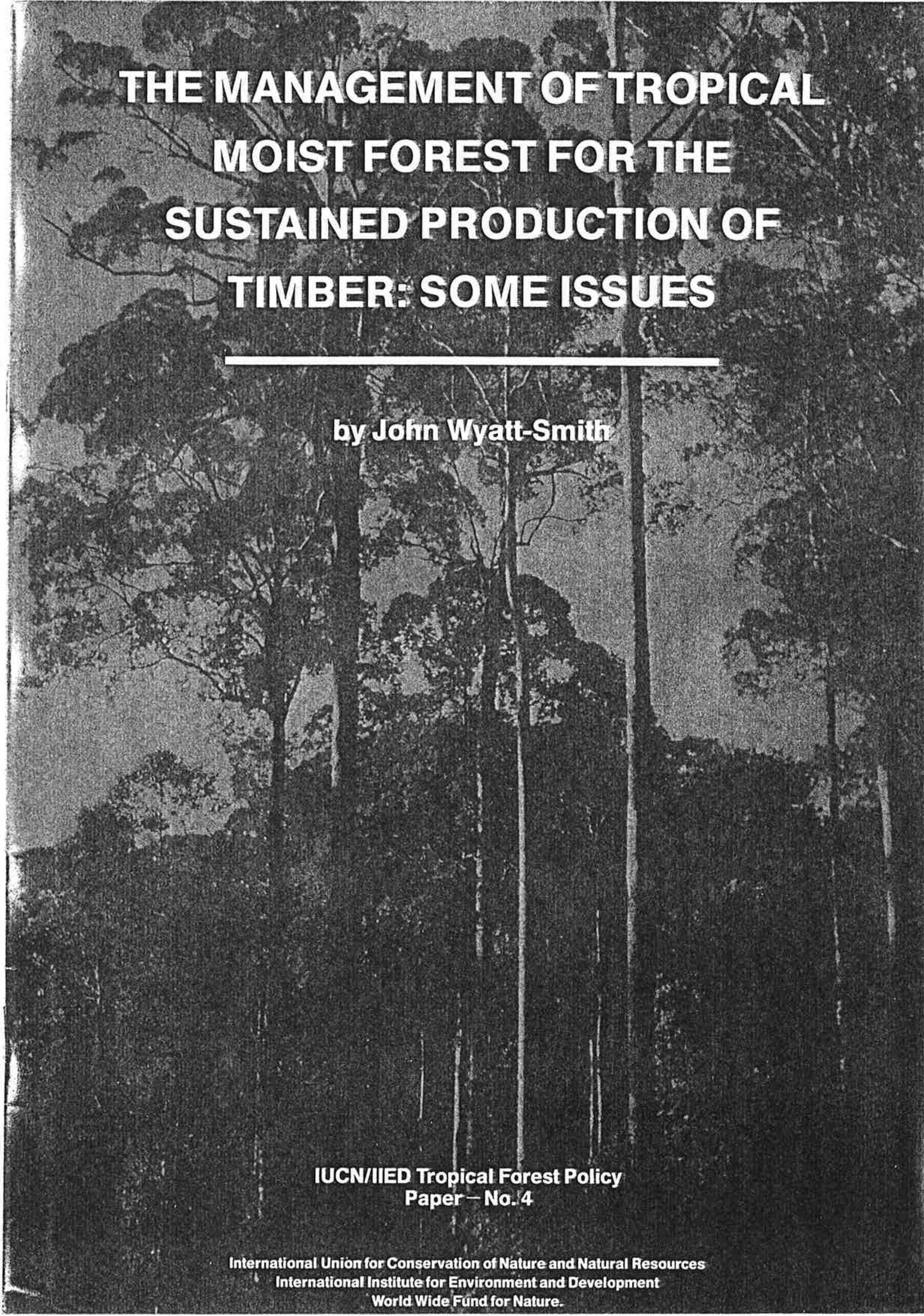

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- Land Clearing in the Humid Tropics, based on experience in the conversion of tropical moist forests in South East Asia.
- Runway and Treadmill deforestation: reflections on the economics of forest development in the tropics.
- The International Tropical Timber Agreement:Its prospects for tropical timber trade, development and forest management.

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CHAPTER 1: INTRODUCTION

The Tropical Moist Forest (TMF-see definition in annex) is a complex ecosystem. It is dynamic and possesses a high order of organisation, in which physiological, morphological and ecological features of individual plant and animal members are strongly linked to form a variable continuum in time. The fauna and flora are numerous and diverse with species even of mammals still being discovered to science. Knowledge of the microfauna and flora, of insects, herbs, ground flora and shrubs, is still rudimentary especially in terms of their value to man and their contribution to the working of the ecosystem.

The flora of TMF is very rich and that of Malaysia, the islands of the Sunda shelf together with Peninsular Malaysia (the latter itself with about 8,000 species in an area of only 7.4 million ha), is probably the richest in the world, estimated conservatively to number 25,000 species of flowering plants (Whitmore, 1986 ex van Steenis, 1971). This represents about 10% of the world's higher plant species of which about 40% occur inTMF. Yet TMF only occupies about 7% of the world's land surface. The great diversity of flora is reflected in the complex structure of vegetation. Trees can rise to a height of up to 60 metres and provide innumerable different niches within which plants of a wide range of life form grow.

TMF occurs in all the principal tropical regions ie. Africa, America, Asia, Australasia and the Pacific. In 1982 tropical forest resources were surveyed in 76 countries (FAO, 1982). This area embraced 97% of the total land area of countries lying for the most part in the belt between the tropics of Cancer and Capricorn or which are subject to a tropical monsoon climate. The survey found that at the end of 1980 there were 1,200 million hectares of closed forest, 97% of it broadleaved, and 990 million hectares of which had not yet been touched by logging. On grounds of stand and terrain characteristics, 675 million hectares of this forest could be classed as commercially productive and 275 million hectares as unproductive. An area of 41 million hectares had been constituted National Parks and other reserves.

Of the 210 million hectares of productive closed forest which have been commercially logged, only 42 million hectares are even allegedly under forest management, implying the forest has a working plan of sorts, that annual felling cuts are prescribed and some silvicultural treatment is carried out. Working plans or agreements have been prepared for many more areas in other countries, but the prescriptions are rarely followed and the plans rarely updated. Much of the 170 million hectares of logged forest not regularly managed is destined for other uses, predominantly agricultural development. The survey found that 4.4 million hectares, (0.65% of the total of unlogged productive forest) is opened up annually for exploitation. This does not appear alarming **provided the area is largely retained under forest cover after exploitation and the rate of logging does not drastically increase**. The problem is that commercial logging is so often the first stage leading ultimately to clearance; logging removes the biggest trees and provides access, thus removing the two main obstacles confronting the shifting cultivator or settler in their use of forest land.

In addition, 7.5 million hectares of closed TMF are cleared each year for other land use. This is predominantly for agriculture, of which 45% is ascribed to shifting cultivation (FAO, 1982). Logging is, however, much more selective in America and Africa than in Asia, where the forests generally contain a much higher standing volume of merchantable timber (see definition in annex) per hectare, the result both of a high proportion of larger trees and a higher percentage of merchantable species. In spite of these advantages the Asian forests, particularly the valuable dipterocarp forests of south-east Asia, are selectively exploited to a far greater extent than is either necessary or desirable. Unnecessary waste occurs and one thus loses the benefits of extending the life of the currently preferred species and of taking advantage of the expected hardening of prices as supplies decrease. There is a deficiency in the management of these forests and in rational land use policies – unfortunately short term gains generally rule the day.

It must be remembered, however, that the timber in a country's TMF resource often represents a significant asset and one which is relatively easily realised. Export of logs and other forest products from tropical countries currently amounts to a value of some US $ 7.5 billion annually.

Moreover, logging is necessarily a rural activity bringing income and employment to remoter parts of a country, though frequently it is not the local people who benefit since many operations work with a mobile imported labour force.

There are few genuine examples of TMF management which have demonstrated that selective logging and silvicultural treatment can be successfully carried out, and then repeated after a long interval of 30-70 years while maintaining substantially the ecological character of the preexisting TMF and increasing the proportion of exploitable species (see definition of sustained production in annex). Most logging has begun with such hopes and intentions but all too often further exploitation has followed too soon, shifting cultivation has encroached or, as in Peninsular Malaysia, land use policy has been changed and future potential has been lost. Various examples, such as the Malayan Uniform System in Malaysia and the work of Jonkers and de Graaf in Surinam demonstrate that in the absence of encroachment by shifting cultivators and too early repeated exploitation, **tropical moist forest can be managed as a truly renewable resource**. It is a pity that existing knowledge about sustainable TMF management, although far from complete, is often not being put into practice. This paper focuses on the policies and techniques involved in TMF management and examines the possibilities of extending and enlarging the successes attained so far.

CHAPTER 2: ATTRIBUTES OF TROPICAL MOIST FOREST[1]

2.1 Introduction

Tropical moist forest is probably the world's most complex ecological system and the one least known scientifically, both in terms of its overall contents and their biological interdependence. It is certainly the most diverse in species and contains the greatest number of different ecological niches, by virtue of the height to which the dominant trees can grow and the complexity of forest profile and structure. TMF provides many environmental services in climates characterised by high rainfall both in total and in intensity, particularly in monsoonal areas after periods of drought when the physical structure of the soil is least able to contain such a force. TMF also supplies a wide range of 'goods and services' to mankind, both locally and globally, known and unknown, directly and indirectly. Some of these are so valuable that if they were to be interrupted, the consequences could be disastrous. It is one of our most valuable natural resources and requires sensitive and understanding treatment, at least until considerably more is known about it than at present.

2.2 Goods

In terms of marketed value, the main raw material obtained from TMF is industrial timber, accounting for an estimated 56% of global timber production. Yet the number of species growing to timber size and the potential volume of timber of those species actually logged is usually only a small percentage of the whole, even in the southeast Asian lowland dipterocarp rain forests. Moreover, logging methods are such that a high percentage of the remaining forest (often deliberately left to provide the basis of a future crop under a polycyclic system of management) is damaged beyond recovery, and hence valuable raw material is wasted.

In terms of volume, the greatest amount of raw material provided by TMF is probably burnt by shifting cultivators in order to create room for and fertilise their swiddens. Although over 85%of the energy consumed in tropical rural areas is obtained from fuelwood, most of this derives from agricultural land, 'wasteland' and secondary forest, and *not* from TMF. Moreover, much of the fuelwood yielded by TMF is dead wood and conversion waste. TMF does provide a considerable amount of small-sized timber for small cottage type industries in both rural and urban centres, for house construction in rural areas and, to a lesser extent, for agricultural purposes.

Many other products, collectively called minor forest products, a title not reflecting their often important place in regional and even national economies, come from TMF. These include edible and non-edible oils, exudates such as gums, latexes, resins, waxes, tannin and dyes, roofing material, rattans, fibres, bamboo, fruit, spices and tubers. It also provides raw material for the manufacure of pesticides, perhaps a more desirable source than man-made chemicals since, being organically produced, there is less danger of problems caused by harmful residues. TMF is also the source of innumerable predators and parasitic insects, which may prove useful in the biological control of agricultural and horticultural pests. In this respect it is interesting to note that epidemics of insect pests rarely arise in TMF. This is partly due to the wide diversity of plant and animal species, especially of birds and insects, the latter including both predators and parasites.

One of TMF's greatest, and yet on a modern scale scarcely tapped, resources lies in their produce of raw materials, especially alkaloids, for the manufacture of drugs. Primitive forest dwelling communities have long exploited medicines and narcotics obtainable from many plants for the treatment of their ailments. Some of these plants are now the source of pharmaceutical products estimated to have an annual commercial value of the order of US $10,000 million. Yet no more than 1% of the TMF plant kingdom has been screened for possible benefit, though known species of potentially important genera and families,

[1] Mainly adapted from Myers (1983).

especially for alkaloids, have been moderately well examined for their economic chemical potential. Research has also been undertaken on the possibility of obtaining nutritious food from plants with leaves of high protein content – a resource of great possible importance for mankind.

Another major benefit from TMF lies in the wide genetic diversity of natural wild plants of many of the well established agricultural crops. These can be the source of new genetic material for introduction in breeding programmes to produce strains which have improved productivity, greater value as food or resistance to disease.

2.3 Services

One of the most valuable attributes of the forest is the protection it affords to the soil. The depth and density of the vegetative cover minimise the impact of raindrops on the soil,which would otherwise cause splash, sheet and gully erosion, and downstream siltation, sometimes resulting in flooding. The forest cover, the decaying leaf litter, the humic top soil, the spread of roots and the former root passages in the topsoil layers, moderate the heavy and often torrential rainfall of the tropics, particularly prevalent at the beginning of the monsoon. This can greatly reduce (but not wholly prevent) erosion and flooding, increase dry season water flow and thus provide a greater chance of achieving perennial and potable water, the absence of which results in the need for extensive and expensive engineering works to protect reservoirs and hydroelectric installations. If forest is removed, all engineering works – dams, roads, electrical transmission lines and terraced agricultural land – are more exposed to risk from landslides and gully erosion, the life-span of reservoirs and canals may be greatly reduced and annual maintenance costs of all engineering works are greatly enhanced. It is often not sufficiently realised that in most circumstances natural vegetative cover is the best and cheapest protection.

Other benefits attributed to TMF are:

(a) the reduction of damage caused by cyclones and other periodic strong winds, which occur in many countries;

(b) that it represents a reservoir of carbon fixed in vegetation (a so-called carbon sink), which is not contributing to the carbon dioxide in the atmosphere, increased levels of which lead to a global increase in temperature due to the 'greenhouse effect';

(c) that variations in the heat exchange equation at the surface of the earth are now considered to be a major element in promoting climatic fluctuations. Forest cover's low albedo and high evaporation, and consequent influences of this upon heat exchange, are believed to lead to increased rainfall in many situations and constitute a compelling reason for maximising the cover of tropical forest.

2.4 Summary

There are evident benefits, both direct and indirect, from TMF. Unfortunately it is rarely asked what is the cost of providing or not providing the necessary services from the forest. If that question is asked and answered thoroughly, decisions on the conversion of TMF might have to be reversed, as has recently been convincingly demonstrated by Burns (1986-in the second paper of this series) and by Leslie (1987). The benefits of TMF are far too often taken for granted and are never adequately assessed in decisions to clear TMF for alternative land uses. This is also the case when compensatory industrial timber plantations are being established or artificial regeneration is being introduced in place of natural regeneration. There is an interdependence between forestry and other disciplines such as agriculture, drainage and irrigation, power and energy, communications and health, which is frequently forgotten by planners and rarely quantified.

CHAPTER 3: FOREST POLICY

3.1 Introduction

It is possible with (a) an existing Forest Law, (b) Forest Regulations prepared and gazetted under this law, (c) an adequate Forest Organisation staffed with trained professional, technical and subordinate field personnel covering all aspects of forestry, including research, and (d) reasonably sustained funding, to survey the forest area, to select suitable areas for future forest estate, and, after negotiation between government and affected populations, to establish and protect the boundaries of those areas agreed upon to become the permanent forest estate. It is, however, virtually impossible to manage forest effectively, least of all TMF, without a declared and firmly committed national forest policy. The production cycle of TMF goods and services is too long to endure either vascillation or sudden change in policy, especially when the full implications of such changes are not effectively considered and dealt with.

Forestry must be considered as an integral part of a national land use policy and all interdependent facets must be taken fully into account on a medium to long term scale.

Unfortunately, such an integration is only rarely realised.

The objectives of the International Institute for Environment and Development's (IIED) Forestry and Land Use Programme are "to assist nations to re-examine and revise those policies which damage and devalue their forest resources, and to define and promote genuinely sustainable and productive management for tropical forest lands." The problems facing any policy decision regarding TMF are manifold, particularly when its ecosystems are probably the most complex and least understood in the global environment. As already described, many of its benefits are well-known but equally many are undoubtedly unknown. Due to the global importance of the TMF resource, policy decisions are complicated even further: an insular attitude of individual countries is no longer acceptable and will be less so in the future.

Consideration must be given not only to the country in which the forests are located but also to the region and to the world as a whole.

The theme of the First ASEAN Forestry Congress held in Manila, Philippines in 1983, "ASEAN Forests: A World Heritage", indicates that ASEAN forestry professionals fully appreciate the situation. In the Review of Forest Policies in Indonesia, carried out jointly by the Government of Indonesia and the International Institute for Environment and Development, it is stated under 'the importance of forest resources': "...they protect the genetic variety of plants and animals which may be needed to ensure the future supply of natural raw materials for agriculture, forestry, medicine and other uses." This clearly demonstrates regional, if not global concern. However, do all politicians and governments of TMF countries fully appreciate the significance of their forests, and if so have they acted or are they prepared to act accordingly? Moreover, do all the international organisations involved in forestry sufficiently appreciate the situation?

The major policy issues affecting the management of TMF for the sustained production of timber are the following:

Demands on forest land

- The demands on forest lands for **agricultural or other non-forest use**
- The demands on forest lands for **protection and conservation purposes**
- The demands on forest lands for **timber production**
  - The production role of forests
  - Self-sufficiency in and export of forest products

Resources needed for successful forestry management operations

- **financial** resources
- **trained human** resources
- **research**

In this chapter, these issues are dealt with consecutively although they are all interdependent in practice. The order in which they are treated does not indicate relative importance.

3.2 Demands on forest lands

Introduction

As a result of increasing populations needing more land to grow their crops, their legitimate desire for a higher standard of living, and people's aspirations in the field of industrial and urban development, an ever increasing demand is being placed on forest land for agricultural and other non-forest purposes. The estimates of the present rate of deforestation, although differing substantially, have caused alarm in many circles, because of concern for the environment as well as for the long-term availability of forest produce. One of the most well-known estimates is that based on a comprehensive survey co-ordinated by FAO, of 11.3 million hectares of tropical forest deforested annually, of which 7.5 million ha was closed TMF and 3.8 million ha consisted of open tree formations outside the TMF range – the analy sis of tropical forest areas is shown in Table 1. The larger part of the TMF cleared was converted to agriculture, with about 45% attributable to shifting cultivation,and thus not necessarily entailing a permanent conversion (FAO,1982).

TABLE 1: SURFACE AREAS OF TROPICAL FOREST AT THE END OF 1980 (FROM FAO, 1982) (*)

Type of forest	Areas in millions of hectares	
Closed forest (97% broadleaved)		
– Virgin forest		
– productive	675	
– non-productive (inaccessible)	275	
– National Parks etc	40	
		990
– Logged forest	210	
		1,200
Forest fallow from shifting cultivation (**)	410	
Total TMF area		1,610
Open forest formations	735	
Shrub land	625	
Total tropical forest (all types)		2,970

(*) 76 Countries, representing 97% (4,814 million ha) of the total area of countries lying for the most part in the tropical belt or subject to a tropical monsoon climate, surveyed.

(**) including food crop areas.

Lumping together the forest areas and deforestation trends of 76 countries of course does not do justice to the large variations between them: circumstances are different for each country and will, moreover, change with time. If little natural forest is currently available, it is unlikely to be possible to set aside sufficient permanent productive forest estate to be managed for timber production on an extensive and relatively low productivity basis, under a natural regeneration (see definition in annex) system. Natural regeneration systems are generally much lower in productivity compared with those practising clear felling and the establishment of fast growing plantations, usually with exotic and often coniferous species. On the other hand, if there is still quite a large area of undisturbed or relatively undisturbed TMF as in several countries (e.g. Brazil, Indonesia, Papua New Guinea, Venezuela and Zaire), it is a very worthwhile option to set aside, after fully meeting protection and conservation needs, as large an area as possible of productive natural forest that can be managed on a natural regeneration system. A prerequisite to this type of management is the presence of abundant natural regeneration of existing and potential merchantable timber species. This area would serve as a bank of natural resource wealth, which can only increase in value as global supplies diminish and as its contents and potential value are better understood.

The demands on forest land for agricultural or other non-forest use

Farmers realise the value of natural forest land, using the nutrients accumulated and its initial freedom from pernicious weeds. This fertility largely arises from the above-ground biomass which, when cut and burnt, releases the store of nutrients that has built up over the centuries, but is often only a veneer over infertile soil. Traditional shifting cultivation with its lengthy fallow period is based on these premises. Therefore, planned development of sedentary agriculture is bound to fail if fertiliser inputs are inadequate and sound agricultural practices are not carried out. For a more extensive treatment of this topic, the reader is referred to 'Land Clearing in the Humid Tropics', the first paper in this series (Ross and Donovan, 1986).

Frequently, government authorities are encouraging clearing of forest land for agricultural development rather than trying to improve or sustain the productivity of existing agricultural land, while the latter would often be more cost-effective.

In the long run, the basic agricultural problem cannot be solved extensively, because there is only a limited amount of land. That is not to say, however, that subsistence agriculture must necessarily give way to a wage economy now or in the near future. Petty producers, who are not incorporated in a wage economy, need not be subsistence producers: they can produce agricultural surpluses in which development is rooted. They have done so in the past, and doubtlessly will do so in the future. Conversely, plantation economies, growing food and raw materials for export, with little or no processing *in situ*, replacing traditional agriculture and bringing about a wage economy, have often contributed to the armies of resource-poor peasants who are responsible for a considerable proportion of present-day deforestation.

Nevertheless, if intensive agro-forestry operations creating more food and wood – basic raw material for domestic secondary processing – and hence more jobs per unit area while consuming less forest than extensive agriculture, are socio-economically and technically feasible, governments should try to involve farmers in these rather than provide land for extensive agriculture.

Another aspect of the unequal competition of forestry with agriculture is the difference in quality of the lands allocated to them. Forests at favourable sites provide forest produce at a high volume per unit area and sustain such activity at a low cost both in human and financial input. Poorer land will neither meet the production rate of those sites nor provide a meaningful volume of forest produce at a low cost. Logically, forestry is often required to give up good productive land to agricultural development and then given compensatory land which is much poorer or even outright degraded as a result of unsustainable agricultural practices. Thereupon, however, the administration expects the forestry organisation to achieve the same high production in the compensatory area without the additional funds, technical knowledge, and trained staff necessary for such an operation of increased difficulty and intensity. It is ironic that in some instances it could even be preferable if agricultural development were carried out on the poorer sites, as it would at least be able to command the higher inputs necessary to achieve greater productivity.

From Table 1 and the figures mentioned in 3.2, it can be derived that about 0.63% of the closed forest is cleared annually. Three quarters or more of this (that is 5.6 million ha per year) is likely to be productive logged forest. The creation of a network of roads necessary for extracting logs is unfortunately an open invitation for itinerant squatters and local shifting cultivators to move into the estate. Furthermore, most areas cleared for planned agricultural or other development are logged beforehand. If this assumption is correct, then the much higher proportion of 2.7% of productive logged forest is being lost annually.

In the case of shifting cultivation being practised in logged-over forest which is managed for the production of timber, considerable losses are incurred. Traditional shifting cultivators are forest dwellers who use patches of natural forest on a mozaic basis, clear felling and burning a site before growing their agricultural crop for two or three years at the most. They operate on a cyclical fallow basis and return to a site after a period of up to thirty years, depending on land recuperation and availability. Little environmental damage is done to cultivated areas, as many of them practice zero tillage and minimal tending of crops and often do not fell all large trees. Their activities, however, can do untold damage to regeneration of merchantable species and to the valuable standing crop, rendering large areas unproductive to timber operations.

Conversely, in some instances, preferred timber species were found to profit from intervention by shifting cultivators, such as in Cameroon, where light hardwood species (Sapelli, *Entandophragma cylindricum*, among others) regenerate far more abundantly in abandoned swiddens than in primary forest. In some areas, farmers have used such opportunities to intensify their shifting agriculture, by planting or favouring species which can be harvested after the forest 'fallow' phase. A well-known example is the "talun/kebun" system in west Java, where bamboo and *Albizzia falcataria* are planted among the annual crops cultivated during the first two years of a 15-year cycle. The possibilities for combining traditional shifting cultivation with timber production also deserve closer consideration.

Itinerant squatters are rarely from the forest area, tending rather to be landless individuals from (semi-) urban areas or from over-populated agricultural regions. They move into logged-over forest, following closely behind the logging operations along the extraction roads, and carve out a patch of land for semi-permanent agricultural settlement. The damage caused is not only the loss of regenerated forest land for the next cutting cycle, but, in cases where a selective logging system is in operation, the loss of a great quantity of merchantable timber from residual trees which have been retained to form the basis of the next cutting cycle's crop. These valuable timber trees are mostly clear felled and burnt, and not utilised as timber, unless the squatter requires some for construction purposes. In addition it must be recognised that much forest, especially open tree formations and areas along the fringe of agricultural and other development, is being subjected to exploitation for small scale timber and fuelwood, to grazing and the burning that is often associated with it.

The problems stated above are often said to be caused by inadequate protection of the forest, due to the lack of adequate laws and, more importantly, the capability or political will to enforce them. These are genuine factors, especially in the case of large-scale illegal logging practices.

However, the ultimate causes of much forest encroachment are the forces that keep pushing poor people into the forest. Adequate legal protection can only be part of a broader solution involving an integrated land use policy analysing and tackling those "push" forces.

The demands on forest lands for protection and conservation

The protective role of forests

The protective role of natural forests is usually taken to include the physical protection of soil and litter from the climatic elements, and the provision of a perennial and potable water supply. In most tropical countries, agricultural yields depend for a considerable part on the state of the forests protecting the upstream areas of their watersheds.

The needs for protection forest should therefore be largely satisfied before consideration is given to production forest.

Protection forest is almost invariably located in the hills and in broken country where slopes are steep. Because of the danger involved in site degradation, it is undesirable to permit normal timber exploitation in such areas, though light selective logging might be possible. In addition, hill forest and certainly forest on steep terrain is generally of poor timber quality, low standing volume, and difficult if not impossible to regenerate naturally with current prime merchantable species. It might be possible to regenerate such areas through enrichment planting with indigenous merchantable species, but this would almost certainly minimise the protection role of the resultant vegetation. Moreover enrichment planting has not in general been successful, especially in TMF without frequent and expensive tending and cleaning operations. Where minimal timber exploitation is possible in declared protection forest, this area should be regarded as a bonus and of possible reconsideration when and if improved logging techniques, in respect of site and forest protection, have been developed.

Protection must have priority in forest designated to that end

The demands on forest lands for protection purposes

The demands will depend very much on the nature and topography of the terrain, the non-forest use to which undulating and broken terrain is being put, and the needs of downstream agriculture. It will also be necessary to set aside a narrow forest strip along the banks of all main rivers and canals, even in the flat terrain of the lowlands, to protect the banks and prevent or minimise erosion and meandering, especially during the rainy season in areas with monsoonal climates. Similarly protection areas will have to be set aside on the uphill side of major roads and in downhill areas where gully erosion could threaten engineering works which have been created at great capital cost.

The conservation role of forests

The protective role of forests as defined above takes no specific account of the protection of the various montane, hill and valley ecosystems as a whole, and the conservation of the fauna and flora in all their manifestations and genetic diversity. Indirectly, those aspects will be covered at the same time, if the protected area is large enough. Still, problems arise in the case of larger mammals and some avifauna, especially the predators. In general, those animals require a large area to sustain themselves, and many have developed fixed migratory routes. For instance, the surface of a forest area sufficiently large to support a healthy population of tigers (minimally 500 individuals) is considered to be very large—thousands of square kilometres.

These aspects have to be considered carefully in forest management where conservation is a primary goal, as they constitute major limitations to the intensity of forest exploitation and subsequent silvicultural treatment.

It is no longer possible, in view of present day intensive and mechanised exploitation and the subsequent silvicultural operations, to rely on the production forest estate for meeting conservation demands. Silvicultural treatment, for instance, often includes the removal of large hollow trees, which are the nesting sites of such birds as hornbills and the homes of small nocturnal mammals.

Some conservation aspects will undoubtedly be provided for by production forest, if the management system in force relies on natural regeneration, or at most includes enrichment planting to supplement natural regeneration needs. But in general, it is impossible to combine strict conservation with production forestry in the same area. This holds even more strongly for agricultural development in TMF lands, although some involves plantations of perennial woody crops, such as rubber, oil palm, coffee, tea, and coconut. In many of these plantations, cover crops and engineering works, for instance contour terracing and silt traps, are employed to minimise physical deterioration of site and soil. In addition, leguminous cover crops and chemical fertilizers are used to compensate for loss of soil nutrients and organic matter. Such development, however, does not provide for the conservation of the former ecosystems and of the genetic diversity of the natural fauna and flora, which to all intents are eliminated in the areas concerned. The development of agro-ecosystems creates new niches to the benefit of some plant and animal species, but unfortunately many of these species are aggressive exotics and cause loss of indigenous species.

Attention must therefore be directed towards the preservation and conservation of natural ecosystems in their own right, though fully recognising that this is already being provided for many ecosystems in traditionally protected forest, and to some extent in the production forest estate. Therefore, in addition to Protection and Production Forest Reserves, the necessary National Parks, Game Reserves, Strict Sanctuaries or Virgin Jungle. Reserves, should be established. An important additional reason for such a line of action is the fact that in many countries forest and wildlife (including flora) activities are administered in separate departments or even in separate ministries.

The conservation of flora and fauna should not necessarily be attributed to land set aside by government for forest production and protection purposes as a primary but only as a recognized secondary objective. Especially in the case of production forest, the traditional, vague concept of the multiple use of forest land should be replaced by one where the various uses are specifically indicated and the management of the forest is carried out accordingly.

The demand on forest land for conservation purposes

Taking into account the variety and present extent of natural ecosystems in a country, the diversity of flora and fauna and the natural range of the latter, and the area required to maintain a small number of independent strong breeding populations, especially those of endangered or rare species, it is possible to determine how large an area should be set aside for conservation purposes from a biological point of view. However, this area will in practice depend very much on non-biological factors such as population pressure, and planned development activities. Areas set aside for the conservation of species and ecosystems will also serve either scientific or recreational demands, or both, but there will also be a demand for small specific areas close to urban centres to serve as additional recreational localities. These will be of historical interest or scenic value, while some may also be of scientific interest. *Minimum* percentages, of up to 10% of land surface to be set aside for TMF conservation, have been suggested, but such global averages are not very useful. The minimum needed will vary greatly with different natural characteristics and national or regional conservation policies and may be misunderstood to the point of even encouraging a disastrous policy of clearing all other forest in the belief that enough has been retained.

A sound recommendation, however, is that conservation measures should be shared between neighbouring countries where possible.

The demands on forest lands for timber production

a. The productive role of forests.

Existing high forest

In the productive role of forests, too often the emphasis appears to be on using the valuable forest resource for short term economic gain, rather than for long term sustained land use and national development, especially as raw material for local secondary industry. Admittedly and understandably, it is almost a matter of course for a country with abundant forest cover to reap the benefits of foreign exchange earnings through the sale of the merchantable timber. On the other hand it is undoubtedly extremely short-sighted to waste valuable resources and potential produce through logging too big an area and then under-exploiting its produce, the so-called 'creaming', allowing much timber of potentially high value to rot, be burnt or be used where lower quality timber would have been appropriate, as too frequently occurs today. It cannot be too strongly emphasised that the market in general terms is relatively limited and overall does not fluctuate greatly in time, although short recessions and boom periods do occur. The market agencies will naturally do all they can to obtain the best quality produce at the lowest possible price.

The producers themselves must ensure they do not succumb to market pressures and must minimise the 'creaming' of their forest resources when planning forestry operations.

Markets do vary with changes in demand and supply. A recent example of the former is the increased demand for white timber following an earlier strong demand for red. More importantly, however, increased demand, reduced supplies and the resulting higher prices will continue to trigger technological innovations in wood utilisation. The increasing use of veneers and reconstituted wood (plywood, block board, laminated timber, chipboard, fibre board, and the like) rather than solid wood, and the use of stains and other devices to produce decorative faces, the use of a far greater range of species (including formerly unwanted 'weed species'), the technical development in conversion resulting in great reduction of waste material (eg wafer boards, the actual use of "waste" material), are all important factors to be considered when making policy decisions. However, ample evidence suggests there will always be a market for prime solid timber, that the price for such timber and for high quality veneer of preferred species will harden in the face of reduced supplies, and that price rises will be greatly in excess of inflation.

It is unlikely, therefore, that there will be any economic risk in favouring species which regenerate easily, grow reasonably fast in relatively pure stands, are relatively free from disease and insect attack, do not cause site deterioration, and produce timber of good quality. These considerations must become a major factor in the design of TMF policies.

Tree plantations

At the end of 1980 there were 11.5 million hectares of industrial and non-industrial plantations in the 76 countries included in the FAO survey, an area increasing at an annual rate of 1.1 million hectares. However, despite a rapid rate of increase during the 1970's, the ratio between areas planted and areas of closed or open tropical forest cleared each year remains at around 1 to 10. This replacement proportion is insufficient to ensure a forest estate capable of meeting expected demands and at the same time catering for deficiencies in regeneration activities in the past. It is recognised that more and more large-scale plantations of fast growing species are being developed both by the private and government sector in the sub-tropical and temperate zones of the southern hemisphere, and that there may in the future be a strong shift of the source of forest products.

However, plantations should not be seen as an alternative to TMF, since products yielded – and protection and conservation services provided for – are different. Few high quality tropical woods, with the main exception of teak, grow well in plantations, and conversely mixed industrial grade woods from TMF are poor and greatly inferior to the uniform product from the plantation. Thus the logic of managing on a sustained basis as large an area of TMF as possible remains unchallenged.

b. Self-sufficiency in and export of forest products.

Important questions preceding policy decisions affecting TMF management are whether or not a country should have a goal of self-sufficiency in forest products for present and future demands, taking into account a rising expectation of quality of life and an increasing population if need be, and whether or not a country should also embark on (sustained) forestry production for export. The data needed to be able to answer these questions are the areas available of the various natural forest types, their respective natural regeneration and growth potential, and the resulting production (amount, type and quality) of timber; they are considered separately below.

The types of forest

Tropical Moist Forest is a broad title embracing all closed high forest lying in the tropical belt of the world, and includes the dry-and wet-land rain forest formations, as well as monsoon forests and mountain rain forests – see Figure 1 in annex. The different formations vary greatly in species composition and forest types, even locally, due to evolutionary and environmental differences. These forest types show a large variation in commercial merchantability, due to differences in quality of timber and quantity of preferred species, and in the costs of access to the forest. Merchantability varies in time, as new technology might lower the costs of access and changes in supply and demand might occur. One of the most conspicuous examples is *Virola*, a light hardwood deemed worthless by the logging industry a mere twenty years ago, but now making up a considerable share of the plywood and mouldings Brazil is exporting to the USA.

Regeneration potential and silvicultural characteristics

Two of the most important factors to be considered in managing the productive forest estate are the regeneration potential of the preferred timber species and their silvicultural characteristics, such as form of crown and bole and tolerance of growing in almost pure communities. Large-crowned and slow-growing species which are tolerant to shade may be undesirable in the future, even though they may occur in abundance in the natural forest. Cultivating such species will almost certainly be uneconomic, owing to the length of cutting cycles. Forest types with relatively fast-growing species with appropriate forms of bole and crown, yielding commercially acceptable timber, tolerant of growing in relatively pure communities, and with sufficient natural regeneration capacity are those of greatest economic potential, and also the ones most easily incorporated in the shifting cultivation systems with intensified fallow described in 3.2. Good examples are the forests in South-east Asia rich in *Shorea* species with a dark red or light red grade of timber, and the genera *Dipterocarpus* and *Dryobalanops*. Such forest can readily be managed to produce a relatively good crop of high-quality timber (cover photograph) which is internationally in demand (especially the dark Red Meranti produced by many *Shorea* species), at low initial and subsequent tending costs, while retaining their inherent biological diversity, especially of plants of lower plant form and status.

Growth Potential of the Types of Forests

An important feature of a forest is its growth potential, especially of its merchantable species. In general terms and by its very nature, gross growth of natural climax forest is nil, since mortality over time is balanced by growth of the remaining stand. Nevertheless, different types of forest have different standing volumes and varying proportions of merchantable species. On average, TMF yields up to 2 m^3 per hectare annually; silvicultural operations and rational management can increase this to about 6 $m^3ha^{-1}yr^{-1}$. Some types of dipterocarp forest can be managed to produce around 15 $m^3ha^{-1}yr^{-1}$ and, where successful, enrichment planting can produce yields of the order of 10 $m^3ha^{-1}yr^{-1}$.

On the other hand, plantations in the moist tropics can produce yields of a substantially greater order, up to 35 $m^3ha^{-1}yr^{-1}$ for some hardwood species, 45 $m^3ha^{-1}yr^{-1}$ for tropical pines and 60 $m^3ha^{-1}yr^{-1}$ for certain eucalypts (Evans, 1982). The greater yield results in a corresponding decrease in land needs for an equivalent volume production, with all the advantages of a concentration of operations. However, the initial planting, establishment and direct tending costs are high. Moreover, with monocultures the risk of fungal and insect attacks are thought to be greater, particularly in the second and subsequent cutting cycles (rotations), and, although modern management techniques and knowledge can usually deal with such attacks, this could result in a significant increase in eventual production costs.

Target for timber production

Within the margins set by the forest areas available at present and in the future and their respective growth and regeneration potentials, the targetted production will depend on the national policy decision whether or not timber production should be sufficient to sustain the total calculated domestic needs, and, if not, what level of production should be achieved and over what period. Other information needed to determine the optimal timber production are the quantity and quality of current and expected timber demands and supplies. The demand depends on the size and growth of the population and the per capita consumption including its future trends, and on factors such as substitution and varying market preferences. The target for the production of timber depends also on the national policy decision whether timber should be produced for export, whether this should be on a volume or on a value basis, and whether or not it should be sustained. This decision will be made on the basis of the present and future need for foreign exchange from this source. It is complicated by the fact that a large amount of timber becomes readily available during deforestation arising out of land clearing for agricultural development, making normal exploitation of forest on land scheduled to become the long term productive forest estate less urgent.

Opportunities to delay utilising long term designated forest until the completion of clearfelling of future agricultural land should be identified and seriously considered.

However, there are difficulties in phasing such operations since modern integrated processing plants should be located close to the permanent long term forest estate to which their capacity is adjusted. Also, the future production of logged-over and silviculturally managed forest should on average be considerably greater than the standing volume of preferred species in natural forest and, from that viewpoint, the sooner the conversion and refinement take place the better it is.

A balanced and phased development of the forest resource as a whole, whether designated as permanent productive forest estate or for future agricultural development, should be carried out, taking into account current and anticipated (greatly increased) timber demands, and resulting in a transition as smoothly as possible to the sustained management of the permanent forest estate.

Type and quality of timber produced

The type and quality of the expected timber are as important as the estimated volume and rate of production. On these factors depend the user value and financial returns, and hence the success or failure of management operations in fulfilling the primary objective of timber production. For instance, even the quality of timber of a given species is not necessarily assured. Fast grown *Shorea* spp. will produce timber of reduced strength and poorer quality and *Swietenia macrophylla*, normally subject to shoot borer, has been found in Fiji, where it was introduced, to be free from this pest but to suffer from ambrosia attack. This resulted in the timber being valueless for producing veneer, the purpose for which it had been grown.

3.3 Resources needed for successful forest management operations

Financial resources

The forest estate in most tropical countries is either government owned or in customary ownership. Government organisations have usually controlled and provided for the management of the public forest estate, while the private sector has managed those areas where exploitation of the forest resources proved possible. In recent years, various governments have adopted clauses in timber concession agreements that require the concessionaire to carry out operations such as afforestation following logging and, in some instances, to protect the concession from illegal encroachment. Government forestry organisations have also tended to enter into the exploitation business themselves – albeit on a limited scale – through the establishment of corporations. The reason for this is that governments with large public forest estates regard forest revenue as a regular source of national funds and often fail to provide the means to replace or develop the forest estate for the future. Thus, by establishing corporations, the profits of exploitation are not immediately "lost" to the Treasury, but can theoretically be ploughed back into the sustained management of the permanent forestry estate. Another constraint to the functioning of government forestry enterprises is the common financial procedure which dictates that unspent funds at the end of any financial year return to the Treasury.

Government financial resources for forestry activities are and probably will remain limited. Emphasis of government policy will continue to be on food production, health, education and infrastructural development. Therefore management systems where possible incorporating natural regeneration, a method which requires considerably less funding per unit area and where available funds can thus be employed to regenerate a far larger area, would seem most appropriate. And although the timber yields and the production per unit area will be less, the overall utility might well turn out to be higher, when the other goods and services provided by TMF described earlier are taken into account. Moreover, more jobs will be created, since natural regeneration is harder to mechanize than artificial regeneration methods. Admittedly, nursery and planting jobs will be greatly reduced, but there will still be a need for artificial regeneration in cleared areas, such as abandoned log yards, along unused roads and extraction routes, and where natural regeneration of potentially valuable species is deficient.

Trained human resources

A major problem associated with the management of TMF under shelterwood systems has been the attempt to prescribe in detail not only the series of operations that should take place, but also the details of these rather than the principles. In so doing, there has been a tendency to apply 'blanket' prescriptions overall types of forest and variants of any individual type. However, TMF is a complex and dynamic ecosystem and the application of prescriptions in a blanket fashion has usually failed. A flexible and pragmatic approach, based on a general understanding of the forest and of the silvicultural principles used, is essential to the sound management of TMF. This requires highly trained personnel at all levels, who in addition show initiative, accept responsibility and are good field workers.

The work force in the field must therefore be both experienced and skilled, a condition which cannot be achieved by employing labourers on a casual basis. A permanent, well-trained and dependable labour force is essential for the successful management of TMF.

Research

The management of TMF depends on a clear knowledge of the composition of the various forest types present, of the timber quality and silvicultural characteristics of the important species, on the reliability of natural regeneration of these species, on the silvicultural characteristics of their main competitors at all stages of growth, and on the growth rates of the important merchantable species. Without this knowledge it is impossible to manage TMF effectively. If enrichment planting is to be undertaken, knowledge on the normal frequency of flowering and fruiting, on the raising and establishment of seedlings of important species, and of the best conditions for their growth is necessary, as is a satisfactory technique to eliminate weed species and other undesirable competitors, both herbaceous and woody.

Research to obtain these data is an integral part of the successful management of TMF and should therefore be provided with sufficient human and financial resources.

CHAPTER 4: MANAGEMENT

4.1 Introduction

The successful management of TMF for the sustained production of timber depends entirely upon the forest policy, ideally embedded in a national land use policy, its effective implementation, particularly including the control of the forest estate, and the area and type of forest available.

As we have seen in chapter 3, the most desirable, if not essential, type of production forest is one with a high percentage of merchantable timber species which regenerate naturally in large numbers, are light demanders and therefore fast growing, as exemplified by some dipterocarp forests. The natural, as opposed to artificial, regeneration management possible in such forest types causes only minor structural and species changes, thus greatly contributing to conservation objectives, as well as minimising site damage and environmental deterioration.

In the management of TMF it is essential to understand the various components of its ecosystems, especially those directly affecting management objectives. 'Clearfelling' uniform systems, particularly those designed to promote seedling regeneration by the retention of seed trees, have generally failed because of the strongly competing herbaceous regrowth establishing itself quickly after exploitation, and the erratic flowering and fruiting of the preferred merchantable species. It has been equally impossible to introduce a truly classical selection system, since the age of individual stems cannot be determined and their current growth rate is impossible to ascertain readily due to the general absence of real annular rings (although rings of a kind are found in a few species in rain forest, and in most species in monsoonal forest and in deciduous species).

In general either monocyclic (where the whole production of one growing cycle is harvested at the same time) or polycyclic (where the growing cycle does not equal the harvesting cycle) shelterwood systems of management, which take advantage of existing natural regeneration of preferred merchantable species,have been adopted for TMF. Unfortunately, in the past, foresters have tended to select one management system for the ecosystem as a whole in any particular country, as in the Philippines, and carry out similar silvicultural operations *everywhere*, without paying due respect to the variation in forest types and associations. It is not surprising this has mostly failed, especially when management systems have been introduced on the basis of its apparent success elsewhere. It may be possible to be relatively inflexible in the management system of temperate forests with only a few species, but in TMF, with its inherent diversity, operations must be carried out in a flexible and pragmatic way.

4.2 Harvesting operations

The type of harvesting operation has to be attuned closely to the management system in operation. The inevitable damage to the soil surface and to the residual vegetation varies according to the exploitation system employed, and is an important factor in forest management, especially when natural regeneration is being used. Furthermore, the intensity of timber exploitation determines the extent to which the canopy is opened up, an operation which stimulates growth of the residual crop, or part of it, and may encourage the growth of existing and the establishment of new regeneration.

In the early days logging was extensive and highly selective. Logs were often partially or completely converted on site and the produce removed by animal transport along narrow trails protected by forest cover. Damage to regeneration, advance growth and soil was small. With increasing mechanisation, roads of a higher quality have to be established and much wider tracts of forest land utilised. The forest is cleared to prevent rain drip on roads and to enable the road surface to be sun-dried. Instead of wheeled vehicles with winches caterpillar tractors are now used, because of their higher traction power and to reduce the need for spur roads. These tractors, in particular the large and more powerful vehicles, do great damage to regeneration and to the bark of residual trees during skidding and winching operations, and also compact the soil surface on which they operate. Apart from the necessary clearing of a wide and muddy track, logging involving cable systems (high lead, skyline) also inevitably causes damage, in particular when large and increasingly powerful machinery is employed.

Such logging damage can be tolerated to some extent with a clearfelling system of forest management and when the new crop is established by artificial regeneration. It can be tolerated to a lesser extent when the "clearfelling" management system is dependent on both natural seedling regeneration and advance growth of smaller (ie. below the specified minimal felling girth) timber. It can rarely be tolerated when a selective logging system is employed and the next crop is entirely dependent upon the survival and adequate growth of the residual trees of preferred species. In the latter case, damage not only reduces the yield of the next cutting cycle but also wastes merchantable timber, since under a clearfelling system such timber would have been harvested immediately. With the increased mechanisation and extraction costs, timber operations became more intensive in order to pay for these capital costs.

Timber operators rarely appreciate that they are partners with government authorities in the management of TMF, partly because they are usually not granted sufficiently long leases or concession agreements and therefore have no interest in the longterm sustainability of the resource. Licensees are inclined to purchase the most powerful machinery available to handle the large logs of virgin forest and pay only lip service to the health of the residual trees which should form the main crop at the end of the next cutting cycle. Since government authorities generally license the import of machinery and technically approve the logging plan and set the conditions for the trees to be removed and retained, it is in their hands to ensure that unnecessarily damaging machinery is not utilised and that the health of the residual trees is assured. The conditions of logging are often inadequately controlled and supervised by both concessionaires and government authorities, a hazardous omission when logging personnel are usually paid on a task or output basis.

Improved supervision of logging operations, better training of all personnel and firm implementation of penalty conditions for inadequate work are essential.

4.3 Attempts at management of TMF

An overview

It is a reflection of the many problems affecting the sustainable use of TMF lands,that the area of managed forest is so small. It is 33.6 million ha out of a total of 1,223.5 million ha of closed forest or only 2.9% (FAO, 1982).

In the Americas, its very limited area is located in Trinidad and Tobago, with experimental areas in Colombia, Costa Rica, Puerto Rico, El Salvador and Surinam. Management plans have been prepared in some other countries, but few have been implemented. Silvicultural trials and other relevant research have been greatly accelerated in a number of countries.

In Africa, working plans and shelterwood systems were introduced several decades ago in most English-speaking countries and the former Belgian Congo, but they have in most instances been gradually abandoned for various reasons. These include shortage of trained staff and insufficient funding.

In Asia and the Pacific, intensive forest management has been carried out in the Indian sub-continent and south-east Asia, principally Malaysia and the Philippines. However. as in Africa, working plans in most countries, although introduced many decades ago, have been poorly implemented in recent years or gradually abandoned for various reasons, such as sudden changes in land-use policies, and national over-felling because of short-term expediency. India is one exception, but until recently most of her forests were being managed on a very low yield.

An example of TMF management: Peninsular Malaysia

The Malayan Uniform System (MUS) was developed in Peninsular Malaysia, following research, and experience gained with Regeneration Improvement Fellings adapted from classical shelterwood systems of the temperate world (Wyatt-Smith, 1963). It was designed to take account of the continuous, though fluctuating, abundance of natural regeneration of the preferred merchantable timber species, and the ability of their seedlings and limited number of saplings to respond to increased light and win their way through the tangle of climbers, herbs and small trees resulting from substantial canopy opening. This system met with the loggers' desire to remove all the standing merchantable volume per unit area in one operation, in order to meet the high capital investments involved in mechanisation and road construction.

The preferred timber comprised the red meranti group of species of the genus *Shorea* and several species of the genera *Anisoptera, Dipterocarpus* and *Dryobalanops*, of which *Shorea* and *Dipterocarpus* were in particular abundance in most areas of lowland rainforest. These species were known to be strong light demanders, to flower and fruit prolifically at intervals of about 3 to 5 years, to have seedlings which can survive dense shade in reasonable numbers for around 5 to 7 years, and to be able to grow in relatively pure stands.

The MUS used a monocyclic system of 70 years, a conservative estimate of the time required after exploitation for the seedlings to produce a crop with an average 1.8 metres girth at breast height (gbh). Advance growth, i.e. trees below the specified minimum felling girth, were treated as bounty. Species were classified in three main preferential groups according to timber potential. Enumerations of stocking intensity, distribution of classified stems and their growth status were undertaken when required, taking timber classification and subsequent priority into account. There was provision for drawing up local species' lists and for categorisation of species within these lists, to render management more flexible.

The first stage of canopy opening was the exploitation of the crop, when all merchantable stems of 45 cm diameter at breast height (dbh) were marked for felling and logged. The second stage, undertaken departmentally, was the completion of the canopy opening by frill girdling and by pouring poison in the frill of all unfelled stems above the minimum felling girth and the cutting and poisoning of all woody climbers. This ensured the removal of nearly all unwanted large trees over a period of a few years, while refraining from too drastic a canopy opening and preventing extensive damage to sapling regeneration which would have been the case if unwanted trees were felled. The same operation removed stems below the minimum felling girth which were of undesirable species or of bad form and defective. Subsequent enumerations to determine the status of the regeneration were undertaken and further refinement operations carried out. Special prescriptions were introduced if the forest was deemed to be of a slow heavy hardwood type, and in some cases climber cutting and poisoning was carried out two to three years before exploitation to minimise felling damage. Management prescriptions were flexible and depended on an understanding of the problems and the measures required to overcome them.

What, however, had not been sufficiently realised in practice was that the system had been developed around the rich red meranti species of *Shorea* and species of *Dipterocarpus*, and that if these or similar light-demanding species with abundant natural regeneration are not present in the natural forest, it should *not* be applied. At the time of the system's development and early implementation, most of the designated future forest estate had these desirable characteristics. This is no longer the case today, owing to a sudden change in government land use policies and the criteria underlying these. However, it is understood the

MUS is still being applied in Peninsular Malaysia, albeit on a limited scale, to those forests that have the necessary characteristics for it to be successful.

Malaysia's recent polycyclic Selective Management System (SMS) for hill forest has been adapted from the Selective Logging System in existence in the Philippines. There, a bicyclic system with a cutting cycle of around 35 years, in which a percentage of the merchantable timber crop above a minimum felling girth and of smaller dimension is retained for the next cutting cycle, is employed. In the SMS a pre-exploitation inventory is carried out in four size classes (15-30, 30-45, 45-60, 60 cm dbh and over). On the basis of this inventory a minimum felling diameter is specified for dipterocarps and another, five centimetres less in diameter for non-dipterocarps. Trees are marked for directional felling. The minimum cutting limits are determined so as to ensure a net economic log-outturn of at least 21 m^3ha^{-1} and at the same time leave an adequate residual stocking for the next cut. The cutting cycle is one of 25 to 40 years (Griffin and Caprata, 1977).

It is accepted in Peninsular Malaysia that the yield of the second cutting cycle will be less than that of the first and that the species composition will change greatly. There are as yet no informed predictions regarding yields from the third and subsequent cutting cycles if the present system of management is retained. This flexible system has been designed to compensate for the overcutting that took place in the late fifties and sixties and to combat the current shortage of prime sawlogs for the industries established. However, many problem areas exist. Damage caused by exploitation to residual growth and to regeneration will be doubled compared with the MUS. The forest areas are not rich in strong, fast-growing, light-demanding species of the timber quality of the genera *Shorea* and *Dipterocarpus*. There is little knowledge of the nature of the future crop and how it should or can be treated. Research was unfortunately ill-prepared for the sudden policy changes.

TMF management experiences in other countries

In the Philippines the Selective Logging System,which has been in general use for four decades, is a bicyclic shelterwood system of management in rich lowland dipterocarp forest. The forests have fewer species, but are richer in timber than those of Peninsular Malaysia and show excellent regeneration of the preferred timber species.

However, different forest types and different rates of growth of the preferred timber species are known to exist. The prescriptions for the percentage of trees to be felled in each girth class have unfortunately been applied rigidly, though admittedly three categories of cutting cycles (40, 35 and 30 years) have been recognized, according to the forest location. Moreover, use of heavy and powerful exploitation machinery has been permitted, causing extensive damage to residual trees. On the other hand, excellent examples of regrowth have occurred in rich forest areas originally exploited under a highly selective system with a high minimum felling girth which employed less powerful machinery. It is unlikely, however, that such results can be consistently repeated. Moreover, much of the forest exploited today is of poor quality compared with that of the past, and regeneration potential is not as good, although it is certainly not deficient in most forest areas.

In Nigeria, West Africa, attempts to introduce the MUS failed because the essential ecosystem components were different. Similarly, subsequent application of the Tropical Shelterwood System has also largely failed due to the lack of adequate regeneration and insufficient advance growth of the preferred species, the Meliaceae. However enrichment planting with *Terminalia spp, Triplochiton scleroxylon* and certain Meliaceae has had some limited success. In Ghana, a Selection System has been in operation over many areas for several decades. This is designed to increase growth rates of individual trees of valuable species larger than 10 cm of diameter at breast height (dbh) at time of harvest. The forest is, however, not rich in commercial timber and the system is unlikely to be either cost-effective or practical, or sustained once the over-mature stems of the natural forest have been exploited.

In Uganda, East Africa, a Selection System has been in operation – see Dawkins (1958), but regeneration of merchantable species has generally been scanty. To reduce the costs of operations to remove unwanted woody growth competing with high quality timber trees, charcoal production operations near urban centres were introduced to convert what had been a financial net cost to a net gain. This is an excellent example of a flexible pragmatic approach to the management of TMF. The production of firewood and charcoal in such circumstances was earlier carried out in Peninsular Malaysia.

In Latin America there has been little management of TMF. Natural regeneration is being successfully carried out in Mora forest in Trinidad, and in Puerto Rico there has been successful management on a selection cutting system over a very restricted area of hill forest. In Surinam, the polycyclic CELOS Silvicultural System has been developed after 25 years of research in lowland areas (de Graaff,1986). Monitoring of the trial sites has shown no undesirable ecological side-effects, and treatment costs are considered reasonable. Sustainability of timber yields after second and consecutive harvests on a cycle of 25 years, and large-scale applicability of the system cannot yet be determined, but it is reported that the prospects are promising.

Shelterwood systems incorporating natural regeneration

The operations for the management of TMF by natural regeneration under a shelterwood system, whether monocyclic or polycyclic, are very similar. They are broadly as follows:

(i) enumeration of the tree crop of merchantable size, by species and species groups, in pre-determined size classes;

(ii) assessment of the existence and distribution of adequate seedling and/or advance growth regeneration and the crop potential of the merchantable species in appropriate size and stocking classes;

(iii) the opening of the upper canopy to let in light, initially by exploitation and thereafter in some cases by the rapid removal of unwanted trees by frill girdling and poisoning or, where possible, by felling for profit (fuelwood or charcoal);

(iv) the killing of all woody climbers (a) to minimise felling damage to sapling regeneration and residual large trees, and (b) to facilitate seedling regeneration, and growth of saplings and residual larger trees; and

(v) in limited cases: the refinement and release at necessary intervals of sufficient numbers of the new growing crop depending on size and distribution, by the removal of competitors which are potentially harmful to sound regeneration of timber species. Care is taken not to remove competitors to excess and thereby promote, as a result of too much light, the proliferation of weed species, especially herbaceous climbers, of earlier successional stages.

Ideally, the sequence of operations is approximately as follows:

Timing	**Operation**
E – 1-2 yrs	Climber cutting and poisoning to minimise felling damage (this operation is not universally carried out).
E	Exploitation down to a minimum felling girth. (i) Monocyclic systems – dependent on seedling regeneration and a long cycle to enable average tree to reach timber size. (ii) Polycyclic systems – dependent on residual growth after felling and an approximate cycle of half the average rotation of the main species to reach timber size.
E + 1 yr	Removal of unwanted trees of commercial size and of competitors down to sapling size by poisoning or if possible for use as firewood or conversion to charcoal to refine stand and complete canopy opening, preferably at a profit. (This eminently desirable operation is rarely carried out today owing to cost)
E + 1 yr	Climber cutting and poisoning combined with previous operation.
E + 2 yrs	Regeneration enumeration (usually monocyclic systems only).
E + ? yrs	Cleaning and tending (the minimum number of occasions necessary to save the crop; rarely carried out today).

The length of time taken for the operations and the frequency of cleaning and tending will depend very much on local circumstances. Refining of the crop and tending operations will be carried out at a profit whenever possible.

Essentially, all the successful examples of TMF management have been flexible and pragmatic towards varying local circumstances, taking advantage of any possibility of combining necessary silvicultural refinement and crop release operations with obtaining produce which can be sold.

CHAPTER 5: SUMMARY AND CONCLUSIONS

Tropical Moist Forest is a natural resource that provides a multitude of products and services, which are indispensable to human well-being. Its role in the protection of the environment against erosion and flooding, as well as its supreme importance to the conservation of the invaluable genetic diversity on this planet, go unchallenged.

Although it can be managed as a truly renewable resource, it is not always possible to manage it for the sustained production of merchantable timber. Moreover, existing knowledge about TMF management is often not being put into practice. The reason for this is that there are increasing and often competing demands for agricultural and other development purposes and for increased goods by a rapidly expanding population. Short-term expediency has unfortunately tended to rule the day. Long term planning and the value of TMF goods and services, both known and unknown, have rarely been given meaningful priority.

Growing emphasis has been placed on providing increased forest goods through artificial regeneration using fast-growing, higher-yielding species and the use of agricultural-type methods in growing timber crops. However, these plantations do not provide the same products, nor the same environmental and conservation services as does TMF, nor have they been over successful in the humid tropics.

Governments drawing up their forest policies and systems of management are placed in a difficult position. Fortunately, it is increasingly being realised that the artificial separation of agriculture and forestry, the management of land on short term economic grounds, and ignoring the welfare and participation of rural people in rural developement and implementation, can no longer be tolerated in rational land use.

Unfortunately, few countries can meet all their domestic needs from managed TMF. However, it is folly not to preserve what is left in countries with limited remaining natural forest areas, and for the time being to retain as much as possible in the few fortunate countries with abundant TMF resources and to manage it on a sustained basis, rather than mine it unnecessarily and waste its potential. Management must be designed and executed flexibly and pragmatically, taking into account not only local circumstances and conditions but also both medium and long term effects of the management decisions taken.

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ANNEX: DEFINITIONS

1. Tropical Moist Forest (TMF)

Tropical moist forest is a term used by Sommer (1976) and adopted by FAO to describe the closed high forest lying in the tropical belt of the world (Figure 1) where the dry season is short (4 months) or nonexistent. TMF is a complex ecological system, still poorly known and understood and includes both the dryland and wet rain forest formations, as well as the monsoon and mountain rain forests.

In this account mangrove and upper montane forests, though closed moist forests of the tropics, are excluded because in neither case is management for sustained production of timber (see definition below) ever likely to be important. Mangrove forests do offer opportunities for sustainable production, for instance of firewood and/or tannin whether or not combined with pisciculture, but these will not concern us here. Upper montane forests are usually inaccessible, have an important protective role and have species of low or no commercial timber value owing to small size, poor form of stem (usually short and crooked) and often a low volume per hectare both total and of individual species. Foothill forest and lower montane formations are included, eg. the upper dipterocarp forest of southeast Asia, the montane *Araucaria* and *Nothofagus* forest in Papua New Guinea and accessible mountain forests of central Africa, central and south America.

2. Sustained Production

To exploit forest in a way that provides regular yield of forest produce without destroying or radically altering the composition and structure of natural forest as a whole. Thus it is more than maintaining the rate of production at the low level of natural forest which merely replenishes natural mortality. It is used in the sense of enhanced production through silvicultural practices while conserving the protective role of the vegetation and the genetic pool of all species other than those regarded as weed species and which compete with and suppress favoured timber trees.

3. Timber

This is narrowly defined to cover logs suitable for sawtimber, plywood manufacture and veneer.

However reference is also made to the other components of the TMF ecosystems, namely herbs, shrubs, lianes, lichens, fungi, microfauna and flora, small tree species and fauna generally. Some of these can be managed for sustained production too, as is shown by the examples of butterfly and rattan farming in intact forest ecosystems.

4. Natural Regeneration

To favour the spontaneously occurring regeneration of species of known preferred value to man plus those considered likely to be acceptable in the future. It involves treating as weeds those species which compete adversely with those favoured.

5. Enrichment Planting

This embraces all planting, whether along regular lines and spacing, or as groups, or as irregularly spaced individuals (patch planting), within an overall matrix of the original vegetation, however this is treated, where the planted trees constitute less than 50 per cent of the estimated future crop. It excludes planting and sowing whether with indigenous or exotic species in areas clear-felled and burnt.

Definitions 4 and 5 accord closely with those published by FAO (1967).

Figure 1. Distribution of Tropical Moist Forest.

Source: Adapted from U.N. Food and Agriculture Organization (FAO). *Unasylva, Vol.* **28**. No 112-113 (1976).