

Conservation, Management and Development of Forest Resources

Proceedings of the Malaysia-United Kingdom
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Forestry Department Peninsular Malaysia



Forest Research Institute Malaysia



Government of Great Britain
and Northern Ireland



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CONSERVATION, MANAGEMENT AND DEVELOPMENT OF FOREST RESOURCES

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Jointly organised by
Forestry Department Peninsular Malaysia, Forest Research Institute Malaysia,
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(Environmental Economics Programme)

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FOREWORD

It is indeed a pleasure for me to share a few thoughts in this foreword to the Proceedings of the Workshop on Conservation, Management and Development of Forest Resources. The research programme that led to this workshop was developed from a Memorandum of Understanding signed between the Government of Malaysia and the Government of the United Kingdom in May 1992, aimed at strengthening the capacity of collaborating institutions to assess and develop sustainable forest management systems through the exchange of experts and information, transfer of appropriate

technology, training of personnel as well as adoption of methodologies to monitor and evaluate environmental and social impact and methodologies for forest resource accounting. It is gratifying to note that the Workshop had brought together all interested parties, researchers as well as the agencies concerned, to share information, research findings and the benefits derived from this collaborative effort.

This joint research programme was carefully designed to focus on widely debated issues related to the conservation of biological diversity and sustainable forest management. These issues are of global concern and have featured prominently in Agenda 21, the Convention on Biological Diversity and the Forest Principles that were endorsed at the Rio Earth Summit in June 1992. The Post-Rio era has seen many nations taking measures to operationalise what was agreed to in Rio, including the Commission on Sustainable Development, the Intergovernmental Panel on Forests as well as the Conference of Parties to the Convention on Biological Diversity. Both the United Kingdom and Malaysia, have participated actively and are continuing to do so in these intergovernmental and other international and regional fora relating to the conservation and sustainable utilisation of biological diversity, as well as the sustainable management of forest. It is, therefore, only fitting for both countries to continue and demonstrate partnership through this research programme that was the subject of the Workshop held in October 1996.

The contribution of forest resources to the economic well-being of Malaysia is significant. Yet like many other countries in the world, much of the biological diversity contained within our forest is insufficiently documented, and the role of biological diversity in forest ecosystem functioning still leaves much to be discovered and understood. Similarly, there is also a need to recognise and attach proper values to the many goods and services provided by forests at the national, regional and global levels. As a developing nation, our capacity to address these issues effectively depends to a considerable extent on the technical and financial assistance from the developed countries and the relevant international organisations. Thus, this collaborative programme represents not only a partnership which will be of mutual benefit to both countries, but more importantly its findings will further contribute to the knowledge base of mankind on biological diversity and sustainable forest management.

Dato' Seri Dr. Lim Keng Yaik
Minister of Primary Industries
Malaysia



FOREWORD

It is with great pleasure that I contribute this record of technical achievements in what is a fascinating and crucial area of development. This programme, which has been jointly funded by Malaysia and the UK, has set new standards in international cooperation. Over the past four years it has opened up fresh prospects in several crucial fields of endeavour, incorporating rain forest bio-diversity and applying new concepts in forest resource economics. The papers in this volume address a range of topics of particular concern to everyone on this planet. Concerns that we ignore at our peril.

This programme has tackled broader, and still emerging, questions as to the value in economic terms of non-timber products and services. Successive papers tackle individual forest food crops, medicinal plants of possibly major international significance and the scope for cultivating rattan or bamboo as the basis for a profitable export trade. The programme has also attempted to address the conservation values of forest in reducing sediment load in rivers, the potential of forests for local and regional rainfall generation, and also the income earning opportunities from recreational visits to the fine Malaysian forest countryside. These are issues of significance both within and beyond Malaysia's borders. They are of great importance to us all.

This is an excellent example of Malaysia and Britain working together in order to understand more clearly the internal workings of the rain forest, together with the range of contributions which rain forests make to the welfare of all mankind. Forests are under immense threat globally. It is important now more than ever that humanity gains a rapid understanding of all that the rain forest can bestow - and acts accordingly.

HE Mr David Moss CMG
British High Commissioner to Malaysia

KEYNOTE ADDRESS

FUTURE CHALLENGES IN SUSTAINABLE FOREST MANAGEMENT

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Introduction

Allow me first and foremost to thank the Organising Committee for providing me this opportunity to address this distinguished and diverse audience regarding the topic of sustainable forest management. As you are fully aware, sustainable forest management is the topical issue of today, not just for resource managers but for people from all walks of life. This is not surprising as the forest is nature's most bountiful and versatile renewable resource which is capable of providing simultaneously, a variety of benefits including economic, social and cultural benefits, as well as services. The multiple roles played by forests are far reaching and have been recognised and appreciated by society at large, more so today than they have ever been before. Consequently, Malaysia recognises that in the long run, it is to her own benefit that the forest resource be managed sustainably to ensure that the needs and the aspirations of not only the current but also the future generations are fulfilled. In this regard, I feel that it is most opportune for me to share with you my thoughts on the topic regarding "Future Challenges In Sustainable Forest Management".

The survival of forest is important for the sustainability of other key resources of planet Earth, such as soil and water, which are essential for the survival and continued development of humankind. In this context, Malaysia is fortunate to be endowed with relatively large tracts of rich and diverse tropical rain forests. The total area of natural forest in Malaysia in 1995 was approximately 19 million ha or 58 per cent of the total land area. Of this forested land, Malaysia has designated 14.3 million ha or 44 per cent of the total land area, as Permanent Reserved Forest (PRF). These are forested lands permanently reserved under legislation to be managed sustainably for protection, production, amenity, research and education purposes.

The economic contribution of the forest is reflected by the fact that the country has emerged as one of the main suppliers of the world's tropical hardwood products. In 1995, the total export value of timber and timber products, including rattan and bamboo, was E.o.b. RM 13.1 billion or 7.0 per cent of the country's total export receipts, and provided direct employment opportunities for about 225,450 people. The forest is also important for the sustainability of many other environmental, hydrological and ecological processes. Although not easily translated into economic values, the roles of forest and trees in watershed protection, conservation of soil and water resources, as well as the conservation of genetic resources and as a gene pool

for agricultural crops have long been recognised by forest managers. To meet such needs, large areas of forest lands and wildlife reserves have also been established throughout the country.

Changing trends

However, in recent years, as a result of changing values and priorities, there is now an increased recognition of the environmental and protective roles of forest, such as in the regulation of climatic and physical conditions, the safeguarding of water supply, maintenance of soil fertility, aesthetic and recreational amenities, as well as in the conservation of biological diversity. These roles may be at the local, national, regional and even at the global level.

Considering the significance of the forestry sector to socio-economic development and the maintenance of environmental and ecological values, the finite size of the resource base, as well as in meeting the changing trends in values and societal needs, the question to be asked is "what kind of challenges will the sector face in the future in sustaining itself?"

This is not an easy question to answer. However, by drawing from past experiences and based on current trends as well as postulations made by eminent futurists, I will try my best to describe the future challenges in forestry, with special reference to Malaysia. As some people say, the best way to anticipate the future is by understanding the present.

Future perspective

One thing sure about the future is that there will be a lot more people residing in this world. It has been estimated that the current 5.5 billion people will increase to nine or ten billion people by the middle of the next century. Most of this growth will happen in developing nations. On one hand, it is predicted that half a billion people will suffer from malnutrition and 15 million will die each year from starvation and diseases. It is also predicted that deforestation, desertification, soil degradation and the unavailability and shortage of clean water will deny the means to sustain the increasing human population. At the same time, there will also be shortages of non-renewable resources, such as oil and gas. On the other hand, it is predicted that the next century will be one of prosperity, with increased output of goods and services, international trade, accumulation of wealth, and increased standards of living and quality of life for all. Nonetheless, two major challenges will face the world communities, namely, to meet the demands of an increasing population and to avert environmental degradation.

In the case of Malaysia, an increase in population is quite clear; this is estimated to reach 52 million people by the middle of the next century and 70 million by the year 2100. Of this, the urban population may well be over 60 per cent. As a result, there will be considerable demand for land, not only for food production, but also for housing. This invariably will exert substantial pressure on the remaining forest areas, as these will be the only lands available in the country.

Based on these predictions, how would the natural resource sector, specifically that of forestry, fare in the future? I am optimistic that with the current achievements and the conducive political, cultural and economic atmospheres, Malaysia will continue to progress well enroute to attaining the status of a developed nation by the year 2020. As the country progresses towards industrialisation, the roles of the forest will become more important. These roles have been clearly stressed in the goals and aspirations of the Vision 2020 by the Prime Minister of Malaysia as follows; I quote: "... we need also to ensure that our valuable natural resources are not wasted. Our land must remain productive and fertile, our atmosphere clear and clean, our water unpolluted, our forest resources capable of regeneration, able to yield the needs of our national development. The beauty of our land must not be desecrated -for its own sake and for our economic advancement." Unquote. In my humble opinion, the future challenges of the Malaysian forestry sector will be focused on the attainment of this Vision.

Future challenges

Based on the above scenario, allow me to briefly touch on the future challenges in sustainable forest management with special reference to Malaysia, I will group these into six main clusters, namely:-

- Resource Management
- Resource Conservation
- Resource Utilisation
- Resource Valuation
- Capacity Building and Research
- Globalisation of Forestry Issues

Resource Management

The major challenge to resource management concerns the sustainability of the forest resource. Although everybody agrees that the sustainability of the forest is of paramount importance, there is still much disagreement over the meaning of sustainability and its assessment. To me, it simply implies that we have to manage our invaluable forest resource to ensure a continuous flow of goods and services in perpetuity for the benefit of the people, compatible with the need to preserve ecology and the environment.

Foresters today are widely criticised for not moving quickly enough to embrace new visions, goals, principles and management approaches. In this connection, forest management practices would need a paradigm shift from sustained yield timber management to sustainable forest ecosystem management. There is also a need to expand the spatial scope of forest management from individual forest stands to entire forest ecosystems and landscapes.

The traditional system of sustained yield management will be replaced by a new paradigm of multi-resource forest management. Multi-resource forest management by definition, is the deliberate application or withholding of labour/capital inputs to or from a biophysical forest system for the simultaneous production of several socially desirable outputs. It is conditioned by prior knowledge of consequences to the system of both spontaneous and management-induced perturbations, and constrained by the intention of maintaining the forest ecosystem as a forest ecosystem. Multi-resource forest management is also land oriented, an exercise in husbandry determined by the ecology of production, and seeks the simultaneous production of several interdependent goods and services. In a multi-resource system, each 'resource' of the forest is perceived by humans to be useful or otherwise appealing, and links all other elements in the system, including the flow of energy and the cycling of nutrients and water.

In this context, forest management in Malaysia is expected to undergo a major re-engineering and transformation. Firstly, the traditional idea of sustained yield management which is based on the concept of equilibrium - a balance between growth and harvest which can be sustained in perpetuity, is deemed to be inappropriate in a society where change is ubiquitous and rapid, and where the forest is appreciated for its provision of an array of commodity and amenity values. Secondly, the supply scenario of the timber sector is expected to be greatly reduced with the diminishing area of virgin forests, at least in Peninsular Malaysia, at the close of the century or early next century. Finally, the dependence on forest as a source of commercial timber for revenue generation will be less significant as the country proceeds towards industrialisation.

However, with the rapid pace of industrialisation and the current policy of halting the opening of new areas of forested land for agriculture purposes, the total area of the Permanent Reserved Forest (PRF) may in fact be increased from the current 14.3 million ha through the inclusion of existing State Land Forests. In addition, the total forested area may also be increased through the rehabilitation of idle and abandoned alienated lands. Perhaps this may be undertaken by farmers and small-holders as a profitable undertaking. At the same time, there will be greater participation from the private sector and local communities to create additional timber resources through the establishment of forest plantations.

My next point touches on non-timber values of the forest. In recent years, much more attention has been paid to the importance of non-timber values of the forest. It is expected that in the future these non-timber values which include plants or animals for food and medicinal purposes, water, rattan, bamboo, dyes, resins, as well as services such as recreation and aesthetics, will be of even greater importance, especially in their local context where they may be considered more valuable than the wood obtained from the forest. Amongst these, the most crucial challenge will be the adequate production of clean water. Hence, emphasis should be accorded to watershed management in order to guarantee food production in high-yield areas. Links must also be maintained between forestry and food production through an integrated approach to watershed management, and incentives must be provided to rehabilitate degraded watershed areas.

In this context, the demand for water in Malaysia is growing at four per cent annually and by the year 2020, it will reach 20 billion cubic meters. Rivers which originate from forested watersheds currently provide 97 per cent of the country's supply of clean water. Subsequently, its management which hinges on the degree of forest protection up-stream will become ever more crucial.

Resource Conservation

Tropical forests, despite their high biological diversity, are fragile ecosystems and are less able to recover from several or repeated human disturbances than temperate and boreal forests. Many tropical forest species are extremely vulnerable to habitat change. This is partly because of the limited and/or scattered distribution of most species, their adaptation to specific ecological niches, and the interdependencies between species.

However, it should be noted that the importance of temperate and boreal forests to global biological diversity has been underestimated in the past. Two main factors contributed to this phenomenon. Firstly, the old growth forests have been replaced with regrowth or plantations in many cases, and to a casual observer, the two may appear similar. Secondly, the emphasis on the conservation of large plants and animals has obscured losses of less noticeable species.

Hence, conservation of biological diversity in forest ecosystems would require some hard decisions from policy makers. Choices may have to be made to prioritise one habitat or species over another. In some cases, long-term conservation strategies may also have to include the rehabilitation and the re-creation of primary forests. In this connection, since the 1930's, Malaysia has been establishing a network of protected areas for the conservation of biological diversity. Currently, Malaysia has a total of 2.13 million ha of conservation areas protected by legislation. Of these, 1.80 million ha are located outside the PRF whilst another 0.33 million ha are located within the PRF. Hence, with the 3.39 million ha of protection forest within the PRF, the total area designated for the conservation of biological diversity in Malaysia is now estimated at 5.19 million ha or 27.2 per cent of the total forested land.

There is also a need to resolve the issue of intellectual property rights (IPRs) and patents of products, including biotechnological products, derived from the use of forest genetic resources. In fact, there is an urgent need to develop mechanisms for the equitable sharing of benefits arising from the commercial utilisation of genetic resources with the country of origin of such resources.

Resource Utilisation

My next point touches on forest industry. Based on the projections made on forest production, log supply in Malaysia is expected to be gradually reduced over the next decade and will stabilise at around 30 million cubic meters per annum. This would give rise to a log deficit of eight million cubic meters. Consequently, the sector in striving to stay above this inherent problem, is expected to adapt itself through

the use of advanced technology, reduction of production costs and wastage, as well as reorientation of products-mix, and subsequently adopting new marketing strategies. In other words, as a result of these developments, future trends of timber utilisation will shift from big dimension logs to smaller logs, commercially well-known timber species to lesser-known species and solid wood to reconstituted wood and panel products.

Another point of concern is the sharp increase in urban centres which will result in greater demand for greenery. In this regard, greenery will be the "in-thing" which will be highly sought after. Public appreciation of the presence of greenery in the city or urban areas is expected to escalate. Consequently, urban forestry will gain greater prominence and its role especially in ameliorating urban heat islands and microclimate will be well appreciated by future generations. In this regard, the roles of the forest, both public and private are expected to be greatly enhanced. At the same time, the demand for recreation and eco-tourism by city dwellers is also expected to increase. The development of eco-tourism will pay significant dividends, as the general public has been sensitised to nature and the environment through the mass media. Many will want to see for themselves and are willing to pay substantially to do so.

Resource Valuation

With regard to resource valuation, many ecologists as well as economists believe that the world's forests are not valued properly in economic terms. In this context, current economic valuation of forest resource on the basis of the monetary costs of extraction and distribution has often resulted in inadequate incentives for sustainable resource use. Hence, fully consistent with market economy principles of product transactions, the system of incentives and penalties will have to be re-examined and reoriented to fully reflect the full costs for forest goods and services, including environmental costs. The internalisation of environmental costs will dispel the assumption that the environment is a free commodity.

Moreover, widely used economic indicators, such as gross national product, do not reflect the sustainability of the forest resource in the overall development process. Thus, it is imperative that national policies and development projects take full account of their effect on the environment and include the cost of natural resource depletion, particularly forests, in the valuation of environmental quality in national accounting systems. This will bring about fundamental changes in the integration and accounting of the environment, as well as forest resource development in decision making. This will also facilitate a paradigm shift from a *post facto* approach to an anticipatory approach in addressing forest resource use and environmental degradation at their roots.

In Malaysia, valuation problems still exist for many of the diverse goods and services that the forest provides, especially those that are not readily traded in the market. Some of these include watershed protection, carbon sequestration and the conservation of biological diversity. Even when environmental values are

recognised, they may not be measured or used to promote efficient resource management. Such situations often lead to unfavourable consideration of forest as an option in land-use allocations. If forest is to be sustainably managed, the people must be convinced that land as an asset will remain more valuable under forest than under any other forms of land-use. It will be necessary to find the means to assess the values of the forest accurately in monetary terms and to develop techniques to compare these values with that of alternative forms of land-use.

Capacity Building and Research

Environmentally sound technologies are fundamental for the transition to sustainable forest management in many developing countries. In this context, many of these countries face an acute shortage of scientific, technical and professional personnel, as well as the institutional capacity for the evaluation of their own development options, the formulation and implementation of the policies required to make them effective, particularly in the field of forestry and its related activities. Hence, it is imperative that these countries double their efforts in building indigenous human and institutional capacities so as to enable them to achieve sustainable forest management and conservation in the overall context of sustainable development and sound environmental practices.

Related to this, there is also the need to look at the forestry profession itself. With all these developments, the forestry profession is now at a crossroads. Traditionally, the majority of foresters, especially in Malaysia, are generally engaged in the management, conservation and development of public forests. This invariably entails involvement in timber harvesting and revenue collection for the government. Consequently, foresters until today have often been associated with timber harvesting and production. Thus, there is an urgent need for foresters to redefine their roles and responsibilities as professionals. The greatest challenge facing the forestry profession in the coming years will be the ability of foresters to meet changing societal needs for both forest goods and services, without unduly degrading the resource and the environment.

In this connection, all foresters particularly those serving in the public sector, must not only acquire special and high levels of technical skills and new knowledge, but more importantly, they must be disciplined and demonstrate a high level of professionalism. This will invariably also require a higher degree of professional integrity and accountability. In other words, they must be creative and innovative, able to think laterally and critically in problem solving and be action oriented. In addition, they must be able to express themselves well and communicate effectively and clearly both with the political masters and the general public in order to garner the necessary support required for effective implementation of sustainable forest management practices. This is very crucial in order to cope with the ever changing global environment.

Another feature which will be expected in the future is the role of the public in forestry and environmental issues. Recently, public awareness and concern on issues such as illegal logging, landslides, flash floods and pollution, are clearly on the rise.

If this continues, the public will be expected to play a vital role in voicing concerns about the management of natural resources and their impact on the environment. In a similar light, the NGO's and private sectors are also expected to play a more significant role in the promotion of sustainable forest management practices. In this regard, the forestry sector will have to pay greater attention to public needs and improve community development and extension, in fulfilling the increasing societal demands that will be placed on the forest in the future.

Another point which I would like to highlight at this Workshop is that there is an urgent need in Malaysia for the forestry sector to take a quantum leap in research and development (R & D). This will provide the necessary impetus needed to transform the sector to meet the challenges of the future. The current inputs from R & D will have to be re-engineered to accord greater emphasis to the fields of genetic engineering, biotechnology, ecosystem management and high-tech development in order to enhance the productivity and sustainability of the finite forest resource base.

Globalisation of Forestry Issues

Conservation and sustainable development of all types of forests world-wide have now become global issues and priority items on the international policy agenda. These issues are being thoroughly addressed in numerous fora, particularly in the context of various decisions reached at the United Nations Conference on Environment and Development (UNCED), held in Brazil in 1992. The roles of all types of forests have received extensive attention particularly in the conventions on biological diversity and climate change where Malaysia is party to both.

However, most of the attention has been focused on tropical forests where their alarming rate of depletion and degradation have been linked to many of the world's environmental woes, such as global warming and the loss of biological diversity. Consequently, tropical timber producing countries have been accused of mismanaging their forest resources. In view of this, mounting pressures have been exerted on these countries to reduce forest exploitation and to adhere to sustainable forest management practices through the imposition of trade restrictions by the consumer countries, such as eco-labelling and timber certification, as well as bans and boycotts of tropical timber.

To address these issues, several global efforts have been initiated. Amongst them, the most relevant to Malaysia is the International Tropical Timber Organisation (ITTO) Year 2000 Objective which requires all tropical timber products traded in the international market to be sourced only from sustainably managed forests. The attainment of this Objective will be amongst the greatest challenges to Malaysia in the near future. In this regard, Malaysia has already taken several concrete steps through the establishment of a National Committee on Sustainable Forest Management with representation from various forestry related agencies. Thus, we can expect that all timber from Malaysia in the future will be sourced from sustainably managed forests and that timber certification will be a norm. There will also be greater understanding, cooperation and commitment from both the government and private sectors.

At this juncture, permit me to touch briefly on the power of information technology (IT). In this era of information, those superior in IT will inevitably have a competitive edge to come out as winners. Prominent futurists such as John Naisbitt stressed that *the new source of power is not money in the hands of a few but information in the hands of many*, while Peter Drucker stated that *the productivity of knowledge has already become the key to productivity, competitive strength and economic achievement. Knowledge has already become the primary industry, the industry that supplies the economy the essential and central resources of production*. Thus, forest managers are expected to modernise and upgrade their expertise and capabilities in information technology to meet future challenges. This is the only way that forest managers can keep pace and be competitive in the borderless world of tomorrow. In this regard, the Forestry Department, Peninsular Malaysia, is already well on its way to providing its own forestry homepage as an integral component of its IT set-up.

Conclusion

In conclusion, I would like to stress that the forest provides a myriad of benefits and values not offered by any other forms of land-use, and that it will remain as a central focal point in international and regional initiatives. Sustainability of forest resources and environmental protection, as well as ecological stability, are all integral parts of the overall global ecosystem and hence must be viewed and addressed holistically.

In this context, the nation's long-term health will be best served by maintaining and sustaining significant areas of natural forest. Healthy, productive forests in Malaysia will contribute not only to the nation's environmental stability and economic development, but also to global health and the well-being of humankind in the future.

Environmental considerations will also be one of the major concerns of Malaysia in the future. Environmental woes such as those related to the disposal of toxic wastes, air and water, as well as noise pollution, emission and concentration of atmospheric CO₂ and the occurrence of acid rain will become the centre of attention as the country moves towards industrialisation. In order to avert these, environmental management must be well planned and coordinated by all parties concerned. Through a concerted and coordinated approach, we will be able to turn the tide of destructive forestry practices, stabilise the complex forest ecosystem and even increase the provision of future forest goods and services.

Hence, I believe the crux of the issue is in the retention of adequate forest cover and in solving the problem of sustainable forest management and development. If these can be undertaken successfully, then all other related issues such as the provision of forest products, conservation of soil, water and biological resources, mitigation of climate change, and the maintenance of environmental stability and ecological balance would also be resolved. With this, the nation's Vision 2020 would also be achieved.

I sincerely believe that these are the most important challenges before us in our efforts to fully attain sustainable forest management. I can see that we have experts from a variety of fields gathered here at this Workshop who are committed to meeting

the mounting challenges faced by the forestry sector. I invite you to consolidate your thoughts and efforts towards addressing these issues. With a unified and concerted action to overcome these challenges I can foresee ourselves moving into the renaissance of forestry, especially in Malaysia.

With these remarks I would like to conclude my address. Thank you for your kind indulgence.

CONTRIBUTION OF THE FORESTRY SECTOR TO THE MALAYSIAN ECONOMY

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Introduction

Malaysia is one of the few tropical countries which is still well blessed with lush, indigenous, natural forest. Forest cover more than 19 million hectares or 58 per cent of the total land area of Malaysia. Of this total, 5.9 million hectares are found in Peninsular Malaysia, 4.5 million hectares in Sabah and 8.7 million hectares in Sarawak. Furthermore, if the areas under oil palm, rubber and tree crops are taken into consideration the land area under tree cover increases to 24 million hectares or 73 per cent of the total land area. The extent of forested land by regions is shown in Table 1.

Table 1. Area under forest by regions in Malaysia (million ha)

Regions	Land Area	Natural Forest	Plantation Forest	Total Area Under Forest	% of Forest To Land Area
Peninsular Malaysia	19.16	5.82	0.07	5.89	44.8
Sabah	7.37	4.34	0.11	4.45	60.4
Sarawak	12.33	8.70	0.01	8.71	70.6
Malaysia	32.86	18.86	0.19	19.05	58.0

Source: MPIM (1996), FDPM (1996a), FDPM (1996b)

Contribution of the forest sector to the Malaysian economy

As a renewable national resource, the forest has always contributed significantly to the economic growth and development of Malaysia. The forest sector is an important source of foreign exchange earnings, GDP growth, government revenue, employment opportunities, resource-based industrialization as well as improvements in the livelihood of the rural population.

Log production

Over the last decades of the 1970's, 1980's and 1990's, Malaysia has experienced increased demands for and production of its tropical timber products. From 1970-1990, total log production grew by an average of 8 per cent per year, rising from 18 million m³ in 1971 to 40 million m³ in 1990 (MPIM 1996). Log production peaked at 43.5 million m³ in 1992, and then dropped to about 33 million m³ in 1996, a reduction of 24 per cent in just three years. This decrease reflects strict adherence to the annual coupe imposed by the State Governments, in line with the policy of sustainable forest management.

The forest products industry

The forest products industry in Malaysia consists of the manufacture of sawnwood, panel products comprising veneer/plywood, blockboard and reconstituted panel-based products, mouldings and joineries and furniture and furniture components. Traditionally the main focus of the industry has been on primary processing activities such as sawmilling, veneer and plywood production. Recent developments have veered the industry into downstream activities such as the production of timber mouldings and furniture and fixtures.

The forest products industry's position in the manufacturing sector is significant. It is among the ten largest of the major groups of manufacturing industries in Malaysia. According to the latest available Industrial Survey Report (DOS 1993), it accounted for 6.2 per cent of the total manufacturing output, 7.7 per cent of the total manufacturing value-added, 11.3 per cent of the total manufacturing employment and 3.4 per cent of the total manufactured exports.

Total capital investment

Total capital investment in the forest products industry from 1992 to 1996 amounted to RM 7,098.3 million. Of this total, 62.3 per cent or RM 4,422.8 million were domestic investment while 37.7 per cent or RM 2,675.5 million were from foreign investment (MTI 1995, 1997).

Timber products trade

Except for a slight drop of 1.1 per cent in 1995, Malaysia's export of major timber products has increased steadily over the last decade, from RM 4.3 billion in 1985 to RM 14.1 billion in 1996. The increasing trend in the export of timber products up to 1996 is mainly attributed to the growing importance of high value-added timber products such as furniture and components and plywood, as shown in Table 2.

Table 2. Exports of major timber products, Malaysia (1992 - 1996) (RM million)

Product	1996	1995	1994	1993	1992
Logs	2,269.6	2,272.8	2,555.7	2,914.1	3,828.8
Sawntimber	3,048.3	3,625.6	4,139.7	4,422.2	3,409.2
Plywood	4,399.5	3,520.8	3,317.6	2,660.0	1,360.9
Veneer	681.6	581.1	662.0	705.5	491.1
Timber	671.6	618.2	633.5	585.1	712.6
Mouldings Furniture and Components	2,579.9	2,138.8	1,525.0	1,026.0	660.6
Others	454.2	363.7	434.5	220.9	199.4
Total	14,054.7	13,121.0	13,268	12,583.8	10,662.6

Source: MTIB (1996)

Despite being a major exporter of tropical timber products, Malaysia still imports a fair amount of timber products to cater to the specific needs of the industry. In fact, recent developments have indicated steadily increasing trends in the total imports of timber products such as sawn timber, logs, veneer, timber mouldings and furniture and components, from RM 130 million in 1992 to RM 589.6 million in 1996.

In the international perspective, while Malaysia has significant market share in plywood (10.85%) veneer (13.5%) and sawntimber (8.8%), Malaysia is still a small producer in the global wood-based market in downstream products. Hence, it is the Government's objective to make Malaysia a major producer of high value added wood-based products in the world market. Specifically, further structural transformation of the wood-based sector has been identified in furniture, pulp and paper, reconstituted wood and panel products.

Employment

The forestry and timber sector also provides employment opportunities in a wide range of activities ranging from planting, logging and transport to industrial processing and the marketing of final products. More than 240,000 people are directly employed in this sector in Malaysia (MPIM 1996). Indirect employment is estimated to be not less than 200,000 people, primarily in forest development works, shipping, chemical and engineering industries, as timber merchants and agents and technical services.

Maintaining forest health

Apart from its traditional economic values, the forest is well recognized for its strategic role in the maintenance of quality of the Malaysian natural environment, especially of soil erosion and nutrient depletion, moderation of local climate, and the conservation of the diverse biological resources that are potentially important economic products. Recognising the importance of forests, the Malaysian Government

has designated 14.3 million hectares or 44.4 per cent of the total land area as Permanent Reserved Forest. These are forested land permanently reserved under legislation to be managed sustainably for protection, production, amenity, research and education purposes.

References

- MINISTRY OF PRIMARY INDUSTRIES MALAYSIA. 1996. *Statistics On Commodities*.
DEPARTMENT OF STATISTICS, MALAYSIA. 1993. *Annual Statistics of Manufacturing Industries - Part A*.
FORESTRY DEPARTMENT PENINSULAR MALAYSIA. 1996a. *Annual Report*.
FORESTRY DEPARTMENT PENINSULAR MALAYSIA. 1996b. *Forestry Statistics Peninsular Malaysia*.
MALAYSIAN TIMBER INDUSTRY BOARD. 1996. *Annual Export Of Major Timber Products, Builders, Carpentry & Joinery & Furniture, 1996*. MTIB-EDP-Annual.
MINISTRY OF INTERNATIONAL TRADE AND INDUSTRY MALAYSIA. 1995. *The Second Industrial Master Plan, 1996 - 2005*.
MINISTRY OF INTERNATIONAL TRADE AND INDUSTRY MALAYSIA. 1997. *Profile Of Wood-Based Industry*.

Sub-programme A

**Conservation of Biodiversity and Sustainable Use
of Forest Genetic Resources**

INVENTORYING AND MONITORING BIODIVERSITY: A TAXONOMIST'S PERSPECTIVE

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This paper addresses the role of taxonomy in biological inventory and, more indirectly, in monitoring. It begins by examining what is required from biotic inventories and then proceeds to discuss some problems that biotic inventories present, both in general terms, and more specifically to the global taxonomic community, the so-called taxosphere. It concludes by offering a series of suggestions for ensuring that taxonomy plays the vital role that is required of it in assisting with the implementation of the Convention on Biological Diversity.

Key words: Taxonomy - biological inventory - monitoring

Introduction

The conservation and sustainable utilisation of biological diversity is a major global political, social and scientific concern, that has attracted almost unparalleled public interest world-wide following the signing of the Rio Convention on Biological Diversity in 1992 (di Castri & YOUNÈS 1996). Biodiversity studies have proliferated in recent years, giving rise to a huge increase in publications. One theme many have in common is the importance of forests, not only for the conservation of biological diversity, but more broadly for human welfare and for the maintenance of complex processes affecting climate change (Harte *et al.* 1992, Okafor & Ladipo 1995, Bignell *et al.* 1997, Kahn & MacDonald 1997). Deforestation and forest fragmentation cause grave concern in the conservation and biological communities (Laurance & Bierregaard 1997), and although the clearing of forests is occurring worldwide (FAO 1995), it is the loss of tropical forests that attract greatest attention. To a very large extent it is because tropical forests are the most species-rich habitats on Earth (*e.g.*, see Manokaran *et al.* 1992). Rising human aspirations and expanding populations ensure that tropical deforestation will continue. Biological diversity increasingly will be conserved, not in true wildlands, but in multi-use managed ecosystems. Successful management will depend on many factors, but an important one has to be biological knowledge of an ecosystem and its component species, and how these organisms respond to intervention practices and other forms of disturbance. The majority of the papers in the biological section of this book, which result from work undertaken within a Malaysia/UK collaborative programme, are focused on what occurs in peninsular lowland forests in Malaysia, and how these organisms respond to perturbation. As little was known of what changes might occur in the biota a broad range of organisms were studied,

representing a wide taxonomic and ecological spectrum. Preliminary results are presented in the following papers, but here the focus is slightly different, and concentrates on some background issues, most particularly the role of taxonomy in biological inventory and monitoring.

Why undertake a biological inventory?

Article 7(a) of the Convention of Biological Diversity commits signatory nations to start to undertake an inventory of their biological diversity. In broad terms the purpose of such biological inventories is to provide fundamental information about the distribution and abundance of biodiversity. Such data are necessary for the long-term sustainable management, use and conservation of biodiverse areas, as detailed in Articles 6, 7, 8, 10, 12-14 of the CBD (UNEP 1992, Stork & Samways 1995). Inventories are not a new idea for biotic resource management. The forestry community has, for many years, routinely conducted forest inventories - surveys of the timber trees present in the forest estates - as part of their management strategy. As forest resource management now often has wider concerns than just timber production, more extensive biotic inventories are needed to satisfy broadening managerial requirements for information. Here I would like to highlight three possible ones:

- to enable priority conservation areas to be recognized;
- to facilitate biodiversity harvesting; and
- provide a basis for biotic monitoring.

Priority conservation area recognition

Over-consumption, the rapidly growing human population, and the rising economic aspirations of humanity are putting increasing pressure on wildlands. Extensive areas of forest and savannah are being converted to other uses, such as plantation forests, farming, or urban development (Myers 1988). Such conversion, involving massive loss of natural vegetation, inevitably has a major negative impact on a wide range of biological diversity, frequently resulting in the local extirpation of many species (Whitmore & Sayer 1992). Economic development is a necessity, and inevitably the physical areas and the financial resources available for conservation are limited. It is important therefore to target conservation efforts in a planned and strategic manner. Inventory data is vital to ensure that areas of endemism or high species richness, which do not necessarily coincide (see Prendergast *et al.* 1993), can be identified. Appropriately refined information derived from biotic inventories is essential if those charged with making decisions about land usage are going to be as fully informed as possible (Bridgewater 1996). Such information allows for the objective assessment of what proportion of a biota has been conserved, and provides a basis for ensuring that new resources for conservation are targeted towards the highest priorities (Pressey *et al.* 1993). To paraphrase an American expression, it allows one to conserve the biggest biota for one's buck.

Biodiversity harvesting

If they are to survive in the long-term, afforested areas need to be seen as productive areas contributing to a country's economy (Gómez 1991, Janzen 1991). There is an increasing awareness that biological resources have a potential value beyond their traditional uses as sources of construction materials or foods. Knowing what one has in a conserved area is a prerequisite to being able to use it in novel ways, such as screening for natural chemical activity (Roberts 1992, Reid *et al.* 1993, Juma & Mugabe 1996). Biodiversity prospecting, however, requires that the chemical extracts that a supplier provides to their partner pharmaceutical company come from recognizable species, so that they are able to supply repeat identical samples if certain types of chemical activity are detected in the screening process. Future, high-tech uses of biological diversity will require knowledge of the species present in the ecosystem (Janzen 1993, Rossman 1994, Vane-Wright 1996). Countries that have the capability to recognize the elements of their own biotas will be in a premium position to collaborate in pharmaceutical prospecting and similar non-damaging harvesting activities.

Biotic monitoring

An inventory provides the necessary baseline data for monitoring the effects of anthropogenic disturbance or climate change on the biota (di Castri *et al.* 1992, Bridgewater 1996). Often whilst conservation efforts will be targeted towards relatively long-lived and slowly maturing species (*e.g.*, forest trees or large mammals) it is the small and taxonomically less well-known species with short mean generation times, that may respond most rapidly to environmental deterioration. Thus these make better indicators for environmental monitoring than the larger, taxonomically better-known organisms. However, monitoring these small and sensitive indicators, such as diatoms, lichens, fungi and insects, requires an understanding of what species are present and how they may be distinguished (Stork & Samways 1995). Several of the papers in this volume are directed towards such groups of organisms, and have investigated which may be of potential use for monitoring (see chapters by Bolton, by Watling, Lee & Turnbull, and by Wolseley, Ellis, Harrington & Moncrieff).

To satisfy these three demands two forms of inventory are required, extensive and intensive. Extensive inventories need to be conducted rapidly on a national basis to supply information necessary for the selection of conservation areas and other types of land-use planning. Speed is critical in this sphere of activity, so it is natural that the focus of inventory should be well-known and easily recognized organisms, such as mammals, birds, trees and butterflies. Surrogates, such as higher taxon richness (*e.g.*, family-richness), can be used as a substitute for species richness (Williams & Gaston 1994, Williams *et al.* 1994). Data collected in these ways can then be analysed by such innovative programmes as WORLDMAP, which will allow the recognition of potential priority conservation areas (Vane-Wright *et al.* 1991,

Margules & Kitching, 1995). Various types of remote sensing (*e.g.*, Lund *et al.* 1995) have a prominent role to play in extensive inventorying too.

Once conservation areas have been established, then the need for monitoring, and for knowing what is present in order to sustainably harvest it, demand more detailed knowledge of a biota. This requires the second type of inventory – intensive inventory – which has as its focus, species. It is this activity which presents some of the greatest challenges to humanity in general, and the systematics community in particular.

Problems with intensive biological inventory

An intensive biological inventory is “big science” and is comparable in its scope (and cost) to putting a man on Mars, or mapping the human genome. Yet this is often not clearly recognized and inventory efforts proceed on shoe-string budgets because the scale of the undertaking was not appreciated at the outset. Three obvious factors contribute to the scope and complexity of the species-inventory problem:

- the magnitude of the terrestrial biota;
- the cost of intensive biotic inventory;
- the capability and resources that exist to undertake intensive species-inventories.

These are discussed below.

The magnitude of the terrestrial biota

Several years ago there was considerable discussion about the magnitude of global species richness and estimates fluctuated over two orders of magnitude (Erwin 1982, Gaston 1991, Stork 1993). The consensus opinion now is that there are between ten and 20 million species on Earth, that is about ten times as many as have been formally described by taxonomists in the 250 or so years since Linnaeus established the binomial system of biological nomenclature in the mid-eighteenth century (Hawksworth & Kalin-Arroyo 1993, Samways 1994).

The problem of cataloguing this huge species-richness is compounded by the fact that terrestrial species are not uniformly distributed over the face of the Earth; most occur in the tropics, where taxonomic resources are scarcest (Bennett 1994). The Cameroon (ca 5°N), for example, has almost ten times as many species of flowering plants than does Sweden, a similar sized northern extra-tropical country, and the tiny country of Panama (ca 78.5 thousand km²) has more species of birds than the entire continental United States (9.3 million km²) (Groombridge 1992). Samways (1994) has estimated that 55 per cent of the world's insect species occur in tropical rain forests, less than seven per cent of the world's land surface.

Inventory problems are further compounded by the fact that, when compared with extra-tropical faunas and floras, a much larger proportion of tropical biotas remain undescribed. For example, recent intensive studies on the Central American flora have revealed two new families of angiosperms (S. Knapp pers. comm.), whilst

comparative studies of parasitic wasps have shown that less than 15 per cent of African species are described, in comparison to more than 70 per cent of European ones (Townes 1969). Rossman (1994) estimated that 50-80 per cent of the fungal species present in Guanacaste Conservation Area, Costa Rica, may be new to science. My own recent studies of a group of moderately large, conspicuous wasps in Costa Rica has shown that approximately 160 of the 200 species present in the country are undescribed (Gauld 1997).

A third complicating factor arises because tropical biotas are more difficult to sample than extra-tropical ones. Longer sampling periods are required in the tropics for species-accumulation curves to reach an asymptote. For example, working in Costa Rica I have found that it was necessary to continue site based sampling programmes for three years for species accumulation curves to approach an asymptote (Gaston & Gauld 1993, Gauld unpubl.).

The cost of intensive biotic inventory

Although the magnitude of the task involved in inventorying our planet's biota is beginning to be understood, the financial implications that this has are less frequently discussed. Indeed, few estimates have ever been made of the costs involved. A notable exception occurred in Costa Rica where a series of workshops were convened with the express purpose of planning and costing an All Taxon Biological Inventory (ATBI) of a large national park (Janzen & Hallwachs 1994). The first of these focused on one hyper-diverse order of insects, the Hymenoptera. This was particularly informative, for in the previous five years an on-going study had been conducted aimed at documenting the scope of the hymenopterous fauna of Costa Rica, the results of which were published in book form (Hanson & Gauld 1995). The workshop, which involved many leading experts in Hymenoptera systematics, thus was able to assess the scope of the ATBI - how many taxa were likely to be encountered, how well they were known and what resources would be necessary to document these species, assess their distribution, and make this information available in a form the potential user-communities required. The estimated cost for the 20,000 species was US\$ 30 million (Rodriguez & Gauld 1995). Subsequent costings of other groups, and retrospective costings of completed projects have yielded surprisingly similar figures - an inventory will cost between one and two thousand dollars per species encountered.

Given the likely magnitude of global species richness, and accepting the limitations of extrapolating from a single site-based study, one can estimate that, at the very minimum an inventory of global biodiversity will cost between ten and 40 billion dollars. A recent document produced in North America, Systematics Agenda 2000 (1994), estimated three billion dollars per annum for the next 25 years (US\$ 75 billion) would be required to discover, describe and classify the world's species. These estimates are not too dissimilar from estimates of what it will cost to put a human on Mars. Both are laudable advances for humanity. The main difference is one of urgency, Mars is likely to still be there in a century!

The capability and resources that exist to undertake intensive inventories

It is now very widely recognized that the taxonomic resources available to undertake large-scale inventories are woefully few, and largely concentrated in the wrong places. Most biodiversity occurs in the tropics (Samways 1994), but most taxonomists - the people who can actually recognize the elements of biodiversity - are working in extra-tropical countries (Lattin & Knutson 1982, Bennett 1994). Accurate inventory requires access to reference collections and literature, and again these resources are primarily concentrated in the large museums of a few temperate countries. For example, more than 90 per cent of all the primary type material of a group of South East Asian parasitic wasps are housed outside Asia (Yu & Horstmann 1997).

The inadequacy of capability of global taxonomic resources to support biodiversity inventory is now widely recognized, and it has been the subject of discussion both by the Conference of the Parties at Buenos Aires, and by the Subsidiary Body for Scientific, Technical and Technological Advice (SBSTTA) to the CBD in the 1996 Montreal meeting. There is widespread agreement by the governments of the signatory nations that these resources need to be strengthened (UNEP/CBD/SBSTTA /2, 1996). But what options are there? Below I review some problems and offer suggestions.

The contribution of the taxasphere

As has already been mentioned above, most taxonomic expertise and resources are concentrated in the national museums and universities of a few extra-tropical countries. This, largely extra-tropical resource with international capability, has been referred to as the taxasphere by D.H. Janzen, and I will use this term here. Mobilising the resources of the taxasphere is essential to the success of intensive inventory (May 1990, Janzen 1993). However, this is not straightforward for several reasons, of which three are:

- the size of the taxasphere;
- competing aims and;
- financial costs incurred.

The size of the taxasphere

Even were it desirable, and clearly in a post-colonial world it is not, it is simply not feasible to expect taxonomists in temperate countries to inventory the biodiversity of the entire world. There are too few taxonomists and their numbers are declining (Holden 1989, Gaston & May 1992). They simply cannot cope with a task of such magnitude within a realistic time frame. This perhaps can most easily be appreciated by reference to the Costa Rican ATBI mentioned earlier (Rodriguez & Gauld 1995). It was estimated that the Hymenoptera ATBI would absorb the energies of some 60 full-time systematists for five to seven years. The entire practising global hymenopteran systematics community does not number more than about 300 full-time

equivalents, and for some large families, such as the Scelionidae (2000 species), Encyrtidae (1000 species) and Diapriidae (1000 species), almost all available expertise would need to be focused on this one ATBI. Thus a significant proportion of the world hymenopteran expertise would be occupied for more than five years on a single study. Very few inventories could be conducted concurrently. Furthermore, with currently available resources some groups, the so-called orphan taxa, (such as the eucoiline Figitidae, 500 species) could not be tackled at all.

Competing aims

The taxonomic baggage - that is the mass of names and unresolved nomenclatural confusion that, for example, exists in European entomology, which has consumed thousands of hours of relatively sterile efforts to interpret - is ample justification of the need for professionalism in taxonomy. Any attempt to use unskilled workers to do taxonomy will almost certainly create similar confusion for the future. Taxonomy is a rigorous scientific discipline requiring similar intensive study to any other scientific endeavour (Wheeler 1995a). By and large professional taxonomists are funded through science agencies, and are thus responsive to pressures of the peer academic community. The goals of the scientific community and those of the biodiversity community tend to differ. The former favours phylogenetic studies, co-evolutionary investigation, and increasingly laboratory based disciplines such as molecular systematics, whilst the needs of the biodiversity community are for field-guides, identification services and distributional information about organisms. It is unrealistic to think that taxonomists will turn all their efforts to cater for the needs of the biodiversity community when their research interests, funding sources and the efforts for which they receive praise from their managers lie in other directions (Wheeler 1995b). Many inventory efforts fail to realise this fact. Instead, they rely on the taxonomist's natural enthusiasm for the organisms they study, and attempt (and indeed often succeed) to obtain free labour in exchange for bizarre or interesting specimens.

Financial costs incurred

Taxonomy is a labour intensive activity requiring considerable input of time from highly trained professionals who, in turn, rely on access to costly facilities. It is thus expensive, though perhaps no more so than any other professional service operating from a developed country base. However, the nature of the effort involved and the geographical distribution of those required to make taxonomic efforts potentially create political problems for large-scale inventory work. Consider again the proposed ATBI in Costa Rica (Rodriguez & Gauld 1995). An inventory of the Hymenoptera could more or less be completed in the time frame for a budget of US\$ 30 million, but how would this be funded? At present the major sources of funding for such undertakings are perceived to be various development agencies and the Global Environment Facility. Assuming the Costa Rican Government decided that an inventory of Hymenoptera was their national priority and that adequate funding could be

obtained from donor agencies, who would do the work? The collecting and much of the preparation and sorting would, of course be undertaken in-country, but at present the overwhelming majority of the taxonomic work would have to be done overseas. In financial terms this would mean about \$5 million of the budget being spent in-country, but the remaining \$25 million being spent overseas, mostly purchasing taxonomic services from wealthy countries in North America and Western Europe (Rodriguez & Gauld 1995). Using aid budgets in this way does not seem to be politically acceptable at present. Yet it is completely unrealistic to expect museums and universities in developed countries - which are themselves often under increasing pressure to generate revenue from non-exchequer sources - to support various major inventories around the world without financial recompense.

Advancing to meet the challenge for the provision of biodiversity information

Recognising some of the problems that impede the systematics community contributing to the implementation of Article 7 is a first step. What then can be done? Here I suggest four areas that should be addressed more or less simultaneously:

- Prioritisation of demands;
- Mobilising the taxosphere;
- Development of taxonomic resources in tropical countries;
- Improving information dissemination.

Prioritisation of demands

It is not feasible to attempt to inventory all biota at once. Difficult priorities need to be established, and prioritisation of groups is likely to become a very emotive issue. In any taxonomic gathering there will be almost as many priority groups recognized as there are taxonomists present. Many of the criteria that have been suggested for selecting priority indicator or other groups (see Stork & Samways 1995) actually require that we have a much greater knowledge of the biology of organisms than in fact we have in order to make the selection. I suggest the following less demanding criteria could be considered in helping to advance the process. Groups selected should:

- be representative of the spectrum of taxic variation in an area. Thus, for a terrestrial study, one might prioritise a set of taxa including vascular plants, cryptogams, insects, fungi, vertebrates and molluscs.
- be representative of the microhabitats in an area, thus one might select soil inhabiting, leaf-litter living, bark dwelling and canopy feeding organisms.
- represent the trophic diversity of an area. Thus one might select a primary producer, a herbivore, a carnivore, a saprophyte and a parasitoid.

These criteria are suggested since, if one of the aims of inventory is to provide baseline data for monitoring, then it is important to choose a wide spectrum of

organisms to monitor, for in the tropics one does not know in advance how the various groups will respond to any perturbations. Experience in temperate regions has shown that lichens respond rapidly to atmospheric pollution, ectomycorrhizal fungi to acid rain, chironomid flies to water quality and raptorial birds to insecticides.

Other factors also need to be included in criterion selection such as user community demand, economic demand, special societal needs and so-forth, and these need to be balanced against what expertise is available. But whatever is included and whatever criteria are adopted, prioritisation should be endorsed by the appropriate political authorities in the country concerned. And whilst one expects the taxonomic community to have an input to this prioritisation process, prioritisation is too far-reaching to be left to the taxonomists alone. In the U.K. the Systematics Forum is setting a good example conducting a market survey among the many users of taxonomic products and services (Blackmore 1996).

Mobilising the taxasphere

It is vital that the skills of this community be mobilised to facilitate inventories (Wheeler 1995a). As I advocate that priorities should be decided by broad consensus and endorsed at high political level, it follows logically that funding to ensure these priorities are met should be channelled through similar broad-based agencies. This should create a source of funding for taxonomy that is independent of traditional academic science agency based funding. This would effectively create a resource for taxonomists, if and only if they adjust their objectives towards what society in general requires from them. I do not imagine that a substantial part of the taxasphere would ignore such funding sources.

Of course it would then be necessary to ensure objectives are achieved, but one can envisage a system of rather formal business contracts whereby taxonomists contract to produce a specified product in a given time frame. Whilst this commercialisation of taxonomy is likely to appal many traditional systematists, society cannot wait for the 2,500 years that it will take the global systematics community to document terrestrial biodiversity if descriptive work continues at its present rate.

Development of taxonomic resources in tropical countries

It has been widely recognised for some time, and highlighted recently at the 1996 Montreal SBSTTA, that there is a major need to assist tropical countries to develop their own taxonomic resources (UNEP/ CBD/SBSTTA/2 1996). The precedent set in Costa Rica by INBio developing a well-curated, representative national biological reference collection is a good example of what can be achieved (Gámez & Gauld 1993). Concomitantly there is a need to develop properly trained in-country taxonomic expertise, as is being undertaken, for example, as part of the GEF funded programme at Bogor in Indonesia. Human expertise is probably the scarcest of all resources (Gaston & May 1992). No one country, not even the United States, has

sufficient taxonomic expertise to inventory its entire fauna, so it must be recognized that taxonomists should, in general, remain international. Tropical countries need to contribute personnel to the international taxosphere. This becomes a more feasible option if, as I have suggested, internationally funded taxonomic contracts are being offered around the world.

There will have to be increased south-south collaboration (Bajjnath 1995) and sharing of expertise, at least within biotic provinces that share large elements of their faunas and floras. Very cost effective projects can be developed building on earlier projects undertaken elsewhere in the region. For example, I recently monographed the pimpline parasitic wasps of Costa Rica - producing a fairly typical revisionary taxonomic study in the English language (Gauld 1991). With modest support (<US\$100,000) from the UK Government's Darwin Initiative my Costa Rican colleagues and I have recently built on this foundation by producing a user oriented identification guide to these wasps in Spanish (Gauld *et al.* in press). During this process students and parataxonomists were involved testing keys to ensure they were user-friendly, Costa Rican taxonomic capability was enhanced by the involvement of a graduate in the project, and the local collection at INBio, cost effectively built up by the parataxonomists, was identified. More broadly, several rare species were newly discovered and described, ensuring a very sound coverage of this tropical wasp fauna. Preliminary studies of the pimpline wasp fauna of other tropical American countries (Belize, Paraguay and Venezuela) show a surprisingly high commonality with Costa Rica, with more than 50 per cent of the species common to all the countries (Diaz pers. comm., Gauld unpubl.). A similar situation is probably true for many arthropod groups (Janzen 1986). Producing identification guides to the faunas of these countries will be relatively straightforward, once collections have been accrued, for most of the taxonomic difficulties were resolved in the initial Costa Rican work.

Improving information dissemination

Under this heading it is appropriate to address two issues:

- the dissemination to country of origin of information housed in museums with biotic collections made outside the country where the museum is located
- producing a taxonomic product that is appropriate for user-needs.

Collection information dissemination

Specimens in the collections in most large "global museums" are arranged in taxonomic order, and although some parts of these collections are electronically databased much of the material is not (Nielsen & West 1994). It is extremely labour intensive to scan a collection and obtain a complete list of specimens from any one particular country, thus any demand for repatriation, to country of origin, of all specimen-based data is liable to be prohibitively expensive. For example, Gauld (1996) estimated that it would require approximately 300 people working for 20 years at a cost of \$10 million per annum to make all specimen-based

information in the Natural History Museum, London, available electronically. It should be remembered that large museum collections were assembled for taxonomic purposes and are not representative samples of any given biota. Their use for broader purposes is thus questionable, and more extensive discussion of this has already been detailed elsewhere (Gauld 1996). The very large cost associated with making all museum data available electronically must be weighed against the value of using scarce skilled personnel in other ways. However, collaborative arrangements can be negotiated between developing and developed country institutions, allowing scientists to work in global museums compiling databases of specimens from their homeland. This practice offers the advantage of allowing these scientists to gain a global overview of the groups they are studying, at the same time as seeing, first hand, type-material.

More innovative ways of making museum collection information available, such as by creating digitised images of specimens that can be transmitted over the Internet, have received little attention to date. As computer technology continues to advance such techniques are likely to become more widespread.

Product development

The main products that taxonomists create for use by the broader non-specialist community are identification keys. However, it is apparent in some cases that rather little thought for the user goes into key construction. Many traditional keys are difficult to use, and consequently they are little-used by non-specialists. There have been some efforts to improve this situation. Perhaps the best known is the production of low cost, well illustrated field guides. These are widely available in some countries and cover a range of the "more popular" organisms from birds and butterflies, to plants and seashells. A surprising number of young biologists or conservationists first developed an appreciation of their biotic surroundings through popular field guides, demonstrating the important educational role such taxonomic products may play. Less well-known groups of organisms that often need microscopic examination for identification present more of a problem. In the UK the Field Studies Council has pioneered the innovative AIDGAP series of publications which are identification keys tested extensively before their final publication (Tilling 1987). Various types of computerised multi-access keys have been developed in order to make keys more user friendly (Pankhurst 1978), and a number of multimedia identification CDs, such as CABIKEY are appearing on the market (White & Scott 1994).

However, one problem largely remains to be overcome. This is the fact that specialist taxonomists, with years of experience examining specimens, can often perceive minute differences in shape, colour or texture which virtually defy explanation. Language is too coarse for describing many such details, and even photographs need experience to interpret. Using computers to present taxonomic characters, while relying on users to compare specimens to images or illustrations, represents a failure fully to utilise the immense potential offered by information technology. Image analysis techniques and technology, in particular, have seen tremendous

advances in recent years, raising the possibility of automating, or at least semi-automating, much of the process of routine taxonomic identification. However, such an approach has to date only been used in a very limited fashion (Edwards & Morse 1995, Weeks & Gaston 1997). In an attempt to begin to bridge this gap, Paul Weeks and collaborators have developed a prototype novel automated identification system (DAISY - the Digital Automated Identification SYstem) (Weeks 1996, Weeks *et al.* 1997). Published tests of the system thus far have revealed that it can discriminate between five species of ichneumonid wasps, on the basis of wing structure alone, with 94 per cent accuracy in correct identifications and a reasonably predictable pattern of errors (Weeks *et al.* 1997). Although in their infancy such systems offer the hope, that in future identification of samples may become routine. Taxonomists can then push ahead with documenting the terrestrial biota, without necessarily having to re-acquire the experience of their predecessors. Automating the identification process will allow rapid progress with inventory, and will in part remove the need for identification centres to maintain large and costly collections of fragile and perishable biotic material.

Conclusion

Article 7 of the Convention on Biological Diversity presents a great challenge to the biosystematics community. Whilst this community can, and is making efforts to address this challenge, these achievements could be enhanced if more funding was available globally, and if efforts were directed to more explicitly identified societal needs. The third meeting of the Conference of the Parties in Buenos Aires was asked by SBSTTA "to consider instructing the Global Environment Facility to support a global taxonomy initiative, providing the necessary funds...[for taxonomic capacity building]" (Recommendation II/2, UNEP/CBD/SBSTTA/2 1996). Thus more funding is potentially available. For this to be most effective in achieving the objectives of the CBD it is essential that the broader community plays a greater part in helping to establish precise objectives, and linking funding to the attainment of these, rather than just the undirected pursuit of academic interest.

References

- BAGNATH, H. 1995. Networking African herbaria for biodiversity conservation. Pp. 198-198 in Bennun, L.A., Aman, R.A. & Crafter, S.A. (Eds.) *Conservation of Biodiversity in Africa*. 400pp. National Museums of Kenya, Nairobi.
- BENNETT, A. 1994. A review of existing identification services and future needs. Pp. 57-67 in Hawksworth, D.L. (Ed.) *The Identification and Characterization of Pest Organisms*. 501 pp. CAB International, Wallingford.
- BIGNELL, D.E., EGGLETON, P., NUNES, L. & THOMAS, K.L. 1997. Termites as mediators of carbon fluxes in tropical forests: budgets for carbon dioxide and methane emission. Pp. 109-134 in Watt, A.D., Stork, N.E. & Hunter, M.D. (Eds.) *Forest and Insects*. 406 pp. Chapman & Hall, London.
- BLACKMORE, S. 1996. Knowing the Earth's biodiversity: challenges for the infrastructure of systematic biology. *Science* 274 : 63-64.

- BRIDGEWATER, P.B. 1996. Inventorying and monitoring for what and for whom? Pp. 208-211 in di Castri, F. & YOUNÈS, T. (Eds.) *Biodiversity Science and Development*. 646 pp. CAB, Wallingford.
- DI CASTRI, F., ROBERTSON VERNHES, J. & YOUNÈS, T. 1992. Inventorying and Monitoring Biodiversity. *Biology International*, Special Issue 27: 1-28.
- DI CASTRI, F. & YOUNÈS, T. (Eds.) 1996. *Biodiversity Science and Development*. 646 pp. CAB, Wallingford.
- EDWARDS, M. & MORSE, D.R. 1995. The potential for computer-aided identification in biodiversity research. *Trends in Ecology and Evolution* 10: 153-158.
- ERWIN, T.L. 1982. Tropical forests: their richness in Coleoptera and other arthropod species. *Coleopterist's Bulletin* 35: 53-68.
- FAO, 1995. Forest resource assessment 1990: global synthesis. *FAO Forestry Paper 124*. FAO, Rome.
- GÁMEZ, R. 1991. Biodiversity conservation through facilitation of its sustainable use: Costa Rica's National Biodiversity Institute. *Trends in Ecology and Evolution* 6: 377-378.
- GÁMEZ, R. & GAULD, I.D. 1993. Costa Rica: an innovative approach to the study of tropical biodiversity. Pp. 329-336 in LaSalle, J. & Gauld, I.D. (Eds.) *Hymenoptera and Biodiversity*. 348 pp. CAB, International, Slough.
- GASTON, K.J. 1991. The magnitude of global insect species richness. *Conservation Biology* 5: 283-296.
- GASTON, K.J. & GAUL, I.D. 1993. How many species of pimplines are there in Costa Rica? *Journal of Tropical Ecology* 9: 491-499.
- GASTON, K.J. & MAY, R.M. 1992. Taxonomy of taxonomists. *Nature* 356: 281-282.
- GAULD, I.D. 1991. The Ichneumonidae of Costa Rica, 1. *Memoirs of the American Entomological Institute* 47: 1-589.
- GAULD, I.D. 1996. The cost of data repatriation versus the potential of biosystematic capacity building. Pp. 137-144 in McNeely, J.A. & Somchevita, S. (Eds.) *Biodiversity in Asia: Challenges and Opportunities for the Scientific Community*. 204 pp. Ministry of Science, Technology and Environment, Bangkok.
- GAULD, I.D. 1997. The Ichneumonidae of Costa Rica, 2. *Memoirs of the American Entomological Institute* 57: 1-589.
- GAULD, I.D., UGALDE-GÓMEZ, J.A. & HANSON, P.E. in press. *Guía de los Pimplinos de Costa Rica*. 160 pp. INBio, Santo Domingo de Heredia.
- GROOMBRIDGE, B. (Ed.) 1992. *Global Biodiversity*. 585 pp. Chapman & Hall, London.
- HARTE, J., TORN, M. & JENSEN, D. 1992. The nature and consequences of indirect linkages between climate change and biological diversity. Pp. 325-343 in Peters, R.L. & Lovejoy, T.E. (Eds.) *Global Warming and Biological Diversity*. 386 pp. Yale University Press, New Haven.
- LUND, H.G., EVANS, D.L. & LINDEN, D.S. 1995. Scanned, zapped, timed, and digitized! Advanced technologies for measuring and monitoring vegetation diversity. Pp. 865-882 in Boyle, T.J.B. & Boontawe, B. (Eds.) *Measuring and Monitoring Biodiversity in Tropical and Temperate Forests*. 395 pp. CIFOR, Bogor.
- HANSON, P.E. & GAULD, I.D. 1995. *The Hymenoptera of Costa Rica*. 893 pp. Oxford University Press.
- HAWKSWORTH, D.L. & KALIN-ARROYO, M.T. (Eds.) 1995. Magnitude and distribution of biodiversity. Pp. 167-274 in Heywood, V.H. (Ed.) *Global Biodiversity Assessment*. 114 pp. Cambridge University Press.
- HOLDEN, C. 1989. Entomologists wane as insects wax. *Science* 246: 754-756.
- JANZEN, D.H. 1986. Biogeography of an unexceptional place: what determines the saturniid and sphingid moth fauna of Santa Rosa National Park, Costa Rica, and what does it mean to conservation biology? *Brenesia* 25/26: 51-87.
- JANZEN, D.H. 1991. How to save tropical biodiversity. *American Entomologist*, Fall 1991: 159-171.
- JANZEN, D.H. 1993. Taxonomy: universal and essential infrastructure for development and management of tropical wildland biodiversity. Pp. 100-113 in Sandland, O.T. & Schei, P.J. (Eds.) *Proceedings of the Norway/UNEP Expert Conference on Biodiversity*, Trondheim, Norway.
- JANZEN, D.H. & HALLWACHS, W. 1994. *All Taxon Biological Inventory (ATBI) of Terrestrial Systems. A Generic Protocol for Preparing Wildland Biodiversity for Non-damaging Use*. Report of an NSF workshop, 16-18 April 1993, Philadelphia, PA.
- JUMA, C. & MUGABE, J. 1996. Biodiversity prospecting: opportunities and challenges for African countries. Pp. 519-538 in DiCastri, F. & YOUNÈS, T. (Eds.) *Biodiversity Science and Development*. 646 pp. CAB, Wallingford.

- KATIN, J.R. & MACDONALD, J.A. 1997. The role of economic factors in tropical deforestation. Pp. 13-28 in Laurance, W.F. & Bierregaard, R.O. (Eds.) *Tropical Forest Remnants*. 616 pp. University of Chicago Press, Chicago.
- LATHIN, J.D. & KNUTSON, L. 1982. Taxonomic information and services on arthropods of importance to human welfare in Central and South America. *FAO Plant Protection Bulletin* 30: 92 - 95.
- LAURENCE, W.F. & BIERREGAARD, R.O. (Eds.) 1997. *Tropical Forest Remnants*. 616 pp. University of Chicago Press, Chicago.
- MANOKARAN, N., LAFRANKIE, J.V., KOCHUMMEN, K.M., QUAH, E.S., KLAHN, J.E., ASITON, P.S. & HUBBELL, S.P. 1992. Stand table and distribution of Species in the 50-ha Research Plot at Pasoh Forest Reserve. *PRIM Research Data No. 1*. Forest Research Institute Malaysia, Kepong.
- MARGULES, C.R. & KITCHING, I.J. 1995. Assessing priority areas for biodiversity and protected area networks. Pp. 355-364 in Boyle, T.J.B. & Boontawe, B. (Eds.) *Measuring and Monitoring Biodiversity in Tropical and Temperate Forests*. 395 pp. CIFOR, Bogor.
- MAY, R.M. 1990. Taxonomy as destiny. *Nature* 347: 129 - 130.
- MYERS, N. 1988. Tropical forests and their species: going going...? Pp. 28-35 in Wilson, E.O. (Ed.) *Biodiversity*. 521 pp. National Academic Press, Washington D.C.
- NIELSEN, E.S. & WEST, J.G. 1994. Biodiversity research and biological collections: transfer of information. Pp. 101-121 in Forey, P.L., Humphries, C.J. & Vane-Wright, R.I. (Eds.) *Systematics and Conservation Evaluation*. Clarendon Press, Oxford.
- ORAFOR, J.C. & LAIDPO, D.O. 1995. Fetish groves in the conservation of flora in southern Nigeria. Pp. 167-179 in Bounun, L.A., Ainan, R.A. & Crafter, S.A. (Eds.) *Conservation of Biodiversity in Africa*. 400 pp. National Museums of Kenya, Nairobi.
- PANKHURST, R.J. 1978. *Biological Identification*. 104 pp. Arnold, London.
- PRENDERGAST, J., QUINN, R.M., LAWTON, J.H., EVERSHAM, B.C. & GIBBON, D.W. 1993. Rare species, the coincidence of biodiversity hotspots and conservation strategies. *Nature* 365: 335 - 337.
- PRESSEY, R.L., HUMPHRIES, C.J., MARGULES, C.R., VANE-WRIGHT, R.I. & WILLIAMS, P.H. 1993. Beyond opportunism: key principles for systematic reserve selection. *Trends in Ecology and Evolution* 8: 124 - 128.
- REID, W.V., LAIRD, S.A., MEYER, C.A., GAMEZ, R., SITTENFELD, A., JANZEN, D.H., COLLIN, M.A. & JUMA, C. 1993. *Biodiversity Prospecting: Using Genetic Resources for Sustainable Development*. 341 pp. World Resources Institute, Washington, D.C.
- ROBERTS, L. 1992. Chemical prospecting: hope for vanishing ecosystems? *Science* 256: 1142 - 1143.
- RODRIGUEZ, C.M. & GAULD, I.D. 1995. *A Proposal for a Complete Inventory of the Hymenoptera of Guanacaste Conservation Area, Costa Rica*. Report of the Hymenoptera TWIG working Group, San José, 8-17 February 1995.
- ROSSMAN, A.Y. 1994. A strategy for an all-taxa inventory of fungal biodiversity. Pp. 169-194 in Peng, C.-I. & Chou, C.H. (Eds.) *Biodiversity and Terrestrial Ecosystems*. Academia Sinica, Taipei.
- SAMWAYS, M.J. 1994. *Insect Conservation Biology*. 358 pp. Chapman & Hall, London.
- STORK, N.E. 1993. How many species are there? *Biodiversity and Conservation* 2: 215 - 232.
- STORK, N.E. & SAMWAYS, M.J. (Eds.) 1995. Inventorying and monitoring biodiversity. Pp. 453-544 in Heywood, V.H. (Ed.) *Global Biodiversity Assessment*. 1140 pp. Cambridge University Press.
- SYSTEMATICS AGENDA 2000. 1994. *Systematics Agenda 2000: Charting the Biosphere. Technical Report*. 34 pp. New York.
- TILLING, S.M. 1987. Education and taxonomy: the role of the Field Studies Council and AIDGAP. Pp. 87-96 in Berry, R.J. & Crothers, J.H. (Eds.) *Nature, Natural History and Ecology*. Academic Press, London.
- TOWNES, H. 1969. Genera of Ichneumonidae I. *Memoirs of the American Entomological Institute* 11: 1 - 300.
- TOWNES, H. & TOWNES, M. 1973. A catalogue and reclassification of Ethiopian Ichneumonidae. *Memoirs of the American Entomological Institute* 19: 1 - 416.
- UNEP. 1992. *Convention on Biological Diversity*. Text and Annexes. 34 pp. Secretariat to the Convention on Biological Diversity, Geneva.
- UNEP/CBD/SBSTTA/2. 1996. *Report of the Subsidiary Body on Scientific, Technical and Technological Advice on the Work of its Second Meeting*. 74 pp. Secretariat to the Convention on Biological Diversity, Montreal.

- VANE-WRIGHT, R.I. 1996. Systematics and the conservation of biodiversity. *Annals of the Missouri Botanic Gardens* 83: 47 - 57.
- VANE-WRIGHT, R.I., HUMPHRIES, C.J. & WILLIAMS, P.H. 1991. What to protect? - systematics and the agony of choice. *Biological Conservation* 55: 235 - 254.
- WEEKS, P.J.D. 1996. Fingerprinting biodiversity: what DASY can do. *BBSRC Business*, July : 18 - 20.
- WEEKS, P.J.D. & GASTON, K.J. 1997. Image analysis, neural networks, and the taxonomic impediment to biodiversity studies. *Biodiversity & Conservation* 6: 263-274.
- WEEKS, P.J.D., GAULD, I.D., GASTON, K.J. & O'NEILL, M.A. 1997. Automating the identification of insects: a new solution to an old problem. *Bulletin of Entomological Research* 87: 203 - 211.
- WHEELER, Q.D. 1995a. Systematics, the scientific basis for inventories of biodiversity. *Biodiversity and Conservation* 4: 476 - 489.
- WHEELER, Q.D. 1995b. The "Old Systematics": classification and phylogeny. Pp. 31-62 in Pakaluk, J. & Slipinski, S.A. (Eds.) *Biology, Phylogeny, and Classification of Coleoptera. Papers Celebrating the 80th Birthday of Roy A. Crowson*. Instytut Zoologii PAN, Warsaw.
- WHITE, I. M. & SCOTT, P.R. 1994. Computer information resources for pest identification: a review. Pp 129 - 137 in Hawksworth, D.L. (Ed.) *The Identification and Characterisation of Pest Organisms*. CAB International, Wallingford.
- WHITMORE, T.C. & SAYER, J.A. (Eds.) 1992. *Tropical Deforestation and Species Extinction*. 153 pp. Chapman & Hall, London.
- WILLIAMS, P.H. & GASTON, K.J. 1994. Measuring more of biodiversity: can higher taxon richness predict wholesale species richness? *Biological Conservation* 67: 211 - 217.
- WILLIAMS, P.H., HUMPHRIES, C.J. & GASTON, K.J. 1994. Centres of seed-plant diversity: the family way. *Proceedings of the Royal Society of London B* 256: 67 - 70.
- YU, D.S. & HORSTMANN, K. 1997. Catalogue of World Ichneumonidae (Hymenoptera). *Memoirs of the American Entomological Institute* 58: 1 - 1099.

BIODIVERSITY DATABASE AND ASSESSMENT OF LOGGING IMPACTS

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The data generated from enumeration exercises in the primary forest and logged forest in Pasoh Forest Reserve, Negri Sembilan, Malaysia were used to assess the effects of logging on tree species diversity and abundance in a tropical lowland dipterocarp forest. The taxonomic status of species was updated to provide a more critical species list. Conservation ratings using star classification and species scoring and weights were developed for each species based on several criteria and the average weights derived for each star.

Keywords: Database - conservation - logging impact - tropical forest

Introduction

The integration of biodiversity conservation into forest management systems in Malaysia is regarded as an important approach to attain a measure of forest sustainability. In the past, research in forest management systems has primarily been directed towards methods of increasing timber harvest and yield. In the last two decades however, the rapid demand for land has resulted in a large reduction of natural forest, leading to a network of severely fragmented and isolated forest areas. The country is therefore developing ways of incorporating conservation into forest management systems, to ensure sustainability of forest use and reduction of local species extinction. This report is a preliminary analysis of the effects of logging on tree species diversity and abundance in a tropical lowland dipterocarp forest in Peninsular Malaysia. It aims to demonstrate the potential application of star ratings, weights attributed to each star category and absolute values of indices for conservation.

Materials and methods

The study sites are situated in Pasoh Forest Reserve (PFR) which is located about 180 km south-east of Kuala Lumpur, the capital of Malaysia. The forest reserve consists of a core area of about 600 hectares of primary lowland dipterocarp forest surrounded by a buffer zone of 1,850 ha of regenerating lowland forest (Lee 1995). PFR has been described as 'Red Meranti-Keruing' forest of the Central and Southern type (Wyatt-Smith 1963). The topography is undulating and the under-lying rocks are sedimentary and igneous in the eastern and western parts of the reserve, respectively (Loganathan, 1980). The soil is composed of mostly shale and alluvial deposits (Amir *et al.* 1991). The annual temperature ranges between 24.5–27.2 °C with precipitation of between 1,700–3,200 mm per year (Dale 1959). Inventory data from a 50-ha plot has shown PFR to be very diverse in plant species. A census conducted in 1995 recorded 78 tree families with 290 genera and 814 species, with the Euphorbiaceae, Myrtaceae and Lauraceae having the highest diversity (Kochummen *et al.* 1990).

Sample plots

In 1993, five plots of one hectare each were established in Compartment 25, PFR (Figure 1). This area was managed and logged in 1955 under the Malayan Uniform System. No details of the soil type nor of forestry records were available. All plants above 10 cm dbh in the plots were enumerated and mapped. Sample plot data were compiled into a database for easy retrieval. In addition, five 'control' subplots of one hectare each were randomly chosen from within the 50-ha (unlogged) plot (Manokaran *et al.* 1990) for enumeration of tree species diversity and composition in the primary forest.

Inventory data from the plots in the unlogged and logged forest were used to determine a conservation index for PFR, by linking information separately compiled in a species-level database. This index reflects the concentration of rare species in the community, rather than the absolute number per unit area (Hawthorne 1993, 1996). It can be used to define biological 'hot-spots', to prioritise areas for conservation and, as in our current example, to quantify the impact of disturbance on biodiversity value.

Defining star ratings of biodiversity value for each species

Using the herbarium collection at the Forest Research Institute Malaysia (FRIM), each species (those which are well-defined in taxonomic status or new but unpublished) has been tentatively given a star rating based on various species-level criteria (Tables 1a & 1b). Species are rated as Black, Gold, Blue, Red, Purple or White stars in order of decreasing conservation priority (Table 2). Red star species are species of economic importance, but otherwise of low conservation priority. Black star species are the highest rated because they are locally and globally rare, for example,

occurring in specific habitats with small population sizes. New but unpublished species from a single locality or a restricted range of localities have tentatively been placed here. At the other extreme, White star species are widespread, usually from a variety of habitats, have no regeneration bottlenecks but are not commonly utilised by man. In order to reduce the degree of subjectivity arising from the use of Table 1, a draft categorisation of the star rating for species was circulated to botanists familiar with the local flora, and a consensus sought.

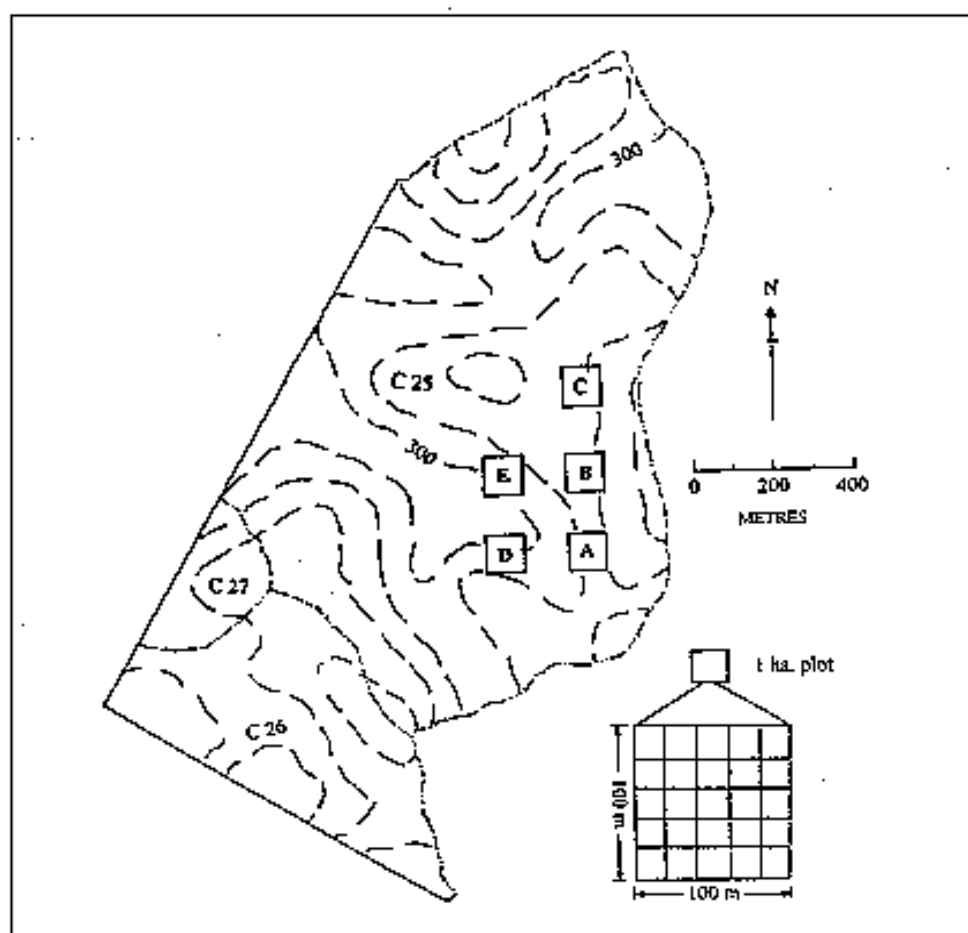


Figure 1. Location of the five one hectare plots in the logged forest of Pasoh Forest Reserve

Table 1a. Main criteria for choosing star ratings based on global and regional distribution*

No. Malaysian states	Number of countries				
	1	2	3	4	5+
1	A	AB	BC	BCD	CDE
2	AB	AB	BC	CD	CDE
3	AB	BC	BCD	CD	CDE
4	ABC	BCD	CD	CD	CDE
5	ABCD	BCD	CDE	CDE	DE

*Alphabets in decreasing order of rarity, i.e. A: rarest, E: least rare

Table 1b: Refinement factors for species scoring, based on species characteristics
(adapted from Ilawthorne 1996)

	Upgrade	Downgrade
Distribution	Scattered and/or in small population size	Widespread and/or locally abundant wherever it occurs
Likely representation of samples	Well-sampled	Probably commoner than data suggest
Taxonomy	Taxonomically isolated, no close relatives, recently revised by a 'lumper', only species in the genus or one of the few species in the family	Closely related to other species, recently revised by 'splitter'
Variability	High, many varieties, subspecies	Low
Successional ecology	Primary forest	Secondary forest species promoted by forest disturbances, pioneer species
Habitat ecology	In edaphic or fragile/threatened habitats	Found in many different forest habitats; well represented in poorly sampled areas
Life history	Slow to mature; regeneration sparse	Fast-maturing; regenerating easily
Ecosystem role	Species playing an important role e.g. soil/erosion stabilisers, food plants, plants used in biological control	Independent
Potential economics	Genes/products important to humans	Possible pest
Discretionary	Only known in specific forest habitats where area size is declining at a rapid pace	Adaptable to new environments

Table 2. Genetic Heat Index (GHI) weight for each star category (weight being in inverse proportion to the average area occupied)

Star	Average area occupied (minute squares)	GHI Weight
Black	120	30
Gold	1509	3
Blue	1688	2
Red	3218	1
Purple	3101	1
White	3417	1

Conservation index

The conservation index employed here is the Genetic Heat Index (GHI), a first-approximation estimate of the 'genetic scarcity' of species in a community based on the representation of different stars (Hawthorne 1993, 1996, Hawthorne & Abu Juan 1995). The Index is calculated from star scores as a weighted average where the weight is in inverse proportion to the average area of the world occupied by species of that star, relative to the area occupied by the least rare (White) star (Table 2). In practice, areas occupied are known for only a small, yet hopefully, representative subset of species. Furthermore, the weights depend on the resolution employed for assessing the area occupied; coarser resolutions (e.g. degree instead of minute squares) decrease the ratios between them, and would therefore decrease recommended weight. In the current study, minute square distributions have been calculated, although for general application, degree square ratios may be more practicable. Note that Purple and Red stars have GHI weights approximating the GHI weight of White star, so the status of Purple star as a separate category now needs to be reviewed.

The Index is thus based broadly on local (Peninsular Malaysia) and global abundance of the species. The use of such an approach to determine the area occupied may be considered fairly crude because it is based on an outdated map of forest reserves (Forest Research Institute Malaysia, unpublished) and the species collection lodged at FRIM's herbarium. In addition, although the use of minute squares leads to a higher resolution, it also leads to an increased potential for distortion due to sampling bias. For these reasons, accuracy in the weights are not expected. However, some degree of subtlety can be expected when scores for each species are combined and the individual errors are averaged out. For Ghana, Hawthorne (1993) has shown that the actual weights for stars are not very critical; sensitivity analyses showed that forest community trends did not change with wide swings in weights. It is not known at present how different the trends are in Malaysian forest communities and whether the weighting approach used in this study will be able to provide some form of sensitive representation. Such inferences can only be made when the approach is applied on a more widespread basis through-out the country. The Genetic Heat Index (GHI) is then calculated as follows (adapted from Hawthorne 1996):

$$GHI = \frac{(Bk \times Bkwt) + (Go \times Gowgt) + (Pu \times Puwt) + (Bl \times Blwt) + (Wh \times Whwt) + (Re \times Rewgt) \times 100}{Bk + Go + Pu + Bl + Wh + Re}$$

Bk = Number of Black star species

Go = Number of Gold star species

Pu = Number of Purple star species

Bl = Number of Blue star species

Wh = Number of White star species

Re = Number of Red star species

Bkwt (Gowgt etc.) = weight for Black (Gold etc.) star species

Results

Number of species and Genetic Heat Index of unlogged forest

The total number of species found in five hectares of the unlogged forest in PFR was 702 (Table 3). This constitutes 86 per cent of the total number of species found in the 50-ha plot. The five largest families, in decreasing order, were Euphorbiaceae (74 species), Myrtaceae (45 species), Lauraceae (38 species), Rubiaceae (38 species) and Annonaceae (38 species). This ranking is similar to that for the 50 hectare plot (Kochummen *et al.* 1990). Kochummen *et al.* (1990) remarked that based on a mean density of 530 trees per hectare representing about 210 species, species diversity of trees at PFR is comparable to the highest diversities recorded on a per hectare basis elsewhere in the world. The results compiled from the random sub-sampling clearly support the validity of this statement.

Table 3. Number and percentage of species and individuals in each star category occurring in the unlogged forest plots (as of 1995, above 10 cm dbh)

Star	Species		Individuals	
	Number	%	Number	%
Black	41	5.84	52	1.79
Gold	108	15.39	276	9.53
Blue	161	22.93	471	16.26
Red	33	4.7	595	20.54
Purple	21	2.99	45	1.55
White	338	48.15	1458	50.33
Total	702	100	2897	100

One hundred and four species in the five hectares unlogged forest plots are endemic to Peninsular Malaysia; this represents 13.9 per cent of all endemic tree species (Ng *et al.* 1990). The families with the largest number of endemic species are, in decreasing order, Euphorbiaceae (12 species), Myrtaceae (11 species), Rubiaceae (7 species), Ebenaceae (7 species) and Myristicaceae (6 species). Euphorbiaceae, Myrtaceae and Rubiaceae are therefore the highest ranking families in terms of species diversity and endemics. Although Ebenaceae is ranked fourteenth in the species diversity list of the 50-ha plot (Kochummen *et al.* 1990), 96 per cent of the species in this family occurred in the five hectares plot. As such, the Ebenaceae has a much higher percentage of endemic species than the Euphorbiaceae, Myrtaceae and Rubiaceae.

PFR has 33 tree species of timber value (Red star) (Table 3) and of these, 26 species are from the family Dipterocarpaceae. This latter figure represents 16.7 per cent of the total number of species occurring in Peninsular Malaysia. The Dipterocarpaceae is ranked the tenth most diverse family in the 50-ha plot (Kochummen *et al.* 1990). Of the three endemic dipterocarp species found in the plot (*Neobalanocarpus heimii*, *Parashorea densiflora* and *Vatica bella*), only *Vatica bella* is

rare. The abundance of Red star species in each dbh class is given in Table 4. Other families with timber tree species include Burseraceae, Moraceae, Sterculiaceae, Leguminosae and Euphorbiaceae.

Table 4. Number of Red star individuals for each dbh category in unlogged and logged forest plots

Census Year	1-10 cm	Unlogged forest			Logged forest		
		11-20 cm	20-30 cm	>30 cm	11-20 cm	20-30 cm	>30 cm
1987	3375	275	103	155	-	-	-
1990	3355	285	115	158	-	-	-
1995	3326	315	124	148	477	703	240

However, what do such analyses imply, in terms of the forest as a whole? The function of the current analysis is to show how standardised techniques can produce simplified, standard indices, based on pre-assessments of species in a general database.

Table 3 also shows the number of species in each star category for the unlogged forest plots. The least diverse category in the unlogged forest was Purple star (2.99%), followed by Red (4.7%) and Black (5.84%) stars. The most diverse was White star, accounting for almost half of the species present. The results indicate that Black star species which are rare/uncommon elsewhere in Peninsular Malaysia (Ng *et al.* 1990) are also rare in PFR. Table 5 lists some Black star species of the unlogged forest plots. In terms of abundance, Purple star was the least abundant group (45), followed by Black star (52) (Table 3). The Black star group made up only 1.79 per cent of the individuals above 10 cm dbh while the White star group made up 50.33 per cent of individuals. The extremely low abundance of Black star individuals above 10 cm dbh is in stark contrast to that of individuals below 10 cm dbh (Table 6) where when the size class 1-10 cm dbh is considered, tree density increased to 195.2 trees per hectare. Although many of the Black star species have been classified as shrubs or small treelets (Whitmore 1972a, 1972b, Ng 1978, 1989, see Kochummen *et al.* 1990 for definition of the habit), it is not known at what dbh size these species attain reproductive maturity.

Based on all species with individuals above 10 cm dbh (the minimum size enumerated in the logged sample plots) the unlogged forest in PFR has a GHI of 299. As previously mentioned, the GHI is a reflection of the concentration of rare species. However, it is not known at present whether this value reflects a level of diversity comparable to that of other lowland dipterocarp forests as there are no similar indices for forest types in totally protected areas.

Number of species and Genetic Heat Index of logged forest

The total number of species found in the five hectares of logged forest in PFR is 427 (Table 7). This number was obtained from the inventory of all plants above 10 cm dbh and would be expected to increase if the exercise had measured all plants

above 1 cm dbh. This figure is equivalent to 60.8 per cent of the total number of species found in the unlogged forest plots (Table 3) indicating that 40 years after logging, the forest has only slightly more than half the number of species of the unlogged forest. The five largest families were, in decreasing order, Euphorbiaceae, Myrtaceae, Dipterocarpaceae, Lauraceae and Anacardiaceae. The families with the highest number of endemic species included Euphorbiaceae (10 species), Myrtaceae (7 species), Myristicaceae (6 species), Annonaceae (4 species) and Dipterocarpaceae (3 species). The logged forest plots contained 6.57 per cent of the endemic tree species of Peninsular Malaysia.

Table 5. Examples of some Black star species found in PFR and their densities (only individuals above 10 cm dbh)

Family	Species	Status in Penin. Malaysia	Density in PFR (trees per ha)	
			Unlogged	Logged
Myrtaceae	<i>Eugenia variifolia</i>	restricted to two states	0.4	0
	<i>Eugenia</i> sp. 4	n.a.	0.2	0
	<i>Eugenia</i> sp. 10	n.a.	0.2	0.2
	<i>Eugenia</i> sp. 16	n.a.	0.4	0.6
Lauraceae	<i>Alseodaphne</i> sp. 1	n.a.	0.2	0.8
	<i>Beilschmedia</i> sp. 1	n.a.	0.2	0
Fagaceae	<i>Castanopsis curtisii</i>	n.a.	0.2	0
Euphorbiaceae	<i>Cleistanthus malaccensis</i>	rare	0	0.4
Rubiacaceae	<i>Diospyros</i> sp. 1	rare	0.6	1.6
Annonaceae	<i>Entosanctum fuscum</i>	n.a.	0.8	0.4
Burseraceae	<i>Dacryodes nervosa</i>	n.a.	0.4	0

Table 6. Number of Black star individuals for each dbh category for unlogged and logged forest plots

Census Year	Unlogged forest				Logged forest		
	1–10 cm	11–20 cm	20–30 cm	>30 cm	11–20 cm	20–30 cm	>30 cm
1987	976	38	12	3	-	-	-
1990	976	38	12	3	-	-	-
1995	977	37	12	3	28	6	3

Table 7. Number and percentage of species and individuals above 10 cm dbh in each star category in the logged forest plots (as of 1995)

Star	Species		Individuals	
	Number	%	Number	%
Black	4	0.94	37	1.04
Gold	65	15.22	322	9.08
Blue	91	21.31	479	13.51
Red	36	8.43	1067	30.1
Purple	11	2.58	40	1.13
White	220	51.52	1600	45.13
Total	427	100	3545	100

Table 7 shows the number of species and individuals for each star category found in the logged forest. The category with the lowest number of species was Black star, followed by Purple and Red stars. The number of Red star species was slightly higher in the logged forest than in the unlogged forest and of the 36 species in the former, 75 per cent were from the family Dipterocarpaceae. The GHI for the logged forest is 225, about 75 per cent that of the unlogged forest.

Discussion

The results show that the logged forest contained only 60.8 per cent of the plant diversity of the unlogged forest 40 years after logging. The greatest difference in the percentage of diversity between logged and unlogged forest was shown by the Red star (commercially interesting) category, followed by the Black star. Red star species were more diverse in the logged forest while the Black star species were more diverse in the unlogged forest. In both forest habitats, White and Blue stars remained the most common categories.

The ranking of the five most diverse families also differed in the unlogged and logged forests. The emergence of families such as the Dipterocarpaceae and the Anacardiaceae in the logged forest clearly indicates that the species composition also differed by a significant degree. In both forest habitats, the five most diverse families are, with the exception of Rubiaceae, families with many timber species.

Although the logged forest had a greater number of individuals compared to the unlogged forest, it contained only 71 per cent of Black star individuals found in the unlogged forest. The increase in the density of trees in the logged forest is attributed to an increase in the density of common species and not of rare species, a fact which contributes to the reduction of GHI in the logged forest.

Blue and White stars were the most common categories in both the unlogged and logged forests, yet they became proportionately less common in the logged forest. Because the GHI is a measure of the concentration of rare species in a community, the 25 per cent reduction in the logged forest indicates that a proportionate loss of rare species had occurred. The fact that nothing is known of the species diversity in the forest area prior to logging only detracts slightly from the significance of this decline. Similarly, in the case of endemics, the logged forest had only half the diversity of the unlogged forest. Families that registered the greatest change in the composition of endemic tree species were Ebenaceae and Myrtaceae. Only two of the seven species of Ebenaceae and seven of the 11 species of Myrtaceae found in the unlogged forest occurred in the logged forest. Although nothing is known of the species diversity of the forest prior to logging, the reduction in the diversity of endemics indicates that changes had occurred during the 40 years after logging which significantly affected the diversity of endemic species.

Tables 3 and 7 showed that the logged forest had a greater diversity and abundance of Red star species compared to the unlogged forest. Thirty-six species were recorded from logged forest plots compared with only 33 in unlogged forest plots. Red star individuals were also 80 per cent more abundant in the logged forest, contributing to the 22 per cent increase in plants above 10 cm dbh compared to the

unlogged forest. Table 4 shows that 40 years after logging, the forest had 67.8 per cent more Red star individuals above 30 cm dbh than the unlogged forest. With the exception of size class 1–10 cm (for which there was no data for the regenerating forest), the abundance of trees in the other size classes in the logged forest was higher than in the unlogged forest (Table 4). These results are in line with those of another study taking place in PFR (Manokaran, this volume).

All the endemic dipterocarp species (*N. heimii*, *P. densiflora* and *V. bella*) found in the unlogged forest also occurred in the logged forest. However, *V. bella*, represented by only five individuals, is rare in the logged plots.

These results have important implications for the conservation of plant diversity in managed forests in Peninsular Malaysia. The scarcity of Black star species in the regenerating forest 40 years after logging implies that the forest management system then practiced i.e. the Malayan Uniform System, generally promoted the regeneration of the commoner species, thereby reducing the global biodiversity value of the forest. At present it is not known whether the Selective Management System (SMS), which came into operation in the late 1970's (Thang 1987), would have similar consequences on tree species diversity, although we suspect that the effects would be less severe. Further refinement of the species database and extension of appropriate samples should clarify this issue in the forthcoming years.

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References

- AMIR, H., MILLER, H.G. & APPANAH, S. 1991. Soil fertility and tree species diversity in two Malaysian forests. *Journal of Tropical Forest Science* 3(4): 318–31.
- DALE, W.L. 1959. Rainfall of Malaya Part 1. *Journal of Tropical Geography* 13: 23–37.
- HAWTHORNE, W.D. 1993. *Froggie Manual (Parts 1 & 2) and Software*. Overseas Development Administration and Forest Department, Republic of Ghana.
- HAWTHORNE, W.D. 1996. Holes and the sums of parts in Ghanaian forest: regeneration, scale and sustainable use. Pp. 75–176 in Swaine, M.D., Alexander, I.J. & Watling, R. (Eds.) *Studies in Guineo-Congolian rain forest, Proceedings of the Royal Society of Edinburgh* 104B.
- HAWTHORNE, W.D. & ABUJUAM, M. 1995. *Forest Protection in Ghana*. xvii + 203 pp. IUCN, Gland, Switzerland & Cambridge, United Kingdom.
- KOCHUMMEN, K.M., LAFRANKIE JR., J.V. & MANOKARAN, N. 1990. Floristic composition of Pasoh Forest Reserve, a lowland rain forest in Peninsular Malaysia. *Journal of Tropical Forest Science* 3(1): 1–13.
- LEE, S.S. (Ed.) 1995. A Guidebook to Pasoh. *FRIM Technical Information Handbook No. 3*, 73 pp. Forest Research Institute Malaysia, Kepong.
- LOGANATHAN, P. 1980. The geology of south-western part of the Durian Tepus area (Sheet No. 96), Negri Sembilan. Pp. 147–158 in *Annual report for 1979*. Geological Survey of Malaysia, Ministry of Primary Industries, Malaysia.

- MANOKARAN, N., LaFRANKIE, J.V., KOCHUMMEN, K.M., QUAH, E.S., KLAHN, J.E., ASHTON, P.S. & HUBBELL, S.P. 1990. Methodology for the fifty hectare research plot at Pasoh Forest Reserve. FRIM Research Pamphlet No. 104. 69 pp. Forest Research Institute Malaysia, Kepong.
- NG, F.S.P., LOW, C.M. & MAT ASRI, N.S. 1990. Endemic trees of the Malay Peninsula. *FRIM Research Pamphlet No. 106*. 118 pp. Forest Research Institute Malaysia, Kepong.
- NG, F.S.P. (Ed.) 1978. *Tree Flora of Malaya*. Volume 3. 339 pp. Longman, Malaysia, Kuala Lumpur.
- NG, F.S.P. (Ed.) 1989. *Tree Flora of Malaya*. Volume 4. 549 pp. Longman, Malaysia, Kuala Lumpur.
- THANG, H.C. 1987. Forest management systems for tropical high forest, with special reference to Peninsular Malaysia. *Forest Ecology & Management* 21: 3-20.
- WHITMORE, T.C. (Ed.) 1972a. *Tree Flora of Malaya*. Volume 1. 473 pp. Longman, Malaysia, Kuala Lumpur.
- WHITMORE, T.C. (Ed.) 1972b. *Tree Flora of Malaya*. Volume 2. 444 pp. Longman, Malaysia, Kuala Lumpur.
- WYATT-SMITH, J. 1963. Manual of Malayan silviculture for inland forest (Second edition). Vol. 1. *FRIM Research Pamphlet No. 101*. 89 pp. Forest Research Institute Malaysia, Kepong.



Plate 1. The colourful fruits of *Garcinia forbesii* (Guttiferae), an uncommon tree in the lowland forests of Malaysia.
Photo: L.S.L. Chua



Plate 2. *Polyalthia cinnamomea* (Annonaceae) which is widespread in Malaysian forests. Note its cauliflorous habit
Photo: L.S.L. Chua

EFFECT, 34 YEARS LATER, OF SELECTIVE LOGGING IN THE LOWLAND DIPTEROCARP FOREST AT PASOH, PENINSULAR MALAYSIA, AND IMPLICATIONS ON PRESENT-DAY LOGGING IN THE HILL FORESTS

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Pasoh Forest Reserve is a lowland dipterocarp forest of the 'Red Meranti-Keruing' type where species of *Dipterocarpus* (keruing) and *Shorea* that yield red meranti timber are common. Data of the structure and composition of the primary forest in 1984 in four 2-ha plots of trees of 10 cm diameter at breast height (dbh) and larger are compared in this paper with these in 1989 in one 2-ha plot in a logged part of the forest. Selective logging under the Malayan Uniform System was carried out between 1955 and 1960 and the silvicultural treatment of GCL (girdling and climber cutting) applied in the logged areas, also between 1955 and 1960. Compartment 25 of the reserve, where the 2-ha plot is located, was logged in 1955. Emergent trees in the primary forest averaged 46 m in height but such trees were lower in height in the regenerating logged forest, averaging 39 m. Density of trees of 10 cm dbh and larger in the regenerating forest was higher by 44 per cent, and the number of individuals of the dominant timber family, the Dipterocarpaceae, was substantially higher by 157 per cent in the logged area. A much more valuable timber stand midway to the expected rotation of 70 years is evidence that the MUS, as originally proposed, has proven to be correct. Total basal area was almost identical at both sites, at 27.43 and 27.63 m² ha⁻¹ in the primary and the regenerating parts respectively, and only marginally different for the Dipterocarpaceae at 8.11 and 7.94 m² ha⁻¹ respectively. Thus while large trees were rare in the regenerating forest, evident from the size-class distribution pattern, the larger number of trees per unit area ensured that the carrying capacity of the forest in terms of basal area was being maintained at 34 years after logging. However, the diameter class distributions at the two sites were significantly different; the distribution of trees being skewed with a much larger number of trees at the lowest size-class in the regenerating forest. Nevertheless, the respective total and dipterocarp populations at the two sites differed only up to a minor degree in tree number in the 30 cm and larger size class. This suggests that a cutting cycle of around three decades, but not less, could have been entertained in such Red Meranti-Keruing forests if logging damage was kept to an absolute minimum and a minimum felling size of 40 to 45 cm dbh rigidly enforced. The size-class distribution pattern suggests that at 34 years after logging, or at about half the expected rotation of 70 years, the forest was not yet fully stocked. From an ecological perspective, therefore, the logged forest was still regenerating, and an artificial thinning regime should be applied to what appears to be a forest in a somewhat static state, to accelerate the movement towards achieving a size-class distribution similar to that of the primary forest. At that juncture, the logged forest could be categorised as regenerated. In the hill forests where timber production is now carried out under the Selective Management System (SMS), a similar tree residual situation as in the Pasoh study is unlikely due to factors such as logging damage, excessive timber extraction and areal soil disturbance from logging operations that can be as high as 80 per cent. The expectation therefore is that the cutting cycle for the hill forest would not be 25-30 years as envisaged under the SMS but would likely be twice-as-long, or even longer.

Key words: Dipterocarp forest - selective logging - regenerating forest - size-class distribution - residual stand - carrying capacity - cutting cycle

Introduction

After the Second World War, Wyatt-Smith (1966) established 2-ha ecological plots in the then Malaya, one in 1947 in a primary lowland dipterocarp forest in Sungei Menyala in Negri Sembilan state, and another in 1949 in a primary hill dipterocarp forest at Bukit Lagong in the state of Selangor. These were established to obtain basic information on structure, composition and dynamics that would assist in the formulation of more concrete management policy and silvicultural prescriptions. More such 2-ha plots were established in a primary lowland dipterocarp forest in Pasoh (also in Negri Sembilan state) in 1971 by Ashton (1971*a*, 1971*b*) for assessing forest-site variation and subsequent forest productivity. Numbered, labelled and identified trees of 10 cm diameter and larger in these plots have been repeatedly censused. Wyatt-Smith (1966) summarised the data of the Sungei Menyala and Bukit Lagong plots, and later, for over much longer periods, Manokaran (1988) and Manokaran and Swaine (1994), compared the dynamic processes that operate in tree populations in lowland and hill dipterocarp forests (Sungei Menyala 1947-1985, Bukit Lagong 1949-1985, Pasoh 1971-1984).

The Dipterocarpaceae is the main commercial timber family in the forests of South East Asia, and usually forms a high proportion of the emergent and main canopy strata of the forest. For example, in surveys covering a total of about 3,200 hectares of lowland and hill dipterocarp forests in Peninsular Malaysia, 30 per cent of trees 30 cm diameter and greater at breast height, and 55.5 per cent by volume, were dipterocarps (Symington 1943). In another survey in Peninsular Malaysia, Poore (1968) found that in a 21-ha area in a lowland dipterocarp forest in Jengka, 28 per cent of trees of 29 cm diameter at breast height (dbh) and greater were dipterocarps, and these occupied 43 per cent of the basal area in the plot. When woody trees are considered to a dbh of as low as 1 cm, dipterocarps are still a significant part of the vegetation. For example, in a 50-ha plot in a primary lowland dipterocarp forest in Pasoh, dipterocarps formed over nine per cent of the total number of stems, second only to the Euphorbiaceae representing more than 13 per cent of the stems, and formed over 24 per cent of the total basal area with Euphorbiaceae a distant second with over seven per cent of the basal area (Manokaran *et al.* 1991).

A significant proportion of the lowland dipterocarp forest at Pasoh, and the major portion of the forest at Sungei Menyala, were selectively logged in the mid-1950s under the Malayan Uniform System (MUS). In 1989 ecological plots of 2-ha size were established, one each in the logged parts of these two forest areas to investigate the effects of such logging, with the plots in the primary part of the forest forming the basis for comparison. In this paper I restrict myself to examining the effects of such logging at Pasoh Forest Reserve.

Based on the effects of treatments and the results of samplings after logging, Wyatt-Smith (1963*a*) considered that a forest logged under the MUS could be classified as successfully regenerated ten years after sampling. This is from the silvicultural viewpoint. In this paper I prefer to use the term 'regenerating' for a logged forest that is perceived to be approaching a state similar to what it was at the

time of logging. This is purely from an ecological perspective. If results show that at least structurally the two types of forest are not dissimilar, then one could conclude that the 'regenerating' forest had reverted to its former state in spite of differences in species composition, and could therefore be classified as 'regenerated'.

Site description

Pasoh Forest Reserve is an inland forest, 2° 59' N and 102° 19' E, at about 180 km south-east of Kuala Lumpur, amidst a broad expanse of flat lands and gently rolling ridges that abut the westward side of the Main Range. The vegetation is mainly primary rain forest and falls within the south-central sub-type of the 'Red Meranti-Keruing' forest sub-type of Wyatt-Smith (1987). The upper canopy is dominated by red meranti, *Shorea* section Muticae, especially *S. leprosula*, *S. acuminata* and *S. macroptera*. Other important canopy emergents are keruing (*Dipterocarpus cornutus*), balau (*Shorea maxwelliana*) and chengal (*Neobalanocarpus heimii*).

Of the original area of the forest reserve, 1,075 ha in the north-west through west to the south was logged and converted to oil palm (*Elaeis guineensis*) plantations in 1971. The oil palm plantations surround the present reserve which now consists of a core research area of about 650 ha of primary lowland forest surrounded by a buffer zone of about 650 ha of logged and regenerating forest (lowland dipterocarp forest in which the natural regeneration, mainly seedlings but also including advance growth, had been released and assisted by silvicultural treatment after exploitation) and about 1,000 ha of primary hill forest to the east. The regenerating buffer zone, as well as much of the area under oil palm now, was selectively logged between 1955 and 1960 and the silvicultural treatment of GCL (girdling and climber cutting) carried out in the logged areas, also between 1955 and 1960.

Pasoh Forest Reserve, constituted in early 1917, has had a long history of research activities. It was the site of collaborative research (1970-1974) between the Malaysian National Committee for the International Biological Programme (IBP), the University of Malaya, the Forestry Department of Malaysia, the Royal Society of London and the Japanese Society for the Promotion of Science. Between 1973 and 1979, the reserve was the site of the University of Malaya-University of Aberdeen project on reproductive biology of rain forest trees. Besides being the site of the 'Conservation, Management and Development of Forest Resources Programme' of Malaysia-United Kingdom, it is also now the site of the Forest Research Institute - National Institute for Environmental Studies (Japan) - Universiti Putra Malaysia Joint Research Project on Tropical Forest Ecology and Biodiversity. Beginning in 1985, a demographic study has been in progress of all woody plants of 1 cm diameter and larger in a 50-ha plot in the primary forest at Pasoh (see Manokaran *et al.* 1990, Manokaran *et al.* 1992a). The plot was recensused in 1990 (Manokaran *et al.* 1992b), and then again in 1995/96.

The reserve has been known as the Pasoh Forestry Research Centre of the Forest Research Institute Malaysia (FRIM) since it became a sub-station of the then Forest Research Institute (FRI) in 1977.

Mean annual rainfall at Pasoh is about 2,000 mm, making it one of the driest stations in Peninsular Malaysia. Further details of the ecology and vegetation of Pasoh Forest Reserve are provided in Kochummen *et al.* (1990) and Soepadmo and Kira (1977). Table 1 summarises the main physical features of the reserve.

Table 1. Physical features of Pasoh Forest Reserve (adapted from Manokaran (1988) and Manokaran and Swaine (1994))

Parameter	Pasoh Forest Reserve
Forest type	Lowland dipterocarp forest
Forest sub-type*	'Red Meranti-Keruing'
Altitude (m a.s.l.)	90
Plot size (ha)	4 x 2 (primary) 2 (regenerating)
Mean annual temperature (°C) (nearest station)	27.1
Mean annual rainfall (mm)	2000
Soil type	Sedimentary-derived soil mainly

* Based on Wyatt-Smith (1987)

Methods

In the primary forest, four 2-ha plots of 100 × 200 m dimensions were established in 1971. All trees of 10 cm dbh and larger were measured for diameter and identified to species level. The plot was recensused in 1979 and then again in 1984. Subsequently the plot has been recensused at regular intervals of two years. The enumeration data of 1984 are used for various analyses and comparisons in this paper.

Compartment 25 of the reserve was selectively logged in 1955 under the MUS. Here all trees of 10 cm diameter and larger were also enumerated similarly in one 2-ha plot established in 1989. Since then, the plot has been recensused at two-year intervals. The initial census data of 1989 has been used to evaluate the effect of selective logging that had taken place in 1955.

The MUS was approved as a system in 1949, and appeared in print in 1950 (Wyatt-Smith 1963a). The essentials of the MUS in its correct form were described by Wyatt-Smith (1963a), in brief terms, as "the felling (and removal) in *natural* forest, in a short single operation over an adequate number of selected natural seedling regeneration determined by systematic linear sampling, of that part of the upper canopy which consists of the economic crop; to be followed immediately by the poison-girdling of the uneconomic balance of the canopy of commercial sized trees and of all the smaller trees and saplings down to a minimum girth over bark of 6 to 18 inches (5 to 6 cm diameter), other than those of economic species of sound form". A systematic sampling of all the trees of exploitable size is frequently carried out at the time of the seedling regeneration sampling.

"The above upper canopy removal is followed after four to five years by a systematic linear sampling of the stocking of young sapling regeneration of economic species, and after 10 years by a similar sampling of the sapling and advance growth of economic species. In both cases treatment is prescribed on the basis of the sampling and a field inspection.

The ten-year period is regarded as the *establishment stage* of the new crop, and the latter sampling forms the basis of whether an area could be classified as having been successfully regenerated or not. Tending aims at the development of several storeyed, 'even-aged' forest with a stocking of emergent and main storey timber species. The rotation (period between successive final fellings) is estimated to be 70 years."

Cheah (1991) noted that felling was generally at a diameter of 45 cm and above, and both he and Wong (1966) emphasised Wyatt-Smith's (1963a) point that the key to the MUS was the presence of seedling/sapling regeneration on the ground.

For purposes of various analyses, some of which are not reported in this paper, species have been grouped into species groups with similar potential ecological characteristics. This was done to overcome the problem of most species being represented by only a few individuals. Five classes of species are recognised: Emergent, Main Canopy, Understorey, Pioneer and Late-seral, defined as follows:

- Emergents (E): Mature phase light-demanding, long-lived species growing above the main canopy of primary forest to more than 30 m, usually with spreading crowns.
- Main canopy (MC): Mature phase light-demanding, relatively long-lived species that form the main canopy of primary forest, growing to heights between 20 and 30 m.
- Understorey (U): Mature phase shade-tolerant tree species forming the lower strata of the primary forest, with maximum heights below 20 m.
- Pioneer (P): Short-lived tree species requiring a gap for germination and establishment, showing rapid growth; extremely light-demanding and intolerant of shade.
- Late-seral (LS): Light-demanding tree species but relatively tolerant of shade, prominent during the late stages of succession. They can persist to form part of the mature forest.

This classification is based partly on knowledge of the tree species from field experience, and is augmented by reference to the Tree Flora of Malaya (Whitmore 1972, 1973a, Ng 1978, 1989), the Foresters' Manual of Dipterocarps (Symington 1943), and the Pocket Check List of Timber Trees (Kochummen 1979). The classification had earlier been used by Manokaran (1988) and Manokaran and Swaine (1994).

Pioneer and late-seral species of this study are probably equivalent to the 'small pioneer' and 'large pioneer' of Swaine and Hall (1983). They are the short-lived, small-statured pioneers and long-lived, large-statured pioneers, respectively, of Swaine and Whitmore (1988) and Whitmore (1989).

Results and discussion

Tree heights

The average height of the emergent layer in the primary forest was measured to be 46 m. The average height of the regenerating forest in 1989 at the plot was less at 39 m. It is unclear as to when, if at all, the canopy of the regenerating forest would reach a height comparable to that of the primary forest. There is no published information of this sort locally nor from elsewhere in the Malaysian region where the dipterocarp forests are dominant.

Tree densities

At 34 years after logging, the density of all enumerated trees in the regenerating forest plot was about 44 per cent higher than that in the primary forest (Table 2). The difference was very much larger when only the dipterocarps were considered - higher in the regenerating forest by 157 per cent. Besides the effect of canopy opening resulting from logging, the poison-girdling treatment of the MUS was meant to favour the growth of the quicker growing, lighter commercial timbers, and particularly those from the family Dipterocarpaceae. The much higher tree densities in the regenerating forest were likely the effect of such increased crown exposure by silvicultural operations.

Table 2. Density and basal area of trees of 10 cm diameter and larger in primary and regenerating lowland dipterocarp forest at Pasoh

	Primary	Pasoh Forest Reserve Regenerating	Difference %
All trees			
Density (ha ⁻¹)	514.8	742.5	+44.2
Basal area (m ² ha ⁻¹)	27.43	27.63	+0.7
Dipterocarpaceae			
Density (ha ⁻¹)	50	128.5	+157.0
Basal area (m ² ha ⁻¹)	8.11	7.94	-2.1

It is worth noting that dipterocarps are in general all canopy species - of the 23 species in the regenerating plot, 17 are species of the emergent layer and the remaining six, of the main canopy layer. Hence the huge response indicated in Table 2. Understorey species make up about 40 per cent of the population of trees of 10 cm diameter and larger in the primary forest at Pasoh, and these have been shown to be slow-growing, and generally respond least to increased light (Manokaran 1988, Manokaran & Swaine 1994). Hence the lower level of response from the population as a whole.

To explore the notion that quicker growing, lighter timbers were the quickest to respond to increased crown exposure, tree densities of the species of dipterocarps in both the primary and regenerating forests were examined according to whether the dipterocarps were light, medium or heavy hardwoods. This is a classification of timbers of Peninsular Malaysia based on wood density (Anonymous 1968). As Table 3 shows, while light hardwood dipterocarps formed about 60 per cent of the total tree density of the family in the primary forest, the proportion was much higher at just over 80 per cent in the regenerating forest. Similarly, the heavy hardwood dipterocarps formed about 23 per cent of the total tree density in the primary forest but only about four per cent in the regenerating forest. The proportion of the medium hardwoods, comprising five species of *Dipterocarpus*, was not very different in both types of forest.

Table 3. Number of species in, and tree frequency of, the wood density classes of the Dipterocarpaceae of 10 dbh and larger in primary and regenerating lowland dipterocarp forest at Pasoh

Pasoh Forest Reserve	Total no. of species	Dipterocarpaceae	
		Total no. of trees	% of total trees in family
Primary (8 ha)	26	400	-
Light hardwoods	17	239	59.8
Medium hardwoods	5	69	17.2
Heavy hardwoods	4	92	23
Regenerating (2 ha)	23	257	-
Light hardwoods	13	207	80.5
Medium hardwoods	5	40	15.6
Heavy hardwoods	5	10	3.9

These results are evidence that at the time of less than half the expected rotation of 70 years, quicker growing lighter timbers of the Dipterocarpaceae had indeed been favoured by crown exposure at the expense of the heavy hardwood dipterocarps. This is in line with what is known of the response of dipterocarps to increased light, and this subject has been reviewed by Whitmore (1984). In general, light hardwood dipterocarps respond fastest to increased light and grow quickest, so also do the medium hardwood *Dipterocarpus*. Heavy hardwood dipterocarps are slower growing and respond less quickly to increased light. A wood density classification of the dipterocarps present in Pasoh Forest Reserve is provided in Manokaran *et al.* (1991).

Stand structure

The size-class distribution of all trees in the primary forest was significantly different from that in the regenerating forest (Figure 1a, $X^2 = 22.91$, $P < 0.001$). This was also evident when only the family Dipterocarpaceae was considered (Figure 1b, $X^2 = 23.24$, $P < 0.001$). The stand in the regenerating forest had therefore yet to attain, if it ever

does, the distribution characteristic of the primary forest. This is evident if Figure 1 is examined - a preponderance of trees in the smaller size classes in the regenerating forest but a paucity of large trees. For all trees, there was a total of 19 trees of 70 cm diameter and larger in 2-ha of the primary forest compared to only six in the regenerating forest, and for the family Dipterocarpaceae alone, 18 trees of 60 cm diameter and larger in the primary forest and only nine trees of such size in the regenerating forest.

The preponderance of trees in the smaller size classes is well illustrated by the fact that there were 1.5 times more trees in the 10 to 30 cm diameter class in the regenerating forest than in the primary forest but identical number of trees in both forests in the 30 cm and larger size class. When only the dipterocarp population is compared, there were 3.2 times more trees in the regenerating forest in the 10 to 30 cm diameter class, while the difference was 1.6 times more trees in the regenerating than in the primary forest in the 30 cm and larger size class. This, up to only a minor difference in tree number in the 30 cm and larger size class, for the total and dipterocarp population, would suggest that a cutting cycle of around three decades, but not less, could have been entertained in such Red Meranti-Keruing forests if logging damage was kept to an absolute minimum and a minimum felling size of 40 to 45 cm dbh rigidly enforced. However, almost all of this type of lowland forests have already been converted to mainly oil palm plantations, and commercial timber production is now from hill forests.

A point worth noting is that although there is a paucity of large trees in the regenerating forest, in total the forest stand is now more valuable since there are more trees. It is more valuable because the regenerating trees, although generally smaller in size, are readily marketable and processed under present-day conditions.

Basal area

Despite the large differences in tree density and stand structure, total basal area in both the forests were almost similar (Table 2). Thus the lower basal area in the largest size classes of the regenerating forest was compensated for by the greater basal area contributed by the larger number of trees in the smaller size classes. This similarity in total basal area is evidence that there is this carrying capacity in terms of basal area in a unit of forest and that any departure from this level brought about by logging activities or other large-scale disturbances sets in motion forces that tend to bring back this equilibrium - the recruitment of a large number of trees into the minimum size class, as is clear from Figure 1, as well as diameter growth of these and the remaining trees at the site.

Movement towards equilibrium with respect to basal area in a unit of forest has been shown through long-term studies in primary dipterocarp forests by Manokaran (1988) and Manokaran and Swaine (1994). Despite decline in tree density by 14 per cent in a hill dipterocarp forest at Bukit Lagong over 36 years and also by 14 per cent in a lowland dipterocarp forest at Sungei Menyala over 38 years, basal areas were approximately constant over the period of study. In these sites, net loss in trees was offset by incremental growth in surviving trees.

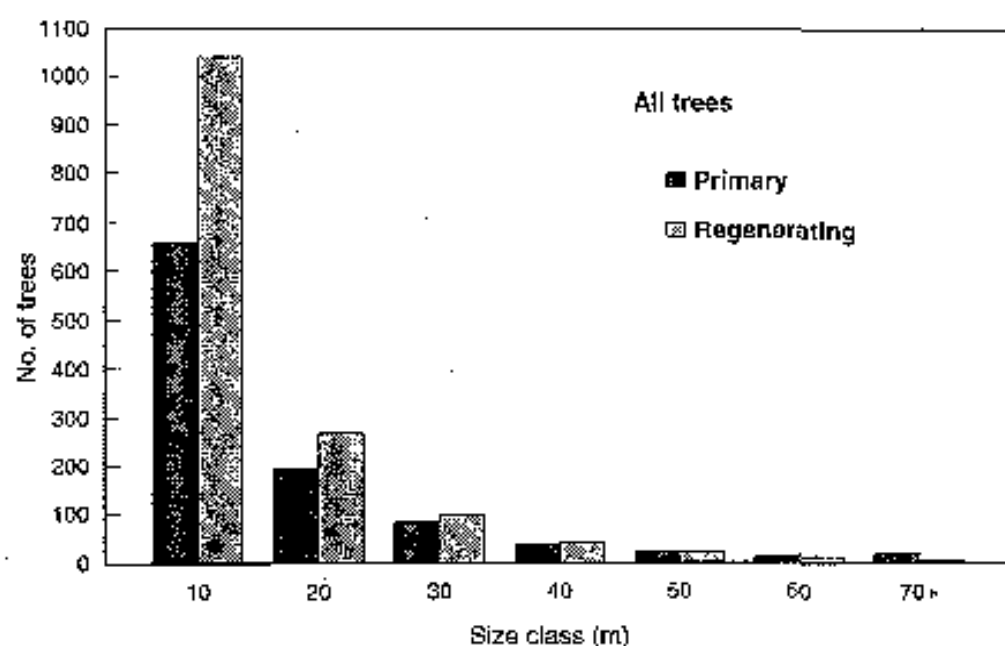


Figure 1a. Diameter class distribution for trees of 10 cm dbh and larger in primary and regenerating lowland dipterocarp forest at Pasoh. Plot size = 2 ha; Primary, $N = 1029.5$; Regenerating, $N = 1485$

Species composition

Species composition in the four 2-ha plots in the primary forest was variable between 231 and 284, with a mean of 257 (Table 4). However, the diversity of species in the regenerating forest was higher at 330, and diversity of genera was higher as well. Greatly increased crown opening brought about by logging and subsequent poison-girdling operations appeared to have provided the opportunity for other species to invade the logged forest at Pasoh.

Table 4. Number of families, genera and species of trees of 10 cm diameter and larger in 2-ha sample plots in primary (four) and regenerating (one) lowland dipterocarp forest at Pasoh

	Pasoh Forest Reserve					Regenerating
	A	B	C	D	Mean	
Families	45	42	43	48	44.5	47
Genera	126	125	129	136	129	148
Species	255	231	257	284	256.8	330

Common families

The five commonest families in the primary forest, in terms of stem density, were also the five commonest in the regenerating forest (Table 5). While Euphorbiaceae was

the commonest family in the primary forest, it was the Dipterocarpaceae in the regenerating forest, the effect of logging and subsequent silvicultural treatments appearing to have favoured its growth and recruitment (Figure 1b) to almost doubling its proportion of the total density. Besides the Dipterocarpaceae, Burseraceae among the top five families showed a large difference in the proportionate representation. Its density had not increased in tandem with the overall increase in stem density in the regenerating forest.

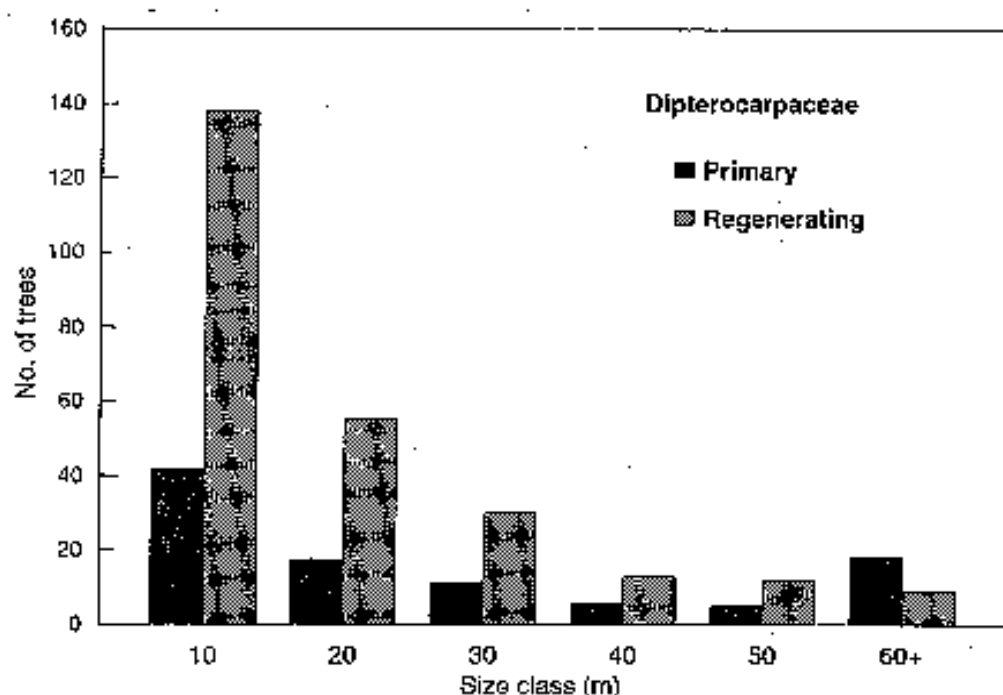


Figure 1b. Diameter class distribution for trees of 10 cm dbh and larger in primary and regenerating lowland dipterocarp forest at Pasoh for the family Dipterocarpaceae. Plot size = 2 ha; Primary, N = 100.2; Regenerating, N = 257

Table 5. Density of the five most common families of trees of 10 cm dbh and larger in primary and regenerating lowland dipterocarp forest at Pasoh

	Pasoh Forest Reserve			
	Primary		Regenerating	
	Density (ha ⁻¹)	% of total density	Density (ha ⁻¹)	% of total density
Euphorbiaceae	62.4	12.1	85	11.4
Dipterocarpaceae	50	9.7	128.5	17.3
Burseraceae	30.4	7.6	35.5	4.8
Leguminosae	35.7	6.9	53.5	7.2
Annonaceae	27.6	5.3	57.5	5.0
All five families	215.1	11.8	340	45.8

Together the five most common families accounted for about 42 per cent of the total density in the primary forest, and about 46 per cent in the regenerating forest.

Four of the five commonest families, Euphorbiaceae, Dipterocarpaceae, Burseraceae and Leguminosae, also contributed the most to the total basal area in both the primary and the regenerating forests (Table 6). Though not shown in the table, Annonaceae, which ranked fifth in terms of density in both the primary and regenerating forests, ranked seventh in its contribution to the total basal area in the primary forest, and sixth in the regenerating forest.

Table 6. The five families with the largest total basal area each in primary and regenerating lowland dipterocarp forest at Pasoh

	Pasoh Forest Reserve			
	Primary (4 × 2 ha)		Regenerating (1 × 2 ha)	
	Basal area (m ² ha ⁻¹)	% of total basal area	Basal area (m ² ha ⁻¹)	% of total basal area
Dipterocarpaceae	8.11	29.6	7.94	28.7
Leguminosae	8.10	11.3	2.94	10.6
Euphorbiaceae	1.74	6.3	2.07	7.3
Burseraceae	1.72	6.3	1.29	4.7
Myrtaceae	1.04	3.8	(1.02)	(3.7)
Myristicaceae	(0.70)	(2.5)	1.18	4.3
Top five families	15.71	57.3	15.42	55.8

Note: Figures in brackets are basal area values ranked below five. Trees are of 10 cm dbh and larger

The Dipterocarpaceae, whose members dominate the emergent layer of the forest canopy, and hence are generally the largest trees in the forest, formed almost 30 per cent of the total basal area in both the primary and regenerating forests. Members of the Leguminosae are also amongst the loftiest trees in the forest and the total basal area of this family was just over 10 per cent in both types of forest.

The proportionate representation of the basal area of both these families was only marginally lower in the regenerating forest than in the primary forest, although the difference was wider for Euphorbiaceae and Burseraceae taken individually. The Euphorbiaceae, despite its commonness in both types of forest, contributed much less basal area than the Dipterocarpaceae or the Leguminosae. It contributes to the lower part of the forest canopy, few species reach the top and none is truly emergent (Whitmore 1973b).

Taken together the five families with the largest total basal area each accounted for about 57 per cent of the total basal area in the primary forest and about 56 per cent of the total basal area in the regenerating forest. This similarity in total basal area of the families that contributed the bulk of the basal area in both types of forest consequently translated into the similarity in the total basal area when all trees were considered together (see Table 2).

Common species

The ten most common species in both the primary and regenerating forests are listed in Table 7. Several differences between these two types of forests are evident. The ten most common species in the primary forest were not the top ten species in the regenerating forest where there was a different set of leaders. While five of the ten in the primary forest were canopy species and only one of them was an emergent species, in the regenerating forest eight were canopy species, including four emergent species. No dipterocarp was among the ten most common species in the primary forest whereas there were five of them in the top ten species in the regenerating forest. Also, the higher densities of the ten most common species in the regenerating forest compared to those in the primary forest are in tandem with the higher overall tree density in the regenerating forest (see Table 2). While the ten most common species in the primary forest accounted for about 17 per cent of the total tree density, the proportion was higher in the regenerating forest at almost 24 per cent.

Table 7. Density, in 2 ha, of the ten most common species of 10 cm dbh and larger in primary (4 × 2 ha) and regenerating (1 × 2 ha) lowland dipterocarp forest at Pasoh

Species	Species group	Family	Pasoh Forest Reserve	
			Primary	Regenerating
<i>Xerospermata noronhianum</i>	U	Sapindaceae	27.8	(13)
<i>Ixonanthes tiosandra</i>	MC	Ixonanthaceae	27.3	(4)
<i>Cleistanthus sumatranus</i>	U	Euphorbiaceae	21.8	(2)
<i>Darryodes rugosa</i>	U	Burseraceae	20.5	(9)
<i>Monocarpia marginalis</i>	MC	Annonaceae	13.0	(21)
<i>Koompassia malaccensis</i>	E	Leguminosae	12.8	(18)
<i>Xanthophyllum eurhynchum</i>	U	Polygalaceae	12.8	(2)
<i>Gironniera nervosa</i>	U	Ulmaceae	12.5	(12)
<i>Ochanostachys amentacea</i>	MC	Oleaceae	12.3	(16)
<i>Scaphium macropadum</i>	MC	Sterculiaceae	12.3	(14)
<i>Parkia speciosa</i>	MC	Leguminosae	(2)	47
<i>Shorea multiflora</i>	MC	Dipterocarpaceae	(0.3)	41
<i>Ganua</i> sp. 1	MC	Sapotaceae	(2.3)	39
<i>Shorea leptosula</i>	E	Dipterocarpaceae	(7.8)	38
<i>Dipterocarpus cornutus</i>	E	Dipterocarpaceae	(10.8)	33
<i>Shorea macroptera</i>	E	Dipterocarpaceae	(7.5)	32
<i>Shorea parvifolia</i>	E	Dipterocarpaceae	(8)	32
<i>Pentaspadon motleyi</i>	MC	Anacardiaceae	(11.5)	31
<i>Pternandra echinata</i>	U	Melastomataceae	(2.3)	29
<i>Porterandia anisophylla</i>	U	Rubiaceae	(6)	28

Note: Figures in brackets are density values ranked below ten

It is clear that canopy opening resulting from logging, as well as from the post-logging poison-girdling treatment of the MUS that was meant to favour the growth of the quicker growing lighter timbers, had favoured the canopy species and

especially the dipterocarps. Of the dipterocarps, *Shorea leprosula*, *S. macroptera* and *S. parvifolia*, for example, are known to be vigorous, aggressive species common in young, regenerated forest (Wyatt-Smith 1954, 1963b, Cousens 1965), and Manokaran (1988) and Manokaran and Swaine (1994) have shown that canopy species in the natural forest are generally faster growing than understorey species.

Of note is the status of *Parkia speciosa*, or 'petai', the most important jungle fruit tree, as the most common species in the regenerating forest. While present in the primary forest in such a low number as shown in Table 7, the effect of logging and the post-logging treatment saw a surge in recruitment of this canopy species into the minimum size class of 10 cm. In 1989, there was a total of 32 trees in the 10 cm dbh class, another 13 in the 20 cm class, and two trees in the 30 cm class. Individuals of this species were probably not poison-girdled in the post-logging treatment. As Wong (1966) noted, field staff were reluctant to poison even the poor-formed individuals of commercial timber trees such as *Parkia speciosa* which produce edible fruits.

Species groups

To explore the notion that growth of canopy species was favoured by canopy opening, the proportionate representation of various species groups and their densities in both primary and regenerating forests are examined in Table 8.

Table 8. Proportions of the various species groups and their densities of individual stems of 10 cm dbh and larger in primary and regenerating lowland dipterocarp forest at Pasoh

Species groups	Pasoh Forest Reserve							
	Primary (8 ha)				Regenerating (2 ha)			
	No. of spp.	%	No. of trees	%	No. of spp.	%	No. of trees	%
Emergents	55	12.5	636	15.4	39	11.8	253	17.0
Main canopy	204	46.3	1611	39.1	159	48.2	756	50.9
Understorey	176	39.9	1843	44.8	126	38.2	448	30.2
Pioneer	1)	1.3	2)	0.7	1)	1.8	1)	1.9
Late-seral	5)		26)		5)		27)	
Total	441	100	4118	100	330	100	1485	100

While species diversity per unit area was higher in the regenerating forest than in the primary forest (Table 4), there were only marginal differences between the two forest categories in terms of species composition within the various species grouping (as percentage of total number of species). However, in terms of density, there was a very much higher proportion of canopy species (emergents and main canopy species), of almost 68 per cent of the total number of individuals in the regenerating forest compared to less than 55 per cent in the primary forest. In

contrast, shade-tolerant, slower growing understorey species formed only about 30 per cent of the total trees in the regenerating forest compared to about 45 per cent in the primary forest.

The effect of canopy opening on light-demanding secondary species (pioneer and late-seral) was as expected. Manokaran (1988) and Manokaran and Swaine (1994) had shown that secondary species are comparatively few in natural forest, and are very low in density. This is also reflected in Table 8, with the difference that there was a relatively higher proportion of almost two per cent, in terms of frequency, in the regenerating forest. Most of the individuals in the regenerating forest are likely the remnants of the population that invaded the area in the aftermath of the logging and silvicultural operations.

Conclusions

Wong (1966) had stated that while the MUS was a monocyclic system dependent on the seedling/sapling natural regeneration on the ground, it was never really truly practised because right from the early days of its application in Makya (since about 1950) there had been a tendency to retain advance growth and relics for the managed rotation in addition to the seedling/sapling population. Wyatt-Smith (1963a) had defined 'advance growth' as 'those trees below the minimum felling girth of the permit' and 'relics' as 'those trees not removed by the contractor at the time of felling though above the minimum felling girth of the permit'. Wong (1966), and later Cheah (1991), provided several reasons why the MUS was not widely adopted and practised. Nevertheless, Cheah (1991) does state that MUS was applied mainly in the west coast states, and Wong (1966) refers to several forest areas, including Pasoh, in the west coast states of Negri Sembilan and Malacca as having been 'naturally regenerated' after felling and poison-girdling operations. However, the poison-girdling treatment may not have been practised in its entirety at Pasoh, as the commonness of *Parkia speciosa* in the regenerating forest would appear to suggest.

The MUS was intended to lead to the development of a several-storeyed, relatively 'even-aged' or 'uniform' forest. This was to be achieved through the felling and removal of commercial trees above a certain girth, said by Cheah (1991) to be 45 cm diameter, and the poison-girdling of remaining trees down to a minimum girth of 6 to 18 inches (5 to 6 cm diameter) (except for small trees and saplings of economic species of sound form), to achieve the desired degree of opening to free the regeneration on the ground.

Though the MUS, in its implementation, was meant to favour the quicker growing lighter commercial timbers, the stratification of the forest into emergent, main canopy and understorey layers was expected to remain in the growth of the forest in its 70-year rotation. What was expected to be different was that there would be 'uniformness' or 'even-agedness' in the next crop and this could be interpreted to mean the absence of the few huge trees normally seen in primary forests. However, these overstorey trees in the primary forest, though tall and majestic, are generally moribund with defects such as holes and hollows in the trunks, thus producing less

wood during processing. Silvicultural manipulation of the forest is to produce more valuable stands, never to recreate primary forest conditions.

Wyatt-Smith (1963*b*) observed that it was principally the lowland dipterocarp forests that had been exploited and silviculturally treated to release and assist the natural regeneration, and that it was mainly the Red Meranti-Keruing forest that could be deemed to have been successfully regenerated. This was in relation to other forest types that were being exploited, these being mangrove forest, peat swamp forest, fresh water alluvial swamp forest, riparian fringes, heath forest and so on. The basis for declaring a logged forest to have been successfully regenerated was if stocking of commercial species at half-chain square sampling was greater than 60 per cent, although Wyatt-Smith (1963*a*) did note that at that time no forest that had been logged under the MUS had reached the 10-year stage. Forest areas did exist, however, where logging had taken place ten years or more ago followed by silvicultural operations to favour regeneration of commercial timber species, and these areas were showing considerable promise.

What then was the situation in the logged forest at Pasoh at roughly half the expected rotation of 70 years?

Basal area in the regenerating forest appeared to have reached a steady state with respect to the primary forest. The five most common families in the regenerating forest were those that were also the most common in the primary forest. The total contribution of basal area of the five families with the largest basal area each was almost similar in the regenerating and in the primary forest, at 56 to 57 per cent.

Against this the average height of the regenerating forest was still seven metres short of that of the primary forest. Tree densities were very much higher in the regenerating forest, and there was greater frequency of the canopy species, and especially the family Dipterocarpaceae as the now most common with a much greatly increased frequency. The increase in frequency of the light-demanding canopy species was at the expense of the shade-tolerant understorey species of no commercial value. This, in fact, indicates that the MUS as a silvicultural system, as originally proposed, has proven to be correct – it has resulted in a more valuable stand mid-way to the expected rotation of 70 years, and has shown that the Red Meranti-Keruing forest could be sustained on such a management regime.

Of paramount importance, however, was that the size-class distribution in the regenerating forest was significantly different from that in the primary forest. The distribution was skewed towards a much larger number of smaller trees in the regenerating forest. All these observations from the available data are very much what would be expected after three decades since logging and silvicultural operations. However, after three decades, the fact that there was relatively little or no difference (dipterocarp and total population) in tree numbers of 30 cm diameter and larger between primary and regenerating forest suggests that a cutting cycle of around three decades, but not less, could have been entertained for the Red Meranti-Keruing forest if logging damage was kept to an absolute minimum and a minimum felling size of 40-45 cm dbh was strictly enforced. The 70-year 'rotation', or cutting cycle, of the MUS was, in fact, always recognised as being conservative (Wyatt-Smith

1988) for this type of lowland forest rich in dipterocarp members of the genus *Dipterocarpus* (Keruing) and of the 'Red Meranti' group of the genus *Shorea*.

It could be that the regenerating forest is in a static state and left to itself could remain in this state for a long time. If a natural thinning process is operating very slowly, the size-class distribution could eventually move towards that characteristic of the primary forest. The MUS, in fact, advocates a thinning regime to be decided on at a crop 'age' of approximately 20, 35 and 55 years (Wyatt-Smith 1963a). However, no thinning regime was ever applied at Pasoh, nor anywhere else for that matter, at 20 years after logging or subsequently except in research plots. This was because by that time, policy changes by the Government meant that vast potentially valuable tracts of forests in the lowlands were cleared for government sponsored cash-crop (mainly oil palm) agricultural land development schemes, and forestry activities were moved into the more difficult terrain of the hills where production forests are now located.

The presence of thriving tree species from components of the original stand of lowland forests logged under the MUS was, in fact, the basis for the cutting cycle of 25-30 years of the Selective Management System (SMS) that is being applied in the hill forests of Peninsular Malaysia. When exploitation of timber became confined to the hill forests about two decades ago, the SMS, a polycyclic system, was subsequently introduced due mainly to lack of an adequate, well-distributed stocking of seedlings of economic species in hill forests. Unlike in the lowlands, commercial species in hill forests are generally concentrated on the crowns of ridges. The SMS utilises pole-sized regeneration of a wider selection of species with accompanying reduction in crop rotation, and the system has been discussed by Griffin and Caprata (1977), Mok (1977), Thang (1987) and Cheah (1991).

To conclude, at about half the expected rotation of 70 years, the size-class distribution of the logged forest was not quite similar to that of the primary forest. An artificial thinning regime applied once, or more than once, may be necessary to accelerate the movement towards achieving the desired size-class distribution. If 'to regenerate' means 'to produce again in the original form', then from an ecological sense the logged forest at Pasoh must still be regenerating.

How, then, would the findings of this study relate to the practicalities of forest management now in the hill forests of Peninsular Malaysia under the SMS? Are there great differences in timber outturn from lowland forests logged previously under the MUS and hill forests logged presently under the SMS? Is the cutting cycle of 25-30 years of the SMS realistic?

The timber outturn from Compartment 25 of Pasoh Forest Reserve where the regenerating plot is located was $60.5 \text{ m}^3 \text{ ha}^{-1}$ (Vincent 1960). While there was considerable variability in timber outturn from various lowland forest types, the average figure was considered to be $52.5 \text{ m}^3 \text{ ha}^{-1}$ (Wyatt-Smith 1987). Wyatt-Smith (1987) noted that timber outturn from Red Meranti-Keruing forests was generally higher than the average, this being an indication that this type of forest was of considerable value.

Timber outturn from recent fellings in hill forest under the SMS are as follows: $64.4 \text{ m}^3 \text{ ha}^{-1}$ from one compartment in Jengai Forest Reserve in the east coast state of Trengganu and $82.8 \text{ m}^3 \text{ ha}^{-1}$ from one compartment in Tembat Forest Reserve in Trengganu (Source: State Forest Department, Trengganu); $136.4 \text{ m}^3 \text{ ha}^{-1}$ in one compartment, and $152.7 \text{ m}^3 \text{ ha}^{-1}$ in another compartment of Sungai Lalang Forest Reserve in the west coast state of Selangor (Source: State Forest Department, Selangor). In the hill forests, too, timber outturn values are variable. Compartments generally vary from several hundred to less than 500 hectares in size.

Table 9 provides more and detailed information on timber outturn from various forest reserves in the east coast states of Trengganu and Pahang and the west coast state of Negri Sembilan. All these areas were felled under the SMS.

Table 9. Timber outturn from various logging licenses in compartments of selected forest reserves in Peninsular Malaysia

Forest reserve	Minimum felling size (diameter in cm)		Timber outturn (m ³ ha ⁻¹)
	Dipterocarp	Non-dipterocarp	
Negri Sembilan state			
Serting	60	45	63.45
Johol	60	55	70.28
Senaling Inas	50	45	48.92
Gallah	55	45	85.98
Senaling Inas	50	45	70.19
Triang	55	45	50.74
Tehong	55	45	60.11
Berembun	55	50	72.97
Angsi	55	45	46.08
Pasoh	55	50	76.89
Trengganu state			
Tembat	55	45	42
Tembat	55	45	103
Jengai	65	50	30
Jengai	65	50	29
Jengai	65	45	37
Cherul	60	55	49
Cherul	60	50	32
Hulu Besut	60	50	133
Pahang state			
Lesong	50	45	85.81
Lesong	55	50	83.08
Lesong	50	45	169.32
Lesong	50	45	157.77
Ibam	50	45	118.18
Ibam	55	45	195.65
Ibam	50	45	93.22
Ibam	50	45	98.15

Source: Forestry Department Peninsular Malaysia

The average timber outturn value was $64.6 \text{ m}^3 \text{ ha}^{-1}$ for Negri Sembilan, $58.0 \text{ m}^3 \text{ ha}^{-1}$ for Trengganu and $125.1 \text{ m}^3 \text{ ha}^{-1}$ for Pahang, with an overall average of $81.2 \text{ m}^3 \text{ ha}^{-1}$. As Table 9 shows, the minimum felling size for both dipterocarps and non-dipterocarps was higher in the Trengganu than in the Pahang examples, hence the lower timber outturn values for Trengganu. The minimum felling size is determined based on information on tree stocking prior to harvesting.

Thang (1987) has stated that the current average timber outturn from primary hill forest is about $40\text{--}45 \text{ m}^3 \text{ ha}^{-1}$. The outturn from the examples given are generally excessive. Notwithstanding the fact that some compartments may inherently be rich in commercial timber stands, there is also the strong possibility that inadequate supervision and enforcement during logging operations lead to a greater number of trees being harvested than allowed for. This point is worth some thought since loggers not tied down to long-term concessions, ideally covering the duration of the SMS cutting cycle, if not longer, would have little incentive to abide by rules.

Logging in Pasoh Forest Reserve in the mid-1950s, as well as in other inland lowland forests under the MUS, took place at the time that mechanised equipment such as chainsaws, bulldozers and 'san-tai-wong' were just being introduced. Terrain was almost flat to undulating and environmental and logging damage must have been minimal. Hence the residual situation as shown by the results of this study, indicating that a cutting cycle of around three decades, but not less, could have been entertained in the Red Meranti-Keruing forest of the lowlands.

In the difficult terrain of the hill forest, it is generally accepted that an average of 30 per cent logging damage to intermediate-size trees (of 30 cm dbh and larger) would occur (Griffin & Caprata 1977). Based on observations in the field in 1987, Wyatt-Smith (1988) felt that logging damage and undue selection of logs extracted was excessive. This is not surprising, considering the high timber outturn from hill forest as shown by the examples given. Considering all this, logging damage could, in fact, be more than 30 per cent. Additionally there is the question of severe soil compaction, especially by crawler tractors, which, according to Kamaruzaman Jusoff (1991), can lead to about 80 per cent areal soil disturbance in hill forest logging operations. The silvicultural setback to the residual stand under these conditions would be tremendous.

To sum up, a similar tree residual situation as in the Pasoh study is unlikely in hill forests logged under the SMS. The findings of this study would only have been applicable to Red Meranti-Keruing forests of the lowlands, and perhaps to some of the other types of inland lowland forests as well. Most Red Meranti-Keruing forests do not, of course, exist now. Unless evidence is presented to the contrary, it is unrealistic to expect that the cutting cycle in the hill forests of Peninsular Malaysia under the SMS can be expected to be 25-30 years as envisaged. It is more than likely that a twice-as-long period, if not longer, would be a more realistic cycle.

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References

- ANONYMOUS, 1968. *Malayan Grading Rules for Sawn Hardwood Timber*. Forest Department, Peninsular Malaysia.
- ASHTON, P.S. 1971a. Identification of trees reaching 30 cm d.b.h. in 5 x 2 ha plots of Pasoh F.R. Mimeographed report.
- ASHTON, P.S. 1971b. Second report on vegetation survey of Pasoh F. R. Mimeographed report.
- CHEAH, L.C. 1991. Sustained yield natural forest management in Peninsular Malaysia: opportunities for more effective forest practices. Pp. 1-15 in Appanah, S., Ng, F.S.P. & Roslan Ismail (Eds.) *Malaysian Forestry and Forest Products Research: Proceedings of the Conference*. Forest Research Institute Malaysia, Kepong.
- COUSENS, J. E. 1965. Some reflections on the nature of Malayan lowland rainforest. *Malayan Forester* 28: 122 - 128.
- GRIFFIN, M. & CAPRATA, M. 1977. Determination of cutting regimes under selective management system. Paper presented at the ASEAN Seminar on Tropical Rainforest Management, 1-10 November 1977, Kuantan, Pahang, Malaysia. Forestry Department, Peninsular Malaysia.
- KAMARUZAMAN JUSOFF, 1991. A survey of soil disturbance from tractor logging in a hill forest of Peninsular Malaysia. Pp. 16-21 in Appanah, S., Ng, F.S.P. & Roslan Ismail (Eds.) *Malaysian Forestry and Forest Products Research: Proceedings of the Conference*. Forest Research Institute Malaysia, Kepong.
- KOCHUMMEN, K.M. 1979. Pocket Check List of Timber Trees by J. Wyatt-Smith. *Malayan Forest Records* No. 17. Second revision.
- KOCHUMMEN, K.M., LAFRANKIE, J.V. & MANOKARAN, N. 1990. Floristic composition of Pasoh Forest Reserve, a lowland rain forest in Peninsular Malaysia. *Journal of Tropical Forest Science* 3(1): 1 - 18.
- MANOKARAN, N. 1988. *Population Dynamics of Tropical Forest Trees*. Ph.D. thesis. University of Aberdeen.
- MANOKARAN, N., LAFRANKIE, J.V., KOCHUMMEN, K.M., QUAH, E.S., KLAHN, J.E., ASHTON, P.S. & HUBBELL, S.P. 1990. Methodology for the Fifty Hectare Research Plot at Pasoh Forest Reserve. *Research Pamphlet No. 104*. Forest Research Institute Malaysia, Kepong.
- MANOKARAN, N., LAFRANKIE, J.V. & ROSLAN ISMAIL. 1991. Structure and composition of the Dipterocarpaceae in a lowland rain forest in Peninsular Malaysia. Pp. 317-331 in Soerianegara, I., Tjitrosomo, S.S., Umaly, R.C. & Umbah, I. (Eds.) *Proceedings of the Fourth Round Table Conference on Dipterocarps*. Biotrop Special Publication No. 41, SEAMEO BIOTROP, Bogor.

- MANOKARAN, N., ABD. RAHMAN KASSIM, AZMAN HASSAN, QUAH, E.S. & CHONG, P.F. 1992a. Short-term population dynamics of dipterocarp trees in a lowland rain forest in Peninsular Malaysia. *Journal of Tropical Forest Science* 5(1): 97 - 112.
- MANOKARAN, N., LAFRANKIE, J.V., KOCHUMMEN, K.M., QUAH, E.S., KLAHN, J.E., ASHTON, P.S. & HUBBELL, S.P. 1992b. Stand Table and Distribution of Species in the 50-ha Research Plot at Pasoh Forest Reserve. *FRIM Research Data No. 1*. Forest Research Institute Malaysia, Kepong.
- MANOKARAN, N. & SWAINE, M.D. 1994. Population Dynamics of Trees in Dipterocarp Forests of Peninsular Malaysia. *Malayan Forest Records No. 40*. Forest Research Institute Malaysia.
- MOK, S.T. 1977. Forest management strategies for sustained maximum socio-economic benefits. *Malaysian Forester* 40: 14 - 26.
- NG, F.S.P. (Ed.). 1978. *Tree Flora of Malaya*. Vol. 3. Longman, Kuala Lumpur.
- NG, F.S.P. (Ed.). 1989. *Tree Flora of Malaya*. Vol. 4. Longman, Kuala Lumpur.
- POORE, M.E.D. 1968. Studies in Malaysian rain forest. 1. The forest on the Triassic sediments in Jengka Forest Reserve. *Journal of Ecology* 56: 143 - 196.
- SOEFADMO, E. & KIRA, T. 1977. Contribution of the IBP-PT Research Project to the understanding of Malaysian forest ecology. Pp. 63-94 in Saxtri, C.B., Srivastava, P.B.L. & Abdul Manap Ahmad (Eds.) *A New Era in Malaysian Forestry*. Universiti Pertanian Malaysia Press, Serdang.
- SWAINE, M.D. & HALL, J.B. 1983. Early succession on cleared forest land in Ghana. *Journal of Ecology* 71: 601 - 627.
- SWAINE, M.D. & WHITMORE, T.C. 1988. On the definition of ecological species groups in tropical rain forests. *Vegetatio* 75: 81 - 86.
- SYMINGTON, C.F. 1943. Foresters' Manual of Dipterocarps. *Malayan Forest Records No. 16*. (New edn. 1974, Penerbit Universiti Malaya, Kuala Lumpur).
- THANG, H.C. 1987. Forest management systems for tropical high forest, with special reference to Peninsular Malaysia. *Forest Ecology and Management* 21: 3 - 20.
- VINCENT, A.J. 1960. A study of the merchantable yield per acre from final fellings in inland forest - Malaya. *Research Pamphlet No. 30*. Forest Research Institute, Forest Department, Federation of Malaya.
- WHITMORE, T.C. (Ed.). 1972. *Tree Flora of Malaya*. Vol. 1. Longman, Kuala Lumpur.
- WHITMORE, T.C. (Ed.). 1973a. *Tree Flora of Malaya*. Vol. 2. Longman, Kuala Lumpur.
- WHITMORE, T.C. 1973b. Euphorbiaceae. Pp. 84-136 in Whitmore, T.C. (Ed.) *Tree Flora of Malaya*. Longman, Kuala Lumpur.
- WHITMORE, T.C. 1984. *Tropical Rain Forests of the Far East*. 2nd ed. Oxford University Press, Oxford.
- WHITMORE, T.C. 1989. Canopy gaps and the two major groups of forest trees. *Ecology* 70(3): 536 - 538.
- WONG, Y.K. 1966. Poison-girdling under the Malayan Uniform System. *Malayan Forester* 29: 69 - 77.
- WYATT-SMITH, J. 1954. Storm forest in Kelantan. *Malayan Forester* 17: 5 - 11.
- WYATT-SMITH, J. 1963a. Manual of Malayan Silviculture for Inland Forests. Vol. 1. *Malayan Forest Records No. 23*. (reprinted in 1995 with two additional chapters and an overall index).
- WYATT-SMITH, J. 1963b. Manual of Malayan Silviculture for Inland Forests. Vol. 2. *Malayan Forest Records No. 23*. (reprinted in 1995 with two additional chapters and an overall index).
- WYATT-SMITH, J. 1966. Ecological Studies on Malayan Forests. 1. Composition of and Dynamic Studies in Lowland Evergreen Rain-Forest in two 5-acre Plots in Bukit Lagong and Sungei Menyala Forest Reserves and in two Half-acre Plots in Sungei Menyala Forest Reserve, 1942-59. *Research Pamphlet No. 52*. Forestry Department, Malaysia.
- WYATT-SMITH, J. 1987. Manual of Malayan Silviculture for Inland Forest. Part 3-Chapter 8 Red Meranti-Keruing forest. *Research Pamphlet No. 101*. Forest Research Institute Malaysia, Kepong. (now incorporated in reprinted Manual of Malayan Silviculture, M.F.R. No. 23, 1995).
- WYATT-SMITH, J. 1988. Letter to the Editor. *Forest Ecology and Management* 24: 219 - 223.

EPIPHYTIC CRYPTOGRAMS AT PASOH FOREST RESERVE, NEGRI SEMBILAN, MALAYSIA - QUANTITATIVE AND QUALITATIVE SAMPLING IN LOGGED AND UNLOGGED PLOTS

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Plots of 1 ha were established in lowland dipterocarp forest in Pasoh Forest Reserve, Negri Sembilan, Malaysia. Cryptogams were sampled from 25 randomly selected trees in a logged (LA) and an unlogged (UP) forest, and the 50 hectare (ha) plot. Quadrat data, tree data and data from whole plots were used to compare diversity and frequency of bryophytes and lichens. Results show that similarity in all samples was high as they belong to the same forest type; that diversity in all groups was highest in the 50-ha plot where conditions are stable and long-term ecological continuity established, and that diversity in the UP and LA was altered by changes in microclimate conditions. Diversity on individual trees was frequently highest on trees <100 cm gbh (girth at breast height). Lichen diversity was higher than bryophyte diversity in LA where retention of mature trees during selective logging has allowed downward colonisation of species from lichen communities on the trunks above. Bryophyte diversity was lowest in LA where logging has altered the microclimate by increasing temperature and UV (ultraviolet rays), and lowering relative humidity (RH). Lichens are good indicators of ecological continuity and the use of cryptogams as indicators of forest microclimate should be developed. Forest management should consider the maintenance of a diversity of tree species and bark types, forest cover and species-rich microhabitats that support unusual cryptogam species, the maintenance of mature trees in logged areas as a source of propagules, and the identification and retention of areas of high cryptogamic diversity.

Key words: Malaysia - tropical lowland forest - bryophytes - lichens - indicators - management - microclimate

Introduction

The use of cryptogams as indicators of environmental conditions is well established in temperate forests, and bryophytes in tropical forests of South East Asia (Pócs 1982). Although literature on mosses is available (Eddy 1988, 1990, 1996), there is little on hepatics and lichens. A bibliography of Malaysian lichenology contains references to literature on taxa from upland forests (Galloway *et al.* 1994), but there is a marked paucity of information on taxa of lowland rain forests. The lichen communities of these forests are frequently dominated by crustose species which are less well-known than the foliose and fruticose lichens characteristic of upland forests.

Recently, epiphytic lichens of seasonal tropical forests in Thailand have been described and used to interpret long and short-term environmental changes (Wolseley & Aguirre-Hudson 1991, 1996, 1997*a*, 1997*b*, Wolseley *et al.* 1994). Conditions affecting the distribution of corticolous lichens include moisture, pH, corrugation of the bark, and microclimatic conditions of the forest. The method used in Thailand (Wolseley & Aguirre-Hudson 1997*a*) has been adapted for sampling bryophyte and lichen communities of logged and unlogged plots at Pasoh Forest Reserve.

Location and climate variation

Pasoh Forest Reserve, Negri Sembilan, consists of lowland dipterocarp forest that supports a high diversity of flowering plants (Manokaran & La Frankie 1990, Lee, 1995). Rainfall is relatively low at 1,727–3,112 mm per annum, well below the rainfall of tropical rain forests on the equator. There are two relatively dry periods in February–March and in July–August, when there may be between 20–26 rainless days in a month. Air humidity (as relative humidity–RH) has been measured 2.5 m above ground level at 70–100 per cent in the wet periods and 61–93 per cent in the drier periods. During the day RH in the canopy may be as low as 50 per cent while temperatures may be as high as 36°C. In the forest at ground level temperatures are between 21–26°C; solar radiation has been recorded with mean daily values (for 1972/3) of approximately 350 cal cm² d^{−1}, and a maximum of 541 cal cm² d^{−1} (Soepadmo 1978).

Objectives of research

This study was carried out with the following objectives:

- To estimate cryptogamic diversity per unit area, per tree and per plot in logged and unlogged forest.
- To compare bryophyte diversity with lichen diversity in a range of conditions.
- To identify cryptogams that are indicators of environmental conditions in the forest.
- To suggest management practices that favour high diversity of cryptogamic species and maintenance of a healthy forest environment.

Sites, materials and methods

Plots of 1 ha were selected in logged and unlogged areas, including the 50 ha plot, in Pasoh Forest Reserve (Figure 1). The 50-ha plot was established in 1985 (Manokaran & La Frankie 1990), as an example of undisturbed pristine forest and all trees >10 cm dbh have been recorded and their distributions plotted. A second census was completed at the end of 1996. The unlogged plot (UP) has been used for a variety of experiments, and has never been logged, while the logged plot (LA) was selectively logged using the Malayan Uniform System (MUS) in the 1950's with retention of mature trees. All trees in the 1-ha plots have been numbered and identified to species

where possible and recorded on a database at the Forest Research Institute Malaysia (FRIM). Twenty-five trees in each area were selected for cryptogamic sampling, using random coordinates from a baseline. Tree girth and number were recorded, and forest density recorded photographically. Quadrats measuring 250 cm² (20 × 12.5 or 25 × 10 cm) were placed on selected bryophyte and lichen communities between 0-2 m up the trunk of each tree. Aspect and height above ground were recorded for each quadrat, the quadrat photographed, and all taxa within the 250 cm² recorded. Other species present on the trunk were noted, and samples taken of all taxa. The plot was searched for additional species so that sampled diversity could be compared with total diversity of the plot. Only bryophytes were recorded in terricolous and foliicolous habitats. Plots were visited in March/April 1995 when 20 trees were sampled in UP and LA and five in the 50-ha plot, and March 1996 when recording was completed in all plots. In addition, in March 1996, tree climbers from project A8 (Gardette, same volume) collected cryptogamic material from the canopy of two trees in, or adjacent to each plot. For the purposes of this paper lichens collected by the tree climbers have not been included in the total number per plot, as they represent a markedly different lichen community which was inadequately sampled. These will be described in a subsequent publication.

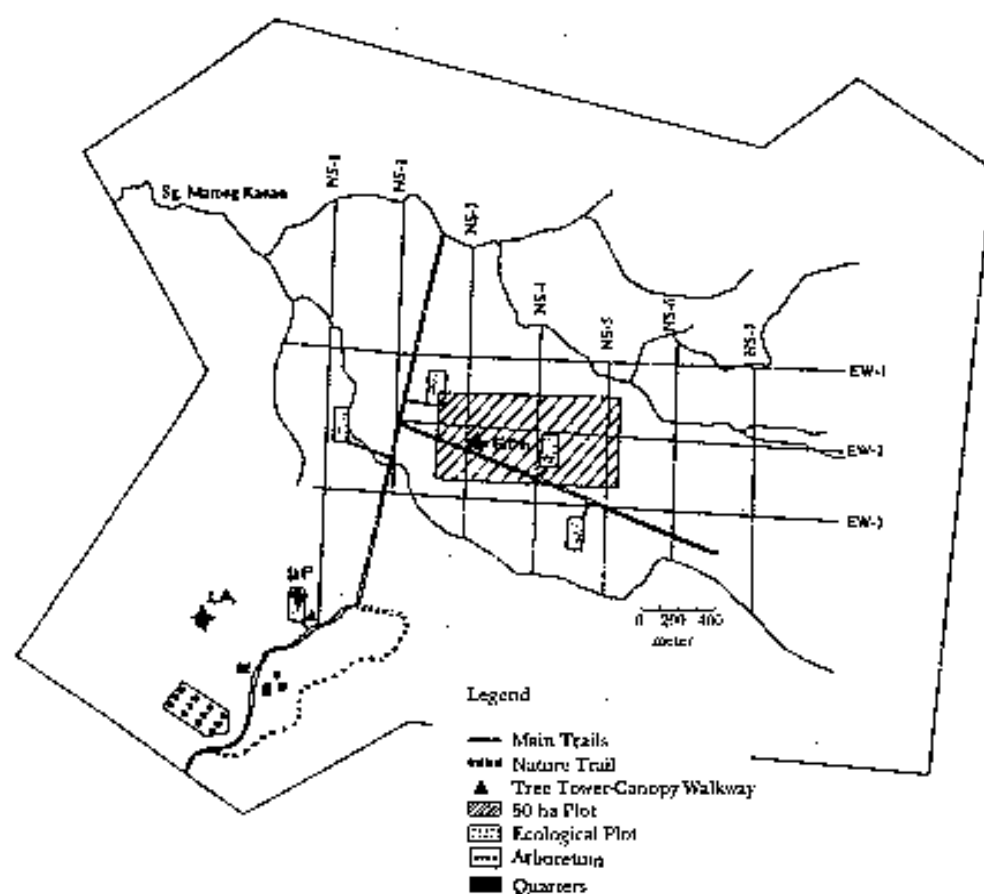


Figure 1. Pasoh Forest Reserve showing location of 1-ha plots in the 50-ha plot (50ha), ecological unlogged plot (UP) and the area logged in the 1950's (LA)

Specimens were dried and packeted for identification at the Natural History Museum (NHM), London. Data was entered on a database (PARADOX 40) and Principal Components Analysis (PCA) was carried out in the Biometrics Department at NHM using GENSTAT 6. Tree species were identified from the tree number on the database at FRIM. Named specimens will be available for further study at FRIM and the NHM.

Results

Similarity of all quadrat samples

The similarity of the axis 1 and 2 values of a PCA of all quadrat samples indicated a strong association with forest type in all plots. Figure 2 shows the distribution of bryophyte (B) and lichen (L) quadrats in all samples, and of quadrats placed on communities where both groups had high cover (Q). Distribution of these samples by plot is shown in Figure 3, indicating the similarity of the quadrats in the logged and unlogged forest plots and the greater similarity of quadrats in the 50-ha plot.

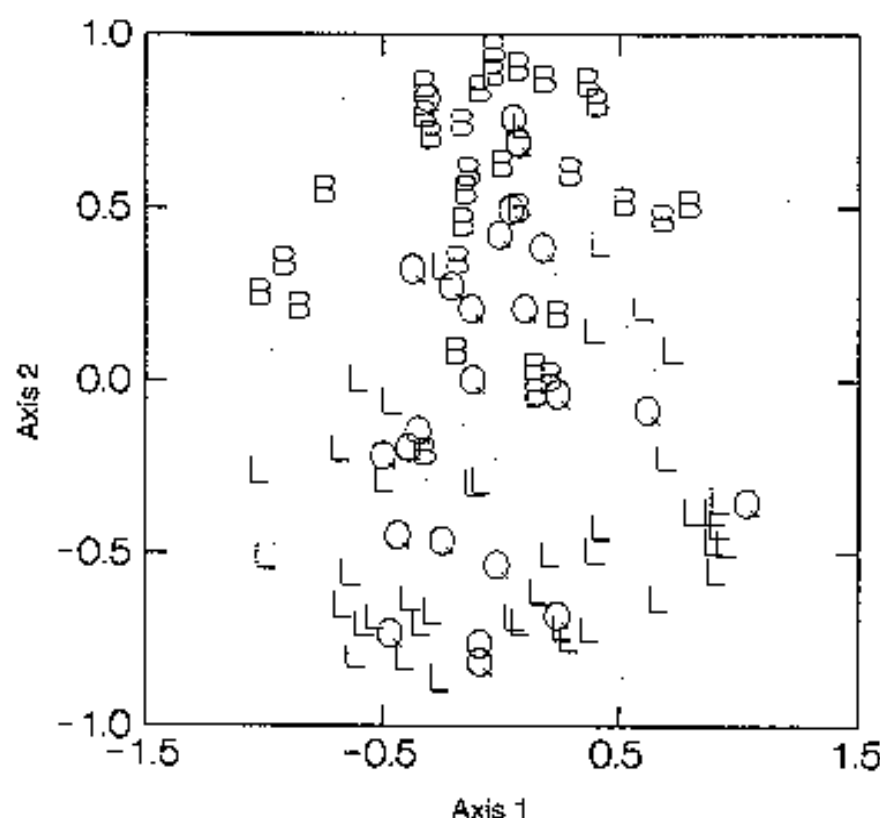


Figure 2. PCA of all samples showing the relative similarity of all samples on axis 1 and 2, the distinction of bryophyte quadrats (B) from lichen quadrats (L), and the overlap of the quadrats with high cover of both groups (Q)

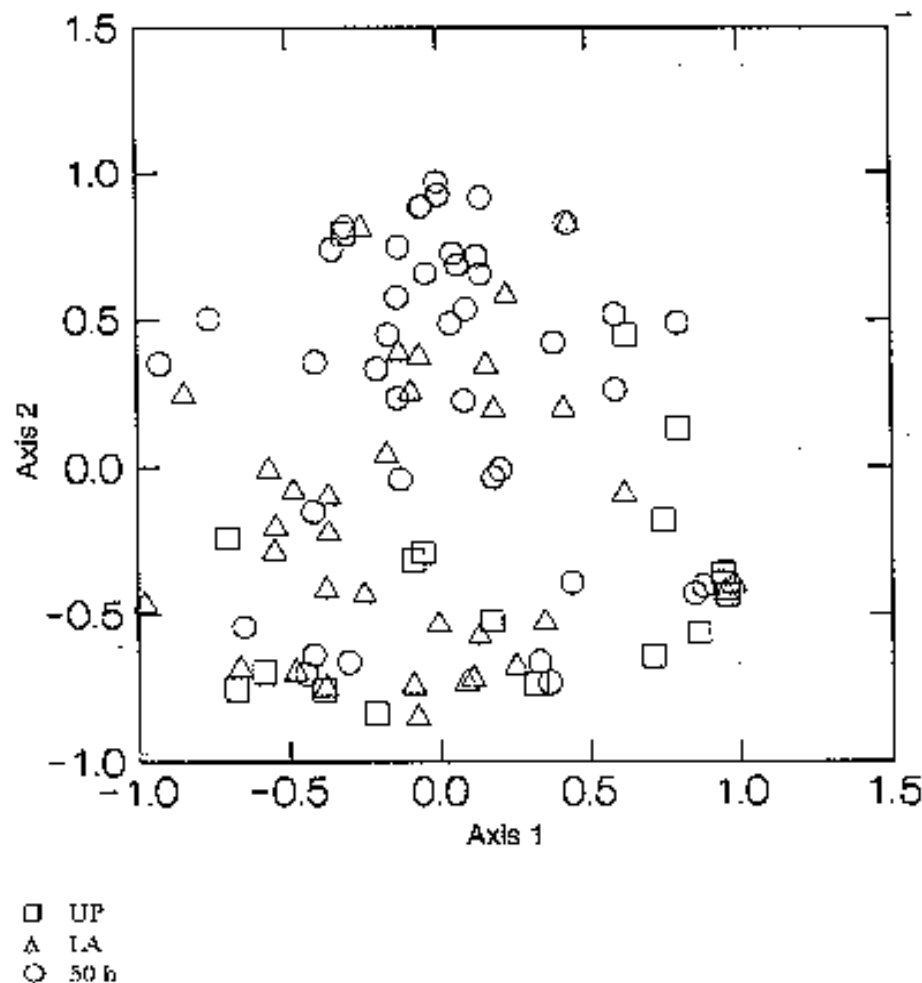


Figure 3. PCA of all samples by plot indicating that similarity in all plots was high and that all samples were in the same forest type. Note, however, that there was greater similarity of quadrats in the 50-ha plot, and overlap of quadrats in LA and UP.

Total diversity in plots and on randomly selected trees

The number of tree species was high in all plots, with a total of 51 species. There were 21 species in the 50-ha plot, 18 in LA, and 18 in UP (Table 1). Diversity of corticolous taxa below 2 m on the tree trunks of randomly selected trees is compared with total corticolous diversity of the plot in Figure 4. The total number of cryptogamic taxa recorded in and around all plots included 47 mosses, 54 hepatics (10 restricted to watercourses, 14 foliicolous), and 74 corticolous lichens (excluding taxa from canopy). The highest total number of taxa was recorded in the 50-ha plot. The lichen diversity in LA remained high on randomly selected trees (45) and in the plot (47), and was lowest in UP, whereas the moss diversity was lowest in LA (11 and 17). The hepatic diversity was similar in all plots, but there was a difference between numbers on sampled trees and in the plot due to the inclusion of bryophytes growing on leaves and decaying wood in the soil. Plot diversity of lichen taxa does not include canopy samples.

Table 1. Tree diversity of 25 randomly selected trees in all plots sampled at Pasoh Forest Reserve (taxa from database of tree species at FRIM)

Tree species	50 ha plot	UP	LA
<i>Adenanthera bicolor</i>	1		
<i>Anisophyllum griffithii</i>		1	
<i>Anisoptera magistocarpa</i>			1
<i>Aluna excelsa</i>	1		
<i>Buccananea sessifolia</i>	1		
<i>Calophyllum tetraphyllum</i>	2		
<i>Calophyllum wallichianum</i>		1	1
<i>Canarium littorale</i> v. <i>tomentosum</i>	1		
<i>Chrysophyllum lanceolatum</i>			1
<i>Cynometra malaccensis</i>	1		
<i>Dacryodes costata</i>		1	
<i>Dacryodes rubiginosa</i>			1
<i>Dacryodes rugosa</i>	1	1	
<i>Dipterocarpus cornutus</i>		2	
<i>Elaeocarpus petiolatus</i>		1	
<i>Elateriospermum lupos</i>			1
<i>Eugenia pustulata</i>		1	
<i>Gironniera nervosa</i>	1		
<i>Gironniera parvifolia</i>	1		1
<i>Gironniera subaequalis</i>	2		
<i>Grewia blattaeifolia</i>	1		
<i>Gynotroches axillaris</i>		1	
<i>Irvingia malayana</i>			1
<i>Knema conferta</i>			1
<i>Knema furfuracea</i>	1		
<i>Knema patentinervis</i>		1	
<i>Knema scortechinii</i>	1		
<i>Lithocarpus curtisii</i>		4	1
<i>Melanochyla auriculata</i>	2		
<i>Nuclea officinalis</i>		1	
<i>Neuscortechinia kingii</i>		1	
<i>Nephelium costatum</i>		1	1
<i>Ormosia venosa</i>			1
<i>Parkia speciosa</i>	1		
<i>Paropsia variciformis</i>	1		
<i>Pavartocarpus bracteatus</i>			1
<i>Pentaspadon mutleyi</i>			1
<i>Pineladendrum griffithianum</i>		1	
<i>Psydrax</i> sp. B	1		
<i>Ptychopterys costata</i>	1		
<i>Quercus argentata</i>			1
<i>Scaphocalyx spathacea</i>	1		
<i>Shorea acuminata</i>			4
<i>Shorea bracteolata</i>	1		
<i>Shorea lepidota</i>			2
<i>Shorea macroptera</i>		1	
<i>Shorea maxwelliana</i>		1	
<i>Shorea parvifolia</i>		1	1
<i>Sindora echinocalyx</i>		1	
<i>Styrax benzoin</i>			1
<i>Xanthophyllum eurynchum</i>	1		
Total species 51	24	32	22

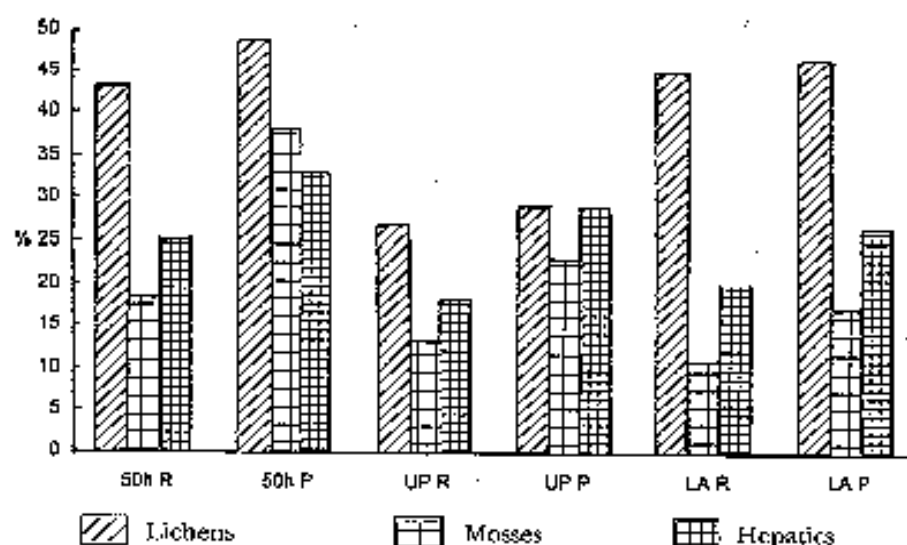


Figure 4. Percentage occurrence of cryptogams on 25 sampled trees (R), and in plots (P), in the 50-ha plot, UP and LA. Total samples (P) included foliicolous and terricolous hepatic species.

Diversity in quadrats and on trees

The mean number of taxa of all cryptogams per tree was 10.6 in the 50-ha plot, 8.9 in UP and 7.2 in LA. In the 50-ha plot, the mean number of taxa in the bryophyte and lichen quadrats was 4.3 and 4.0 respectively; in UP, 3.5 and 3.9, and in LA, 2.6 and 3.2. Species diversity on random trees was highest in the 50-ha plot and lowest in LA, but was highest on small trees of girth <80 cm in all plots (Figure 5). Trees over 100 cm gbh tended to have lower cryptogamic diversity at sampled height. However, a large specimen of *Shorea leprosula* sampled for epiphytes by tree climbers had a diverse and markedly different lichen community on the branches of the open crown, with few bryophytes. Species-rich bryophyte communities were usually found below 1 m on the trunk, whereas species-rich lichen communities were characteristic of the main trunk above 3 m. The latter were sampled at their lowest accessible level.

Associated factors

A distribution of the girth classes of trees sampled in the 1 ha plots showed an abundance of trees <40 cm gbh in the 50-ha plot, their absence in UP and low numbers in LA (Figure 6). In the 50-ha plot all girth classes were represented except trees >200 cm gbh, whereas in LA and UP trees were clumped in girth classes between 40-80 cm. Trees >100 cm gbh were present in all plots and those >200 cm gbh present in LA and UP. The association of the sampled cryptogamic communities with tree species was not possible due to the high diversity of tree species in all plots. However, lichen communities dominated by the Thelotremaaceae occurred most frequently on smooth-barked trees, often extending up the main

trunk to a considerable height, whereas the bryophyte or bryo/lichen communities were found on the lower trunk and buttresses of rough-barked trees, rarely extending up the trunk above the sampling height.

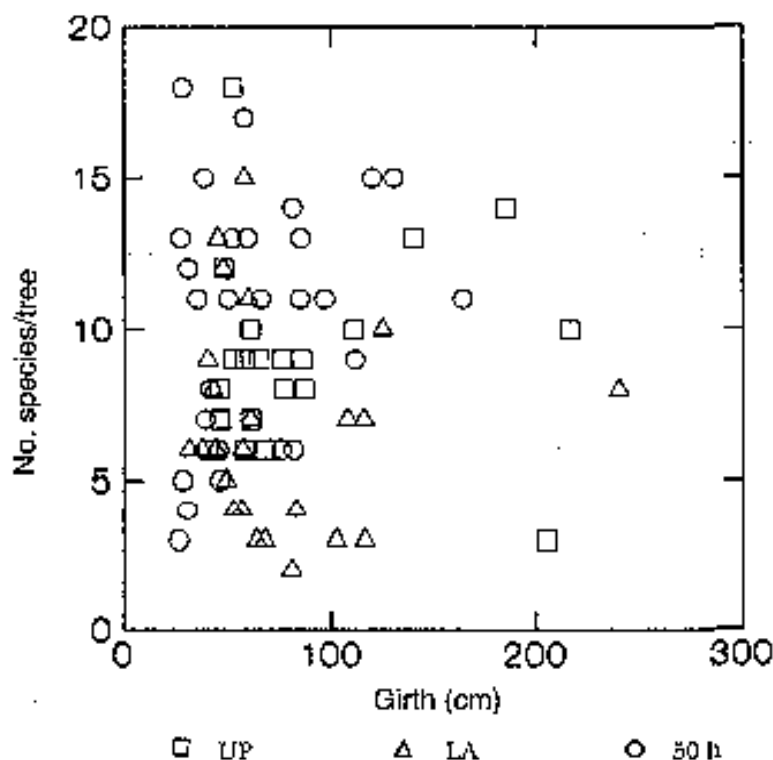


Figure 5. The relationship between species diversity and girth of sampled trees distinguished by plot, showing highest diversity on trees <100 cm gbh in all plots, high diversity of most samples in 50-ha plot, and low diversity of most samples in LA with greatest range of diversity in UP on trees >100 cm gbh.

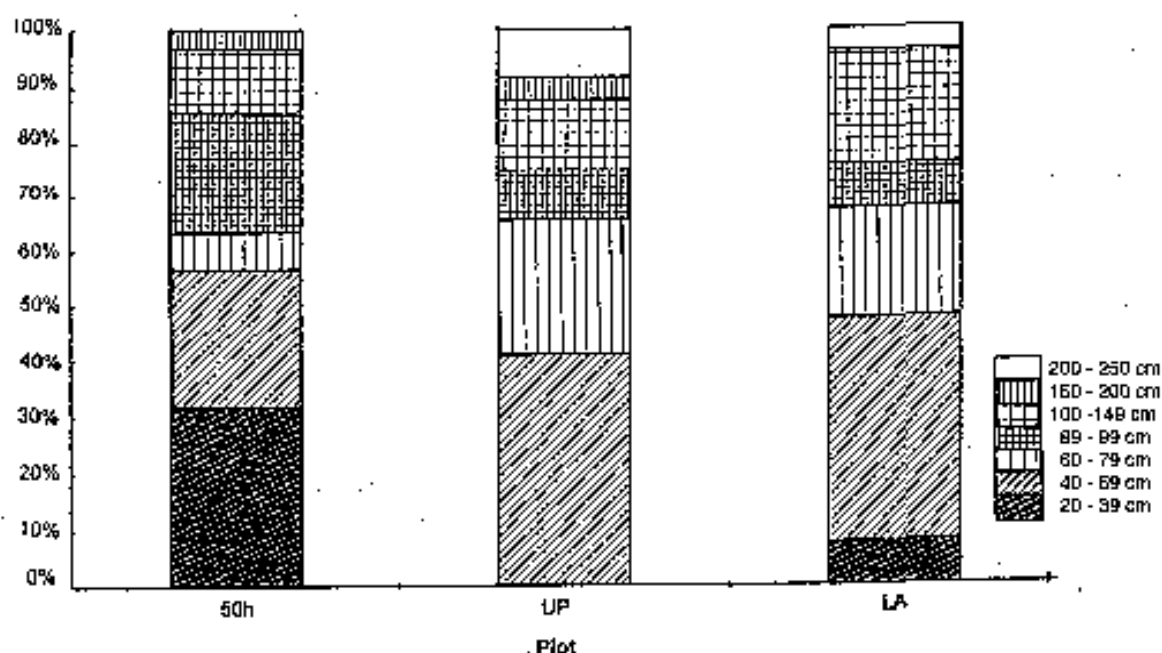


Figure 6. Distribution of girth classes of sampled trees in 1 ha plots (percentage of 25 trees) showing abundance of trees <40 cm gbh in the 50-ha plot, their absence in UP and low numbers in LA. Note the absence of trees >200 cm gbh in the 50-ha plot and their presence in UP and LA.

Distribution of cryptogams in forest plots

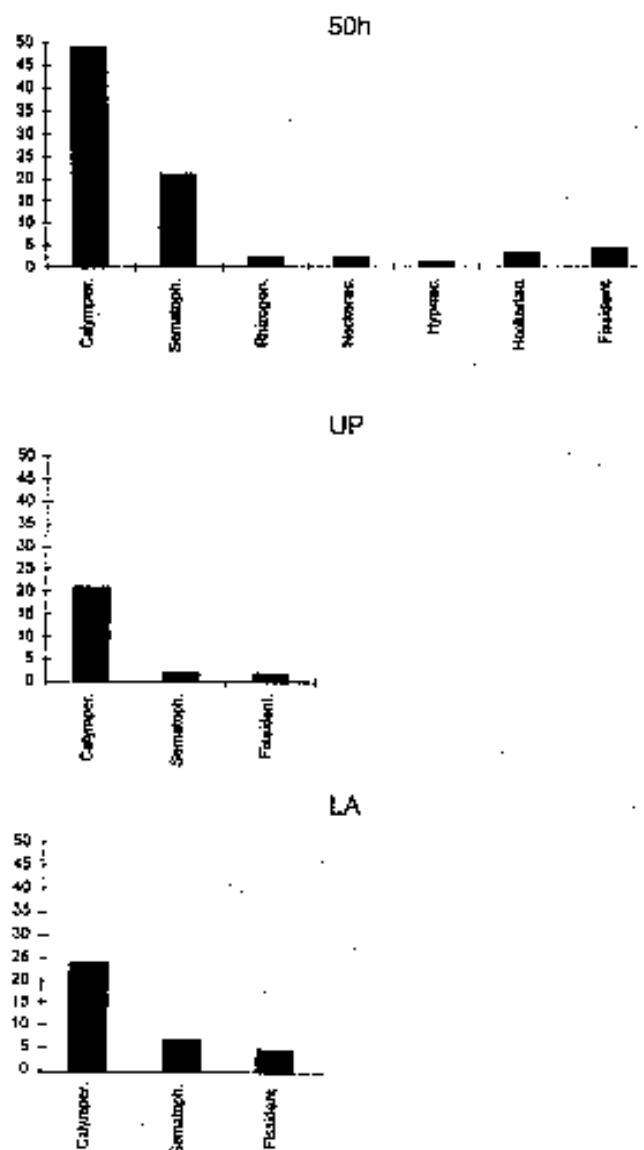
Mosses

Mosses were most frequent in shaded humid microhabitats at and above ground level or in microniches such as bark crevices. In all plots the dominant epiphytic family was the Calymperaceae, including more than 50 per cent of the taxa sampled (Figure 7). The number of families was greater in the 50-ha plot and included small numbers of taxa in Hookeriaceae, Hypnaceae, Neckeraceae, and Rhizogoniaceae. These families were absent on sampled trees in UP and LA. The family Sematophyllaceae, including *Acanthorrhynchium papillatum* and *Trichosteleum boschii*, had one or more representatives in all plots. This family is an important component of tropical bryophyte communities. Distribution of the moss taxa fell into three categories: a) taxa widely distributed and occurring in all plots; b) taxa restricted to the 50-ha plot; and c) taxa limited by local conditions. The widely distributed taxa in group a) frequently occurred and were luxuriant in the 50-ha plot, whereas they were usually sparse and in an impoverished state in UP and LA. Examples of group a) were found within the Calymperaceae (Figure 8); *Arthrocnemum schimperii*, *Leucophanes octoblepharoides* and *Syrhophodon muelleri* were widespread. *Mitthyridium flavum* occurred in all plots, most frequently in LA. Group b) species, i.e. those found only in the 50-ha plot included *Chaetomitrium papillifolium*, *Clastobryum epiphyllum*, *Homaliiodendron exiguum* and *Neckeropsis gracilentia*. The latter two were also found at Ulu Serting Forest Reserve. *Calymperes woodii* (sp. nov.) was found in the 50-ha plot and, in 1954, at Sungei Menyala Forest Reserve. Taxa limited by local conditions (group c)) included those found in association with termite tracks where earth accumulates, such as species of *Fissidens*. Species found only in the vicinity of watercourses where relative humidity is high at all times included *Piloecium pseudorufescens* (Myuraceae) that forms patches on larger trunks about 1 m above stream level, and *Chaetomitrium borneense* (Hookeriaceae), that winds around slender trunks at a similar height. Species of *Calymperes*, including *C. strictifolium* and *C. porrectum*, were also found in this habitat, as was material of *Syrhophodon loreus* that possessed leaves of normal length (>20 mm). This was in contrast to the specimens of *S. loreus* from other plots that had abnormally short leaves (<10mm). *Papillidiopsis complanata* (Sematophyllaceae) occurred on exposed roots in the bed of streams.

Hepatics

Lejeuneaceae was the dominant hepatic family occurring at lower levels of the forest in all plots (Figure 9). Lepidoziaceae and Aneuraceae were restricted to the 50-ha plot, and Frullaniaceae, which was widespread in more disturbed forests, was only recorded in UP. Taxa of Lejeuneaceae included widespread, rapid primary and secondary colonisers of all available surfaces including twigs, tree trunks and evergreen leaves in the shaded forest. Species found in the quadrats in all plots included *Cheilolejeunea vittata*, *C. occlusa*, *Drepanolejeunea vesiculosa* subsp. *propagatifera*, *Leptolejeunea elliptica* subsp. *subacuta* and *Pycnolejeunea grandiocellata*. Follicolous spe-

cies with appressed habit were abundant on leaves where competition is low and included *Leptolejeunea epiphylla* and species of *Cololejeunea*. Only one taxon, *Schiffneriolejeunea*, which is associated with more open conditions, was found in the canopy. The appressed habit of this species allows it to withstand short drought periods. Along the watercourses 12 additional species of hepatics were recorded, including *Plagiochila kurzii*, *Thysananthus fruticosus*, *Colura ornata*, *Leptolejeunea schiffneri*, *Radula lacerata*, *R. acuminata*, *R. anceps*, *R. protensa* and *Frullania intermedia*.



Calymper. - Calymperaceae
 Sematoph. - Sematophyllaceae
 Rhizogon. - Rhizogoniaceae
 Neckerac. - Neckeraceae
 Hypnac. - Hypnaceae
 Hookeriac. - Hookeriaceae
 Fissident. - Fissidentaceae

Figure 7. Frequency of occurrence of families of mosses on sampled trees in all plots showing dominance of Calymperaceae and higher numbers of families occurring at low frequencies in the 50-ha plot, and lower frequency and loss of diversity in UP and LA.

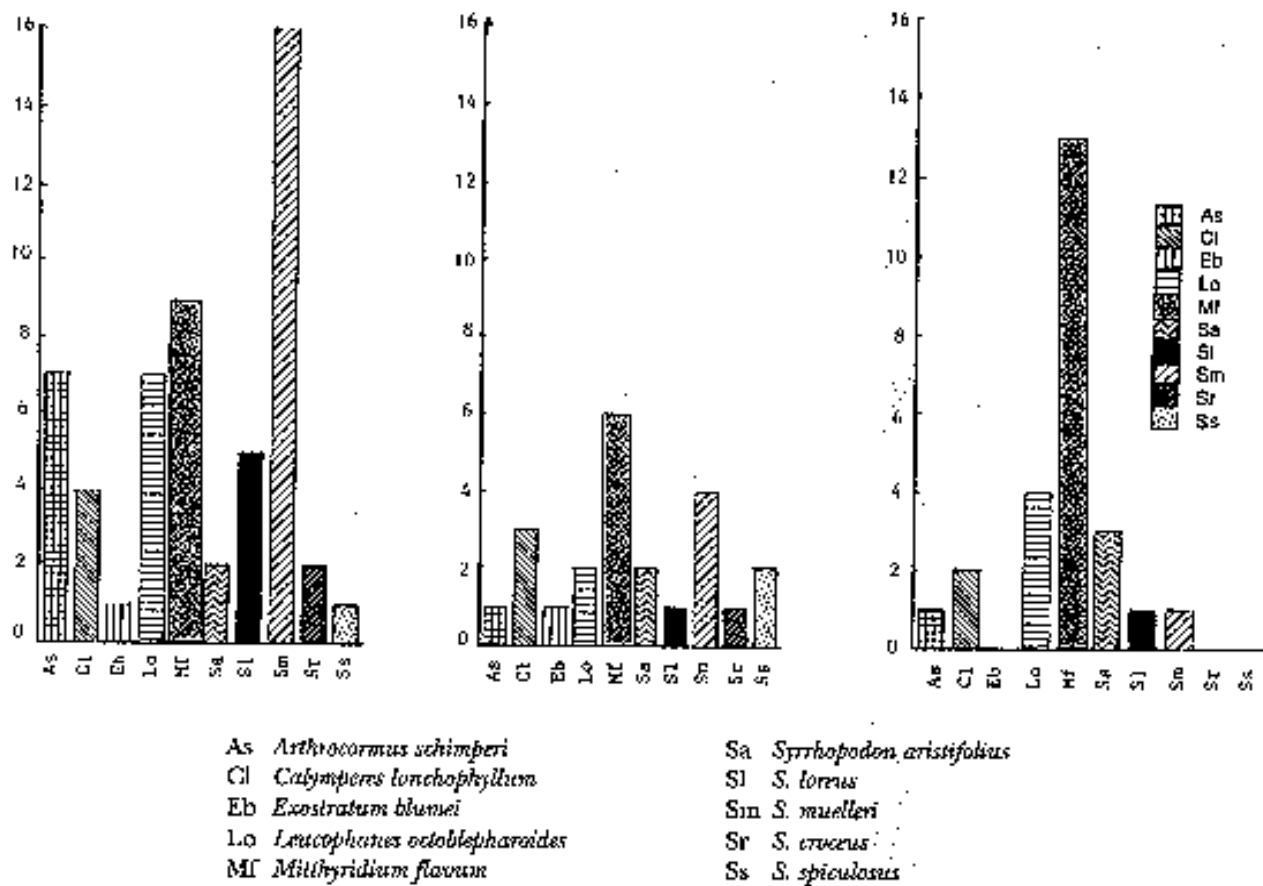


Figure 8. Frequency of species of Calymperaceae in all plots. Note high frequency and diversity in the 50-ha plot, lowest diversity and frequency in UP, and increased frequency of Mf and absence of species Eb, Sr and Ss in LA.

Lichens

Epiphytic lichens were abundant at all levels, from the shaded lower trunks to the sunny conditions of the canopy. Colonisation of tree bark by mainly crustose taxa occurred when trees were <40 cm girth. Lichens continue to grow with the trunk, and often attain a large diameter on older trees. Thelotremaaceae was the dominant family (Figure 10), mainly found on the lower trunk of smooth-barked trees. This included 33 taxa in the genera *Myriotrema*, *Ocellularia* and *Thelotrema* with *Myriotrema* being the dominant genus on the lower areas of the trunks. *Myriotrema costaricense* and *M. wightii* were restricted to the 50-ha plot (Figure 11). The frequency of *M. album* and *M. minutum* was highest in LA. On rough- or moist-barked trees in all plots, a bryo/lichen community developed that included *Eschatagonia prolifera* and *Mitthyridium flavum*. In the 50-ha plot several species that were not found in LA or UP included species of *Phyllopsora* together with *Syrrhopodon loreus* and *Calymperes woodii*. Taxa with cyanobacteria as photobiont were rare; *Coccocarpia glaucina* was found in all plots but species of *Parmeliella* were only found in the 50-ha plot. Indicator species detected by the PCA included *E. prolifera* as a characteristic species of the quadrats

with high cover of both lichens and bryophytes, *M. album* of the smooth-bark community in lichen quadrats and a *Myeloconis* sp. (with yellow medulla) as a characteristic species of smooth-bark lichen communities in LA and UP (Figure 12).

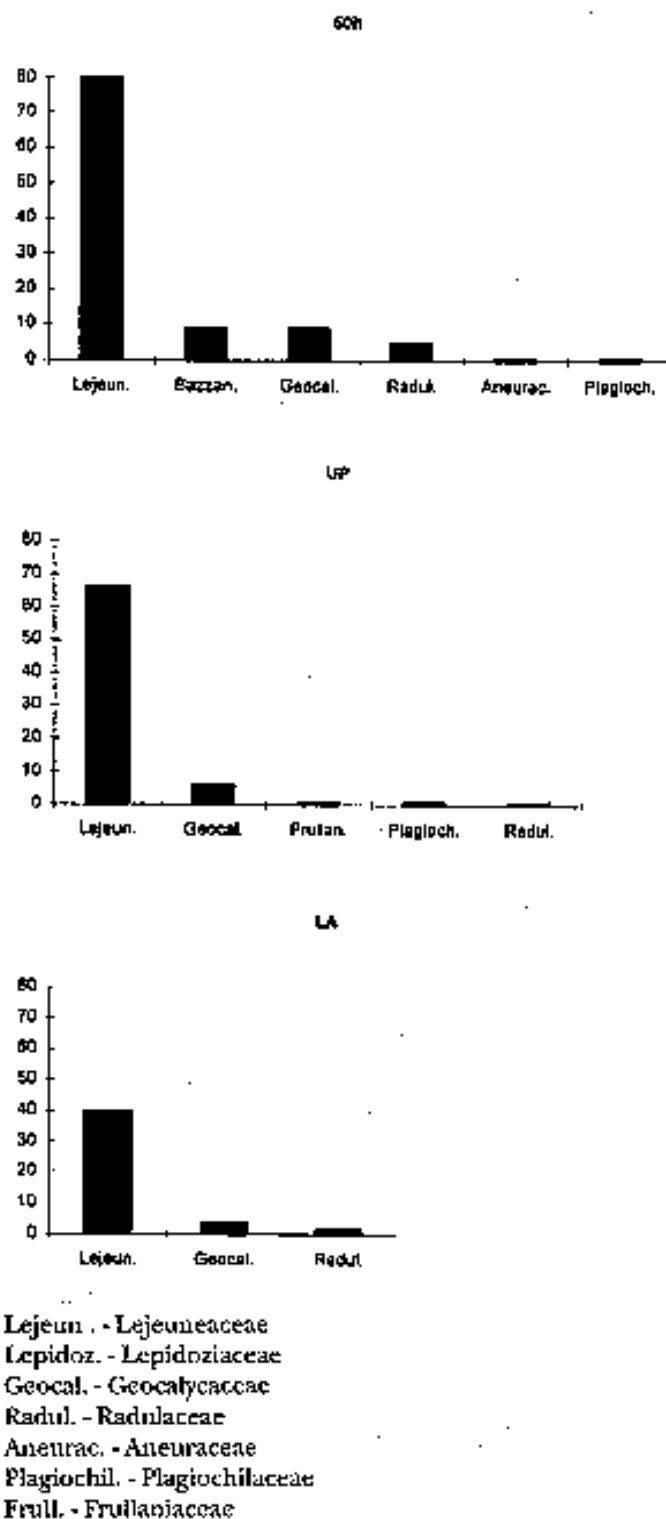


Figure 9. Frequency of families of hepatics on sampled trees in all plots. Note dominance of Lejeuneaceae in all plots, highest frequency and diversity in the 50-ha plot and lowest frequency and diversity in LA.

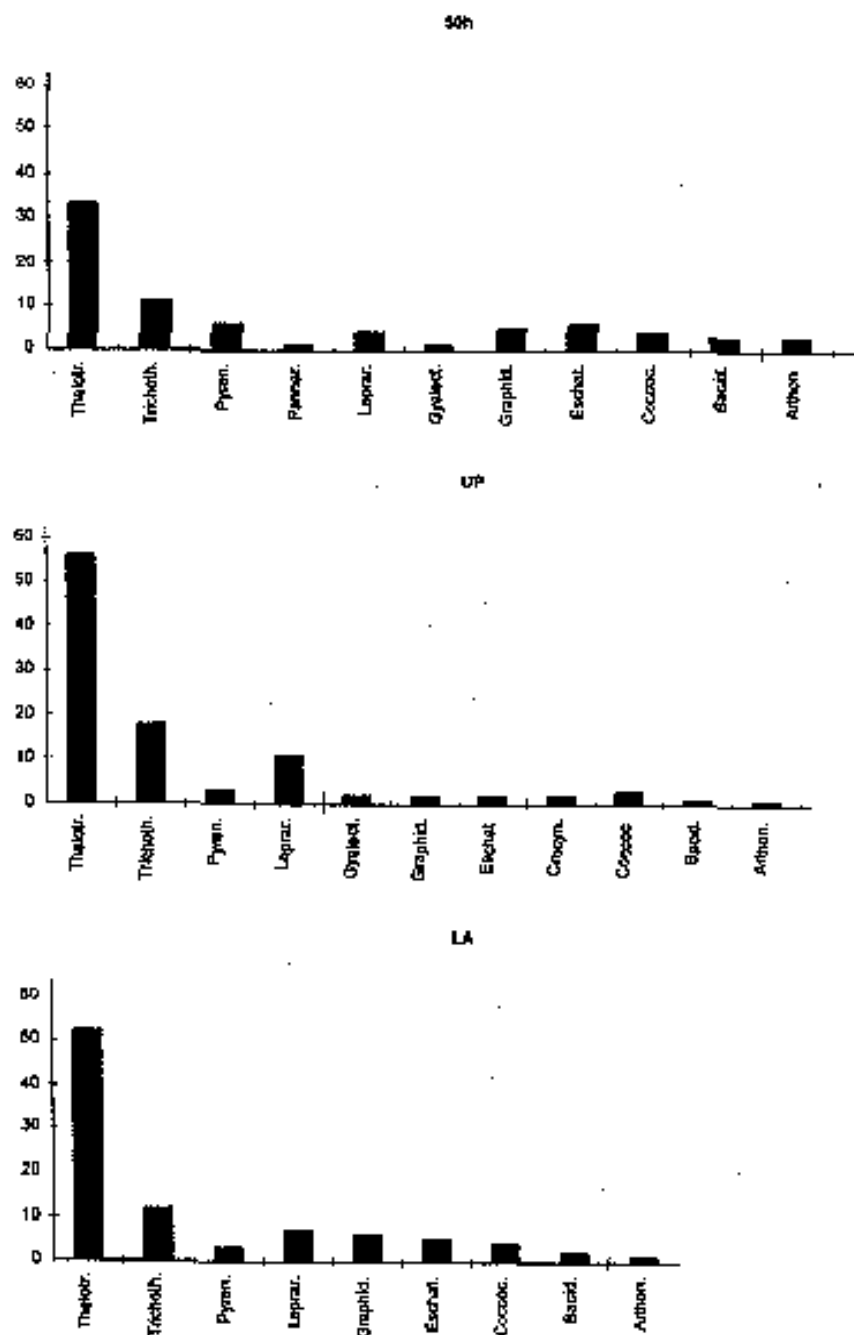


Figure 10. Frequency of lichen families on sampled trees in all plots. Note dominance of Thelotremataceae in all plots and higher frequency in UP and LA, absence of Gyalectaceae, Pannariaceae and Crocyniaceae from LA.

Collections made by tree climbers from the canopy indicated the near absence of foliose lichen and bryophyte taxa and an abundance of crustose lichen taxa with secondary metabolites that acted as sunscreen compounds to protect against UV exposure and high temperatures. Many dominant and conspicuous crustose lichen families in the canopy, often on the largest emergent trees of *Shorea leprosula*, contain anthraquinones. These included Trypetheliaceae (*Trypethelium* and *Astrothelium*), Graphidaceae (mainly species of *Sarcographa*), and Pyrenulaceae (such as *Pyrgillus indicus*). Only one foliose species, *Bulbothrix isidiza*, was recorded.

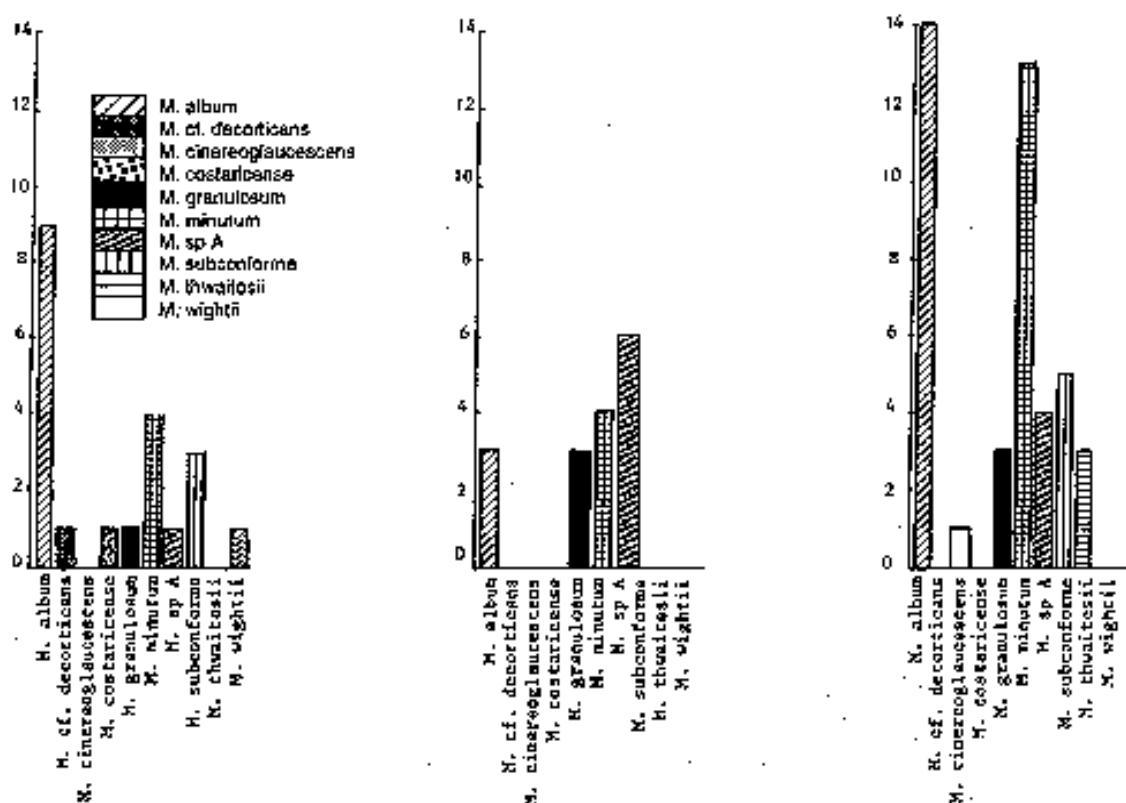


Figure 11. Frequency of taxa of *Myriotrema* (Thelotremaaceae) on sampled trees in all plots. Note number of taxa with low frequency restricted to the 50-ha plot, low number of taxa in UP and dominance of *Myriotrema album* and *M. minutum* in LA.

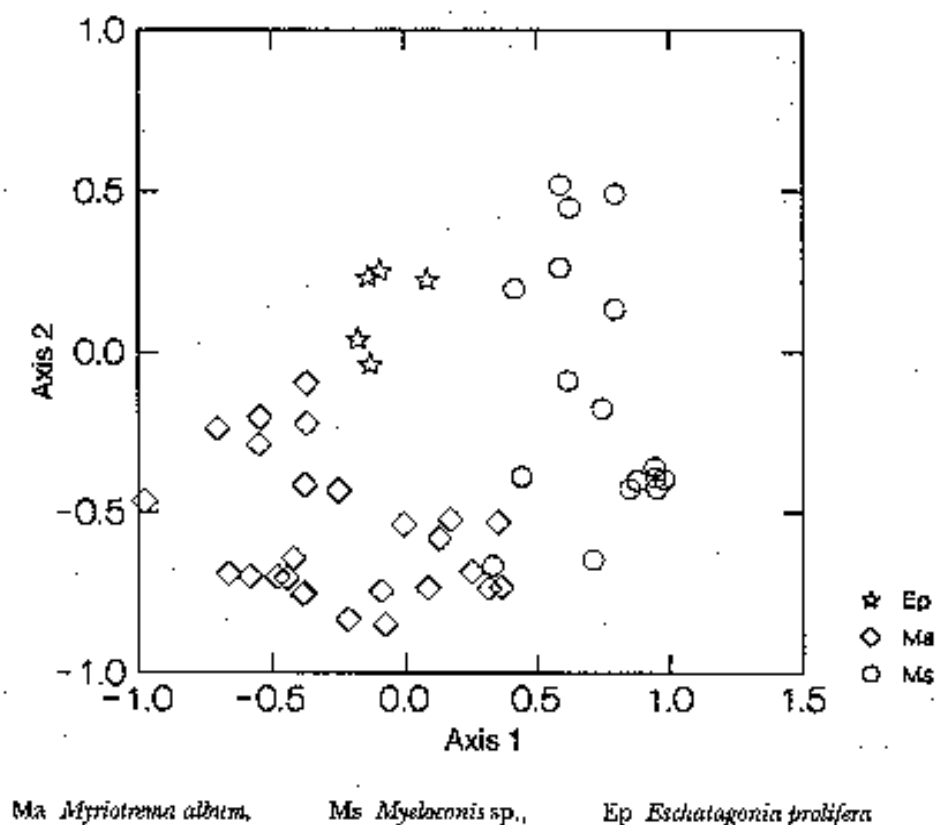


Figure 12. PCA of samples with selected indicator species

Discussion

Corticolous cryptogamic communities sampled in Pasoh Forest Reserve during 1995/6 were characteristic of a Malesian tropical lowland forest, where relative humidity remains high at all times of the year, even in the drier periods experienced in the Negri Sembilan area (Soepadmo 1978). These included bryophyte dominated communities of the lower trunks, buttresses and rough or older bark types, and lichen dominated communities of smooth bark which develop on small saplings and continue to develop on trunks to a great height and age. In addition, there is a bryo-lichen community of rough, moist bark which is found in all plots, but best developed in the 50-ha plot where it contains species that are not found in the logged area.

Key indicator taxa were found in the mosses and lichens, whereas the hepatics were distributed throughout all forest types where suitable substrates are available. The hepatics are not able to grow across living crustose lichen thalli, but can invade once the lichen surface is dead. In quadrats they occurred frequently on dead lichen surfaces. Where conditions were suitable, as in and around the watercourses, specialist hepatics and mosses were found.

The conditions of high UV and temperature in the canopy (Soepadmo 1978) contrasts with those previously described for epiphytic communities in rain forest canopies. Under these conditions foliose species of lichens (Sipman & Harris 1989), and bryophytes (Pócs 1982) are abundant. At Pasoh the canopy cryptogamic community demonstrated a near absence of corticolous bryophytes, an abundance of crustose lichen taxa with secondary metabolites on the branches of emergent dipterocarps, and the presence of one foliose lichen adapted to seasonally dry conditions (*Bulbothrix isidiza*). Together these suggest that high temperatures, UV and periods of drought are controlling factors of the canopy cryptogamic community. The absence of drought-resistant bryophytes, such as species of *Groudiella* or *Macromitrium*, that are characteristic of seasonal forest, suggests that the climate was formerly wetter or that dry periods were not so extensive.

Species recorded in the present survey have a predominantly Indo-Pacific and Indo-Malesian distribution, with a few pantropical species such as *Calymperes lonchophyllum*, *Eschatagonia prolifera* and *Parmeliella* spp. Many of the crustose lichen taxa are new records for Malaysia so wider distribution in South East Asia is little known. Further work in the Malesian region will show whether there are species that are restricted to lowland dipterocarp forests.

The paucity of larger trees in the 50-ha plot has been noted (Manokaran & La Frankie 1990, Laidlaw 1994), but the abundance and diversity of smaller trees ensures a high RH even during the dry season. The abundance of smaller trees and low numbers of trees >110 cm gbh is similar to that found in Virgin Jungle Reserves in Peninsular Malaysia (Laidlaw 1994). In the 1 ha sample plot within the 50-ha plot cryptogamic diversity was high in all groups, and total plot diversity was higher than diversity on the 25 sampled trees (Figure 4). The presence of a variety of microhabitats including logs, damaged and crooked trees and watercourses ensures a high diversity of specialist taxa in this area.

Selective logging in LA has altered the age structure of the forest and reduced habitat niches, so that diversity is lowered per unit area. However, the PCA shows little difference between the samples of corticolous cryptogams in this plot and the unlogged ecological plot UP, and for lichens the number of species and frequency are higher in LA than in UP (e.g. Figure 11). Factors contributing to this are the presence of large trees which pre-date the logging phase, and which have acted as a source of corticolous lichen propagules and spores. The presence of moisture dependent species of *Pyrenula* and *Eschatagonia* (Figure 10) suggests that the microclimate of this forest was not much altered by the selective logging. Propagules of crustose lichens may be transported downwards from the canopy and higher regions of tree trunks by rain or by microfauna, but lateral translocation is slow (Wolseley & Aguirre-Hudson 1996b). Where microclimatic conditions are suitable propagules will become established, and where the community is open, rapid colonisers are more successful than those that require specialist conditions. This was demonstrated by the abundance of *Myriotrema album* and *M. minutum* in LA (Figure 11). Where there is a preponderance of asexual reproduction, as in Calymperaceae, for example, *Mitthyridium flavum* in LA (Figure 8), lateral transport by microfauna may occur enabling rapid colonisation in suitable microclimatic conditions. The low number of cryptogams on the majority of smaller trees in LA and UP (Figure 5), suggests that colonisation is not as rapid there as in the 50-ha plot. The unlogged ecological plot UP shows the lowest diversity and frequency of lichens and mosses, despite the presence of large trees >200 cm gbh. The absence of smaller trees at this site suggests some discontinuity in microclimate conditions. This could have been because of tree fall adjacent to the sample plot causing increased exposure, resulting in high lichen diversity but at low frequency, and low bryophyte diversity and frequency. Further sampling in the adjacent areas did not, however, markedly increase apparent diversity.

Conclusions

The continued ecological stability of the 50-ha plot supports and ensures the highest diversity in mosses and lichens, and of bryophytes of more specialised habitats such as watercourses. Degeneration of cryptogamic communities in UP was apparent in all groups, but more so in bryophyte than in lichen diversity. This suggests that tree fall and associated increase of exposure may affect the bryophytes more than the lichens. Following logging in the 1950's under the MUS with retention of mature seed trees, lichen diversity remains high with a predominance of rapid colonisers and loss of specialist species. However, moss diversity is low probably through alteration of critical microclimate conditions such as RH, temperature and UV. Hepatic diversity is high due to availability of open surfaces for colonisation. The retention of mature trees provides a source of propagules for colonisation from lichen communities of the upper regions of trunks. Further investigation of more recently logged sites should establish a relationship between conditions created by logging and the cryptogamic communities of a site, and provide the basis for the use of cryptogams as indicators of the health of forest communities.

Bryophytes and lichens are good indicators of microclimatic conditions within the forest, and of diversity associated with forests where long ecological continuity has allowed the development of habitat niches supporting specialist taxa. Lichens grow slowly and some thalli may be as old as the tree that supports them (Wolseley & Aguirre-Hudson 1997a). Where older trees are logged, or where logging alters the environmental conditions, taxa may be unable to recolonise and are lost. The retention of mature trees in LA has allowed the recovery of lichen diversity following logging. The maintenance of adequate forest cover is essential for bryophytes which require high relative humidity for propagation and establishment.

Further research on cryptogamic communities of lowland tropical rain forest and the identification of taxa that are indicators of ecological continuity would allow rapid assessment of forest management and harvesting techniques in conditions where it is difficult to measure phanerogamic diversity. This would be a useful tool for foresters to estimate forest health both for logging purposes and for recovery of the forest ecosystem.

References

- AGUIRRE-HUDSON, B. & WOLSELEY, P.A. 1991. Bibliography of South-east Asian Lichenology. *Journal of Hattori Botanical Laboratory* 76: 313 - 350.
- CORNELISSEN, J.H.C. & TER STEGE, H. 1989. Distribution and ecology of epiphytic bryophytes and lichens in dry evergreen forest of Guyana. *Journal of Tropical Ecology* 5: 131-150.
- EDDY, A. 1988. *A Handbook of Malaysian Mosses. Vol. 1 Sphagnales to Dicranales*. 204 pp. British Museum (Natural History) London.
- EDDY, A. 1990. *A Handbook of Malaysian Mosses Vol. 2 Leucobryaceae to Buxbaumiacae*. 256 pp. The Natural History Museum, London.
- EDDY, A. 1996. *A Handbook of Malaysian Mosses Vol. 3 Splachnolobryaceae to Leptostomataceae*. 277 pp. The Natural History Museum, London.
- GALLOWAY, D.G., SAMSUDIN, M.W. & LATIFF, A. 1994. A bibliography of Malaysian lichenology. *Malaysian Applied Biology* 22: 215 - 221.
- GRADSTEIN, S.R. 1992. The vanishing tropical rain forest as an environment for bryophytes and lichens. Pp. 234-253 in Bates, J.W. & Farmer, A.M. (Eds.) *Bryophytes and Lichens in a Changing Environment*. Oxford.
- GRADSTEIN, S.R. & PÓCS, T. 1989. Bryophytes. Pp. 311-325 in Lieth, H. & Werger, M.J.A. (Eds.) *Tropical Rain Forest Ecosystems*. Elsevier Science Publishers B.V., Amsterdam.
- GROLLE, R. 1983. Nomina generica hepaticarum; references, types and synonymies. *Acta Botanica Fennica* 121: 1 - 62.
- HAWKSWORTH, D.L., KIRK, P.M., SUTTON, B.C. & PEGLER, D.N. 1995. *Dictionary of Fungi. 8th Edition*. 616 pp. CAB International, Oxford.
- LAIDLAW, R. 1994. *The Virgin Jungle Reserves of Peninsular Malaysia: The ecology and dynamics of small protected areas in managed forest*. Ph.D thesis, 304 pp. Cambridge.
- LEE, S.S. 1995. *A Guidebook to Pasoh. FRIM Technical Information Handbook No. 3*. 73 pp. Kuala Lumpur, Malaysia.
- MANOKARAN, N. & LAFRANKE, J.V. 1990. Stand structure of Pasoh forest reserve, a lowland rain forest in Peninsular Malaysia. *Journal of Tropical Forest Science* 3: 14 - 24.
- MANUEL, M.G. 1981. A generic moss flora of Peninsular Malaysia and Singapore. *Federation Museums Journal* 26(Part II), 163 pp. Kuala Lumpur, Malaysia.
- NASH, T. H. 1992. *Lichen Biology*. 303 pp. Cambridge.
- PÓCS, T. 1982. Tropical forest bryophytes. Pp. 59-104 in Smith, A.J.E (Ed.) *Bryophyte Ecology*. Chapman & Hall, London.

- SIPMAN, H.J.M. & HARRIS, R.C. 1989. Lichens. Pp. 303-309 in Lieth, H. & Werger, M.J.A. (Eds.) *Tropical Rain Forest Ecosystems*. Elsevier Science Publishers B.V., Amsterdam.
- SOEPADMO, E. 1978. Introduction to the Malaysian I.B.P. Synthesis Meetings. *Malayan Nature Journal* 30(2): 119 - 124.
- WOLSELEY, P.A. & AGUIRRE-HUDSON, B. 1991. Lichens as indicators of environmental change in the tropical forests of Thailand. *Global Ecology and Biogeography Letters* 1: 170 - 175.
- WOLSELEY, P.A. & AGUIRRE-HUDSON, B. 1996. Key to lichen genera in Thailand with special reference to epiphytic communities and notes on distribution. Part I Macrolichens. Pp. 303 - 335. *Natural History Bulletin of the Siam Society*.
- WOLSELEY, P.A. & AGUIRRE-HUDSON, B. 1997a. The ecology and distribution of lichens in tropical deciduous and evergreen forests of northern Thailand. *Journal of Biogeography* 24: 327 - 343.
- WOLSELEY, P.A. & AGUIRRE-HUDSON, B. 1997b. Fire in tropical dry forest - corticolous lichens as indicators of recent ecological changes in Thailand. *Journal of Biogeography* 24: 345 - 362.
- WOLSELEY, P.A. & AGUIRRE-HUDSON, B. 1997c. *A Field Key to Characteristic and Indicator Epiphytic Lichens in Northern Thailand*. Field Studies Council (Produced as trial version).
- WOLSELEY, P.A., MONCRIEFF, C. & AGUIRRE-HUDSON, B. 1994. Lichens as indicators of environmental stability and change in the tropical forests of Northern Thailand. *Global Ecology and Biogeography Letters* 4: 116 - 123.



Plate 1. Young tree in 50-ha plot showing early colonisation by crustose lichens and mosses: *Raphidostichum bruchii* twisting around trunk, sterile *Myelocanis* sp. with yellow medulla (below Rb), *Graphina* sp. in centre and *Thelotrema* sp. above.



Plate 2. Quadrat 20 x 12.5 cms, in undisturbed 50-ha plot with bryophyte and lichen community including *Mitthyridium flavum* (centre left), *Pycnolejeunea grandicellata* (centre right), a dark brown species of *Pyrenula*, and paler sterile crusts



Plate 3. Large trunk of *Sindora* species in unlogged plot with well-developed lichen community dominated by *Thelotremataceae* with large old individuals of *Myriotrema minutum*, *Ocellularia* sp. and *Thelotrema* sp.



Plate 4. Logged forest plot with trunk of mature *Shorea leprosula*, showing quadrat on bryophyte community. Lichen community poor on shaded lower trunk, but propagules from upper trunk and canopy colonising regenerating young trees.

Appendix

Species list for plots and sites in Pasoh Forest Reserve

BRYOPHYTES

Mosses

- Acanthorrhynchium papillatum* (Harv.) Fleisch.
 cf. *Acroporium rufum* (papillose form sensu Hb. Dixon, BM)
Arthrocnemum schimperi Dozy & Molk.
Calymperes graeffeanum C. M. Il.
Calymperes lonchophyllum Schwaegr.
Calymperes moluccense Schwaegr.
Calymperes porrectum Mitt.
Calymperes strictifolium (Mitt.) Roth
Calymperes woodii L.T. Ellis, sp. nov.
Chaetomitrium borneense Mitt.
Chaetomitrium sp. aff. *orthorrhynchum* (Dozy & Molk.) Bosch & Sande Lac.
Chaetomitrium papillifolium Bosch & Sande Lac.
Chaetomitrium sp.
Ectropothecium cf. *maritzii* Jaeg.
Exostratum blumei (Nees ex Hampe) L.T. Ellis
Fissidens hollianus Dozy & Molk.
Fissidens crassinervis var. *crassinervis* Sande Lac.
Fissidens crassinervis var. *laxus* (Sull. & Lesq.) A. Eddy
Homaliodendron exiguum (Bosch & Sande Lac.) Fleisch.
Isopterygium minutivameum (C. M. Il.) Jaeg.
Isopterygium sp.
Leucobryum aduncum Dozy & Molk.
Leucobryum sanctum (Brid.) Hampe
Leucophanes octoblepharoides Brid.
Mitthyridium flavum (C. M. Il.) Robinson
Mitthyridium repens (Harv.) Robinson
Mitthyridium undulatum (Broth. & Geh.) Robinson
Mitthyridium wallisii (C. M. Il.) Robinson
Neckeropsis gracilentia (Bosch & Sande Lac.) Fleisch.
Piloecium pseudorufescens (Hampe) C. M. Il. in Booth
Pinnatella mucronata (Bosch & Sande Lac.) Fleisch.
Pyrrhobryum spiniforme complex.
Raphidostichum bruchii (Dozy & Molk.) Fleisch. [= *Papillidopsis bruchii* (Dozy & Molk.) Buck & Tan]
Syrrophodon albo-vaginatus Schwaegr.
Syrrophodon aristifolius Mitt.

Syrrhopodon confertus Sande Lac.
Syrrhopodon croceus Mitt.
Syrrhopodon loreus (Sande Lac.) Reese
Syrrhopodon muelleri (Dozy & Molk.) Sande Lac.
Syrrhopodon spiculosus Hook. & Grev.
Taxithelium herianum (Broth.) Broth.
Taxithelium sp.
Trichosteleum boschii (Dozy & Molk.) Jacq.
Vesicularia miquelii (Sande Lac.) Fleisch.
Warburgiella complanata (Dix.) Booth [= *Papillidiopsis complanata* (Dix.) Buck & Tan]

Hepatics

Acromastigum inaequilaterum (Lehm. & Lindenb.) Evans
Aphanolejeunea sp.
Bazzania subtilis (Sande Lac.) Trev.
Bazzania sp.
Calypogeia arguta Nees & Mont.
Ceratolejeunea cf. *aliena* Herz.
Ceratolejeunea sp.
Cheilolejeunea ceylanica (Gott.) Schust. & Kachroo
Cheilolejeunea falsinervis (Sande Lac.) Kachroo & Schust.
Cheilolejeunea cf. *intertexta* (Lindenb.) Steph.
Cheilolejeunea occlusa (Herz.) Kodama & Kitag.
Cheilolejeunea aff. *serpentina* (Mitt.) Mizut.
Cheilolejeunea vittata (Steph. ex Hoffm.) Schust. & Kachroo
Cololejeunea acuminata Mizut.
Cololejeunea cf. *amoena* Benedix
Cololejeunea angulata (Steph.) Mizut.
Cololejeunea floccosa (Lehm. & Lindenb.) Schiffn.
Cololejeunea haskarliana (Lehm.) Schiffn.
Cololejeunea siamensis Steph.
Cololejeunea tenella Benedix
Cololejeunea sp. (sect. *Radulae*)
Cololejeunea sp. (? sect. *Stylopedinolejeunea*)
Colura acroloba (Mont. ex Steph.) Jov.-Ast.
Colura conica (Sande Lac.) Goebel
Colura corynephora (Nees et al.) Trev.
Colura ornata Goebel
Drepanolejeunea vesiculosa subsp. *propagulifera* Herz.
Frullania intermedia (Reinw., Bl. & Nees) Dum.
Frullania sp.
Heteroscyphus argutus (Reinw., Bl. & Nees) Schiffn.
Lejeunea caespitosa Lindenb.

- Lejeunea* aff. *flava* (Sw.) Nees
Lejeunea sp. A
Lejeunea sp. B
Lejeunea sp. C
Lepidolejeunea bidentula (Steph.) Schust. var. *bidentula*
Lepidozia wallichiana Gott.
Leptolejeunea elliptica subsp. *subacuta* (Steph. ex Evans) Schust.
Leptolejeunea epiphylla (Mitt.) Steph.
Leptolejeunea schiffneri Steph.
Leptolejeunea vitrea (Nees) Schiffn.
Leptolejeunea sp.
Lopholejeunea subfusca (Nees) Steph.
Microlejeunea cucullata (Reinw., Bl. & Nees) Jack & Steph. [= *Metalejeunea cucullata*
 (Reinw., Bl. & Nees) Grolle
Pictolejeunea mizutanii Grolle
Plagiochila bantamensis (Reinw., Bl. & Nees) Dum.
Plagiochila kurzii Steph.
Podomitrium malaccense (Steph.) Campb.
Pycnolejeunea grandiocellata Steph.
Pycnolejeunea aff. *grandiocellata* Steph.
Radula acuminata Steph.
Radula anceps Sande Lac.
Radula aff. *borneensis* Steph.
Radula javanica Gott.
Radula lacerata Steph.
Radula protensa Lindenb.
Radula vriesiana Sande Lac.
Radula sp. A
Radula sp. B
Riccardia sp.
schizostipean sp. A
schizostipean sp. B
Spruceanthus polymorphus (Sande Lac.) Verd.
Thysananthus fruticosus (Lindenb. & Gott.) Schiffn.

LICHENS

- Anthracothecium macrosporum* Müll. Arg.
Astrothelium sp.
Catarraphia sp.
Catarraphia dictyoplaca (Mont. & Bosch) A. Massal.
Coccocarpia glaucina Krempelhuber
Coenogonium sp. Ehrenb.
Cresponea proximata (Nyl.) Egea & Torrente
Crocynia UV + Or.

Dimerella pale yellow
Eschatagonia prolifera (Mont.) R. Sant. comb. nov.
Graphina sp.
Graphis spp.
Leproloma Nyl. ex Crombie
Leptogium denticulatum (Rabenh.) Korb.
Lithothelium almbornii R.C. Harris & Aptroot
Myeloconis yellow medulla
Parmeliella pannosa (Swartz) M ll. Arg.
Phyllopsora spp.
Porina mastoidella (Nyl.) M ll. Arg.
Porina subcutanea Ach.
Pyrenula mamillana (Ach.) Trevisan
Sarcographa labyrinthica (Ach.) M ll. Arg.

Thelotre mataceae

Chroodiscus sp.
Myriotrema albocinctum Hale
Myriotrema album Fee
Myriotrema cinereoglauescens
Myriotrema costaricense (Müll. Arg.) Hale
Myriotrema desquamens (Müll. Arg.) Hale
Myriotrema granulosum (Leighton) Hale
Myriotrema glaucophaenum (Krempelh.) Hale
Myriotrema minutum (Hale) Hale
Myriotrema subconforme (Nyl.) Hale
Myriotrema thwaitseii Hale
Myriotrema wightii (Taylor) Hale
Ocellularia allosporoides (Nyl.) Patw. & Kulkarni
Ocellularia dolichotata (Nyl.) Zahlbr.
Ocellularia eumorpha (Stirton) Hale
Ocellularia massalongoi (Mont.) Hale
Ocellularia orthomastica (Krempel.) Zahlbr.
Ocellularia papillata (Leighton) Zahlbr.
Ocellularia punctulata (Leighton) Zahlbr.
Thelotrema alborosellum (Nyl.) Tuck
Thelotrema astroideum (Berk. & Broome) Hale
Thelotrema dilatatum (M ll. Arg.) Hale
Thelotrema subpatens Hale
Thelotrema tuberculiferum Vainio
Thelotrema weberi Hale

A PRELIMINARY ANALYSIS OF THE ANTS (FORMICIDAE) OF PASOH FOREST RESERVE

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Ants (Hymenoptera: Formicidae) of the leaf litter and canopy were sampled at Pasoh Forest Reserve, Negri Sembilan, Malaysia, to investigate the differences between the faunas of primary and regenerating forest areas in terms of species present and their population densities. Litter was sampled using Winkler Bags and the canopy by a standardized fogging technique. Species inventories and numerical synopses of the ants collected, and a preliminary analysis of these data are presented here. In terms of overall species-richness the previously logged and pristine forest sites yielded similar samples, both from litter (75-105 species in pristine forest, 64-83 species in logged forest per sample period) and by fogging (50-51 species in pristine forest, 24-60 species in logged forest per sample period). The Cerapachyinae and Aenictinae, present in the leaf litter, are not represented in the canopy, and the arboreal sub-family Pseudomyrmecinae does not occur in the leaf litter. The genera *Anablypterus*, *Emeryopsis*, *Harpegnathos*, *Lordomyrma*, *Probolomyrmex*, *Secostruma*, *Vombisidris* and a new genus were recovered from primary forest but not from regenerating forest. Conversely the genera *Aenictus*, *Philidris*, and *Plagiolepis* were recovered from regenerating forest but not from primary forest.

Keywords: Ants - leaf litter - canopy - primary forest - regenerating forest

Introduction

During 1994 investigating teams from the National History Museum, United Kingdom, visited Pasoh Forest Reserve, Negri Sembilan, Malaysia, to sample the leaf litter and tree canopy faunas of ants. The object of the exercise was two fold; first, to establish what species were present, and second, to compare and contrast the ant faunas of primary and regenerating forest in the litter and canopy, in terms of species occurrence and population densities of each species. The sampling regime was repeated in both dry (March-April) and wet (November) seasons to see if there was any seasonal variation. The purpose of this preliminary discussion is to indicate what taxa were present and in what numbers; more detailed analysis, investigating the significance of results from the different areas and seasons, will follow later.

Materials and methods

The Winkler Bag technique was used to obtain ants from standard samples of leaf litter; each litter sample was sieved prior to being placed in the extraction bag. Approximately 48 hours drying time was allowed each sample and the arthropod yield was collected into 80 per cent ethanol. The samples were then hand-searched

for stragglers and any found were added to the sample. The arboreal fauna was sampled by fogging selected large emergent trees in the same areas from which the litter samples were obtained.

Litter samples were taken across two plots of primary forest (Plot 3 and an area adjacent to the northern end of Plot 1), and two plots of regenerating forest (Plot 1 and an area about 300 m north of Plot 1). Two transects, at right-angles to each other, traversed each plot and standard litter samples, each of 1 m², were taken along each transect at 5 m intervals. Two further transects, at 25 m and 75 m, were taken parallel to one of the original transects; samples along these secondary transects were taken at 10 m intervals.

Fogging for all the tree canopy samples commenced at about 0700 hours on days that had been rain free for the preceding 24 hours. An insecticidal formulation of Reslin and diesel (1:9) was delivered by a fogging machine into the canopy of each tree for 5-7 minutes. A two hour drop-down period was allowed, during which the canopy fauna accumulated in collecting pans, each of 1 m² area, suspended beneath the tree. The number of collecting pans used varied from 38 to 50, depending upon the extent of the tree's crown. The yield was washed from the collecting pans with high pressure ethanol sprays and stored in glass tubes containing 80 per cent ethanol.

All the samples obtained were transferred to The Natural History Museum, London, where their ants were extracted, sorted to species and counted. Representative series of each species were mounted to form a reference collection and voucher specimens of all taxa have been deposited in the collections of the Institut Penyelidikan Perhutanan Malaysia (Forest Research Institute of Malaysia) and The Natural History Museum, London. Species represented by unique specimens are in the former collection. In the tables of material collected the unidentified taxa are represented by a code number (for leaf litter species) or a code letter (for arboreal species). It is immediately obvious, from the low proportion of species that can be named accurately, that much revisionary and alpha-taxonomic work is needed on the ant fauna of the region.

Results and discussion

The leaf litter fauna

The following table illustrates the number of 1 m² leaf litter samples taken in each forest type at the different collecting dates:

Date	Regenerating forest	Primary forest	Total
Mar.-Apr. 1994	68	71	139
Nov. 1994	88	88	176
Total	156	159	315

A synopsis of numbers of all leaf litter ants, indicating numbers of individuals per species per genus in each forest type and at each sampling date is given in Table 1. Omitted from the list are a few workers of *Camponotus gigas* recovered from the litter samples which are treated as tourists and ignored. Sample 299 is omitted as it was obviously taken directly through adjacent nests of *Pheidole* sp. 15 and *Odontomachus rixosus*, yielding over 2000 individuals of the first and over 200 individuals of the second species.

A summary of the information yielded by the raw sampling data shows the following results:

	Regenerating forest		Primary forest	
	Mar.-Apr.	Nov.	Mar.-Apr.	Nov.
No. samples (m ²)	68	88	71	88
No. genera	32	36	32	43
No. species	83	64	75	105
No. individuals	6,302	2,499	4,730	4,715
Mean no. ants m ⁻²	92.7	28.4	66.6	53.6

Total number of ants isolated from all 315 samples = 18,246 (representing 148 species in 51 genera; species density = 57.9 ants m⁻²).

Total ants isolated from the 139 Mar.-Apr. samples = 11,032 (representing 109 species in 39 genera; species density = 79.5 ants m⁻²).

Total ants isolated from the 176 Nov. samples = 7,214 (representing 112 species in 46 genera; species density = 40.9 ants m⁻²).

Total ants from the 159 Primary Forest samples = 9,445 (representing 125 species in 48 genera; species density 75.6 ants m⁻²).

Total ants from the 156 Regenerating Forest samples = 8,801 (representing 103 species in 42 genera; species density 56.4 ants m⁻²).

Taxonomic distribution of leaf litter fauna

Members of six ant sub-families were represented in the samples and distributed as follows.

Sub-family	Genera number (and %)	Species number (and %)	Individuals number (and %)
Myrmicinae	24 (47%)	87 (59%)	12,959 (71%)
Ponerinae	16 (31%)	35 (24%)	1,717 (9.5%)
Formicinae	7 (14%)	17 (12%)	3,182 (17%)
Dolichoderinae	2 (4%)	4 (<3%)	333 (2%)
Cerapachyinae	1 (2%)	4 (<3%)	53 (<1%)
Aenictinae	1 (2%)	1 (<1%)	2 (<1%)

Note the remarkable predominance of Myrmicinae, with nearly half the represented genera, over half the total number of species and nearly three-quarters of the total number of individuals.

The four myrmicine species *Crematogaster* sp. 1, *Lophomyrmex bedoti*, *Pheidole* sp. 1 and *Pheidole* sp. 15 together account for 7,893 individuals, which is 61 per cent of the myrmicine total and 43 per cent of all the leaf litter ants collected. Outside the Myrmicinae only the formicine *Pseudolasius* sp. 1, with 2,246 individuals, approaches these numbers. These five species together make up about 55 per cent of all the leaf litter ants recorded.

In this survey the genera *Amblyopone*, *Emeryopone*, *Harpegnathos*, *Lordomyrma*, *Probolomyrmex*, *Secostruma*, *Vombisidris* and a new genus were recovered from primary forest but not from regenerating forest. Conversely the genera *Aenictus*, *Philidris*, and *Plagiolepis* were recovered from regenerating forest but not from primary forest.

It should be remembered that the sampling technique used (Winkler Bag) will not account for the extensive ant fauna that is restricted to relatively large chunks of rotten wood, nor those ants with very specialised habitat requirements (for example, in termitaries). The samples also fail to show those nocturnal species that remain in rotten wood, among tree roots or under deep stones during the day, but emerge to forage in the litter by night.

The canopy fauna

Canopy fogging was carried out on six large trees, two in the primary forest plots (Fogs 1 and 6) and four in regenerating forest plots (Fogs 2, 3, 4, 5). Of these, Fogs 1 and 2 were carried out in the dry season (April) and Fogs 3 - 6 in the wet season (November). Identity of the trees sampled is as follows: Fog 1 *Mangifera* sp.; Fog 2 *Shorea* sp.; Fog 3 undetermined tree; Fog 4 undetermined tree (adjacent to Fog 3); Fog 5 *Shorea* sp.; Fog 6 *Shorea* sp.

A summary of the information yielded by the raw sampling data shows the following results:

Fog No.	Primary forest		Regenerating forest			
	1	6	2	3	4	5
No. genera	20	20	21	14	12	22
No. species	51	50	60	24	26	55
No. individuals	1,003	3,230	2,171	323	314	888

Total number of ants from all six fogs = 7,929 (representing 146 species in 33 genera; mean density 1,321 ants/tree).

Total number of ants in April fogs (Fogs 1 and 2) = 3,171.

Total number of ants in November fogs (Fogs 3 - 6) = 4,755.

Total number of ants in Primary Forest fogs (Fogs 1 and 6) = 4,233.

Total number of ants in Regenerating Forest fogs (Fogs 2 - 5) = 3,696.

A synopsis of the canopy ants, indicating numbers of individuals per species per genus in each of the fogging samples is given in Table 2.

It is interesting to note that while the total number of species in canopy and litter counts remains about the same (146 and 148 respectively), the number of genera is much higher in litter (51 as opposed to 33). Also there would appear to be a significantly higher number of individuals in the litter than in the canopy (18,246 as opposed to 7,929), though this may just reflect the fact that the two sampling techniques are not really directly comparable.

Taxonomic distribution of canopy fauna

Representatives of five sub-families have been retrieved from the fogging samples and are distributed as follows:

Sub-family	Genera number (and %)	Species number (and %)	Individuals number (and %)
Myrmicinae	18 (55 %)	56 (38 %)	4,572 (58 %)
Formicinae	6 (18 %)	60 (41 %)	2,069 (26 %)
Dolichoderinae	4 (12 %)	16 (11 %)	961 (12 %)
Ponerinae	4 (12 %)	6 (4 %)	27 (<1 %)
Pseudomyrmecinae	1 (3 %)	8 (5 %)	218 (3 %)

The sub-families Cerapachyinae and Aenictinae, present in the leaf litter, are not represented in the canopy. Conversely, the purely arboreal sub-family Pseudomyrmecinae does not occur in the leaf litter.

In both habitats the Myrmicinae come out tops in terms of numbers of genera and numbers of individuals, but the percentage representation of individual Formicinae and Dolichoderinae is much higher in the canopy (up 9 per cent and 10 per cent respectively) and that of the Myrmicinae correspondingly lower, down by 13 per cent. The Ponerinae emerge as a predominantly terrestrial sub-family and the Dolichoderinae as predominantly arboreal.

Isolated and shared taxa

A total of 65 genera has been recorded in this survey. Of these, 51 genera occur in the leaf litter and 33 occur in the canopy; 19 genera have species represented in both localities. The species of genera occurring in both habitats are generally not conspecific between litter and canopy, although there are some exceptions, listed below. Genera occurring in both are *Aphaenogaster*, *Camponotus*, *Cardiocondyla*, *Crematogaster*, *Diacamma*, *Gnamptogenys*, *Meranoplus*, *Monomorium*, *Oligomyrmex*, *Pachycondyla*, *Paratrechina*, *Pheidole*, *Plagiolepis*, *Polyrhachis*, *Strumigenys*, *Technomyrmex*, *Tetramorium*, *Vollenhovia*, *Vombisidris*.

A glance at the tables will indicate that species of these shared genera are not evenly divided between the two habitats. Most show a marked preponderance in one or the other. Among the speciose genera, those predominantly arboreal include *Camponotus*, *Crematogaster*, *Polyrhachis* and *Technomyrmex*; those predominantly terrestrial are *Oligomyrmex*, *Pachycondyla*, *Paratrechina*, *Pheidole*, *Strumigenys* and *Tetramorium*.

During the amalgamation of mounted representative samples of species from the litter and fog faunas, to provide a single unified collection, a small number of species has been detected that occurred in both. These are as follows; in each case the litter sample species number is given first, followed in brackets by the equivalent fogging sample species letter.

Aphaenogaster sp. 1 (= sp. A)

Camponotus sp. 1 (= sp. I)

Crematogaster sp. 2 (= sp. O)

Monomorium sp. 4 (= sp. A)

Oligomyrmex sp. 1 (= sp. A)

Paratrechina sp. 1 (= sp. B)

Paratrechina sp. 5 (= sp. C)

Plagiolepis sp. 1 (= sp. B)

Strumigenys sp. 3 (= sp. A)

Technomyrmex sp. 2 (= sp. B)

Tetramorium sp. 9 (= sp. B)

Vombisidris sp. 1 (= sp. A)

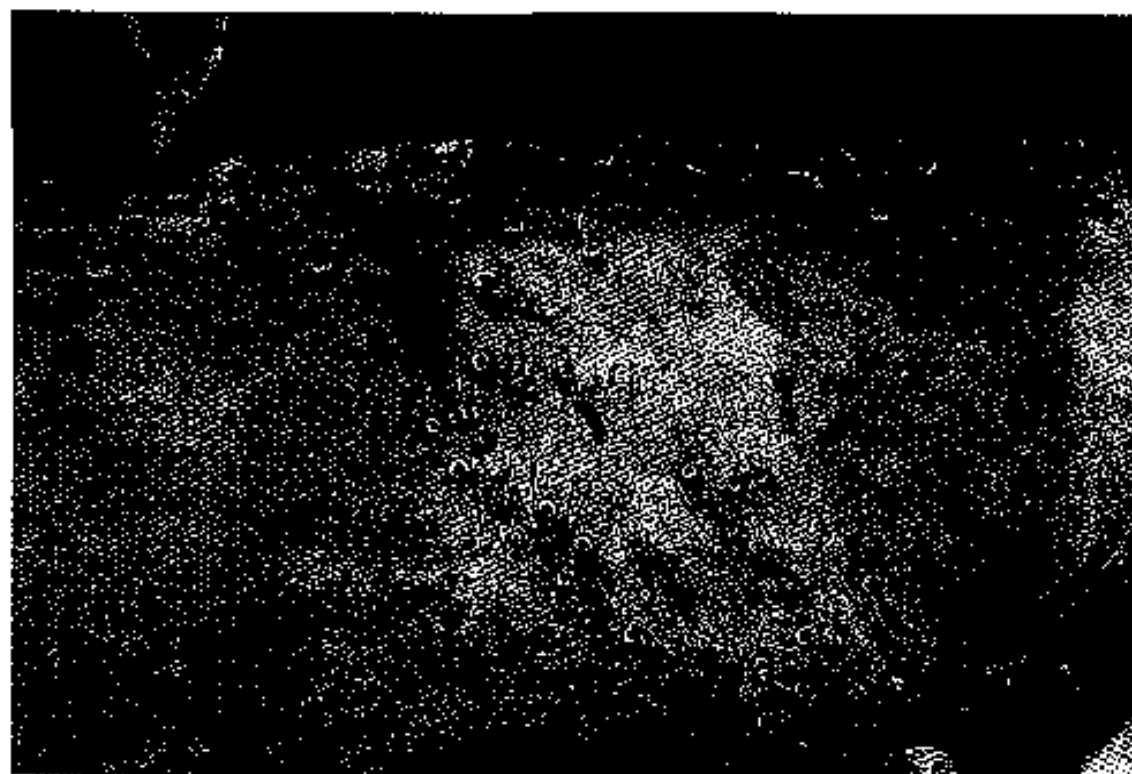


Plate 1. A party of ants, *Polyrhachis* sp. moving nest in Pasoh forest.
Photo: L.G. Kirton

Table 1. Leaf litter fauna. Synopsis of the ant genera and species, and numbers of individuals obtained from the 315 leaf litter samples. Currently unidentified species are represented by a code number that is duplicated upon the data labels of mounted voucher specimens at FRIM and BMNH.

Taxon	Regenerating forest		Primary forest		Totals
	Mar-Apr.	Nov.	Mar-Apr.	Nov.	
<i>Acanthomyrmex</i> sp. 1	12	50	0	51	113
<i>Aenictus silvestris</i>	0	2	0	0	2
<i>Amblyopone</i> sp. 1	0	0	2	0	2
<i>Anochetus myops</i>	1	0	0	6	7
<i>Anochetus</i> sp. 2	0	0	1	0	1
<i>Anochetus graeffei</i>	0	0	2	0	2
<i>Aphaenogaster</i> sp. 1	0	9	4	3	16
<i>Camponotus</i> sp. 1	0	0	1	0	1
<i>Cardiocradyla</i> sp. 1	9	0	3	0	12
<i>Anochetus bryanii</i>	18	18	6	1	43
<i>Anochetus</i> sp. 2	0	0	2	3	7
<i>Anochetus howitti</i>	1	0	0	1	2
<i>Anochetus</i> sp. 4	0	0	0	1	1
<i>Crematogaster</i> sp. 1	727	253	541	37	1558
<i>Crematogaster</i> sp. 2	7	1	0	1	9
<i>Cryptopone</i> sp. 1	9	1	4	17	31
<i>Diacamma rugosum</i>	0	1	1	0	2
<i>Discothyrea</i> sp. 1	7	1	1	3	12
<i>Discothyrea</i> sp. 2	0	0	0	3	3
<i>Emeryopone buttelreeperi</i>	0	0	1	1	2
<i>Euprenolepis procera</i>	0	1	0	168	169
<i>Gnamptogenys binghami</i>	11	23	0	0	34
<i>Gnamptogenys menadensis</i>	1	0	1	1	3
<i>Gnamptogenys</i> sp. 3	0	0	2	0	2
<i>Harpegnathos venator</i>	0	0	1	0	1
<i>Hypoponera</i> sp. 1	3	48	2	8	61
<i>Hypoponera</i> sp. 2	0	0	1	7	8
<i>Hypoponera</i> sp. 3	56	148	30	8	242
<i>Hypoponera</i> sp. 4	25	29	36	189	259
<i>Hypoponera</i> sp. 5	2	0	3	5	10
<i>Hypoponera</i> sp. 6	1	0	0	0	1
<i>Hypoponera</i> sp. 7	0	0	0	10	10
<i>Leptogenys diminuta</i>	0	5	0	0	5
<i>Leptogenys myops</i>	0	1	0	1	2
<i>Lophomyrmex bedoti</i>	708	618	323	703	2352
<i>Lordomyrma</i> sp. 1	0	0	0	1	1
<i>Mayriella transfuga</i>	3	2	0	6	11
<i>Meranoplus nucomatus</i>	0	0	0	17	17
<i>Meranoplus</i> sp. 2	0	5	0	6	11
<i>Monomorium talpa</i>	321	4	79	80	484
<i>Monomorium floricola</i>	9	111	35	115	270
<i>Monomorium</i> sp. 3	69	9	21	18	117
<i>Monomorium</i> sp. 4	1	0	0	0	1
<i>Monomorium pharaonis</i>	0	0	0	3	3
<i>Myrmecina</i> sp. 1	1	0	2	0	3
<i>Myrmecina</i> sp. 2	12	2	3	9	26
<i>Myrmecina</i> sp. 3	1	16	0	16	33
<i>Myrmecina</i> sp. 4	0	0	1	4	5
<i>Myrmecina</i> sp. 5	4	4	2	0	10
<i>Myrmecina</i> sp. 6	3	0	0	0	3

(continued)

Table 1 (continued)

Taxon	Regenerating forest		Primary forest		Totals
	Mar.-Apr.	Nov.	Mar.-Apr.	Nov.	
<i>Myrmecina</i> sp. 7	0	1	1	2	4
<i>Myrmecina</i> sp. 8	0	0	0	4	4
<i>Myrmoteras estradae</i>	0	4	0	9	13
<i>Myrmoteras iriodum</i>	0	0	0	1	1
New genus (<i>Myrmicinae</i>) sp. 1	0	0	0	1	1
<i>Odontomachus rixosus</i>	38	117	88	440	678
<i>Odontoponera transversa</i>	13	22	16	8	59
<i>Oligomyrmex</i> sp. 1	64	28	151	19	262
<i>Oligomyrmex</i> sp. 2	15	0	16	8	39
<i>Oligomyrmex</i> sp. 3	1	1	6	7	15
<i>Oligomyrmex</i> sp. 4	43	0	0	0	43
<i>Oligomyrmex</i> sp. 5	9	0	74	2	85
<i>Oligomyrmex</i> sp. 6	90	6	27	7	130
<i>Oligomyrmex</i> sp. 7	6	0	0	0	6
<i>Pachycondyla rufipes</i>	2	0	0	2	4
<i>Pachycondyla</i> sp. 2	7	116	15	31	169
<i>Pachycondyla leuvenhoeki</i>	2	3	2	9	16
<i>Pachycondyla</i> sp. 4	1	0	1	1	3
<i>Pachycondyla sharpi</i>	0	0	1	0	1
<i>Pachycondyla rubra</i>	0	0	0	25	25
<i>Paratrechina</i> sp. 1	59	12	41	17	129
<i>Paratrechina</i> sp. 2	285	9	78	72	444
<i>Paratrechina</i> sp. 3	55	0	0	0	55
<i>Paratrechina</i> sp. 4	14	0	0	0	14
<i>Paratrechina</i> sp. 5	0	6	0	0	6
<i>Paratrechina</i> sp. 6	0	5	0	0	5
<i>Paratrechina</i> sp. 7	0	0	0	2	2
<i>Pheidole</i> sp. 1	995	101	1232	231	2559
<i>Pheidole</i> sp. 2	20	0	2	20	42
<i>Pheidole</i> sp. 3	376	2	61	24	463
<i>Pheidole</i> sp. 4	19	15	10	78	122
<i>Pheidole</i> sp. 5	1	0	0	0	1
<i>Pheidole</i> sp. 6	22	12	12	12	58
<i>Pheidole</i> sp. 7	1	0	0	0	1
<i>Pheidole</i> sp. 8	2	0	6	0	8
<i>Pheidole</i> sp. 9	3	0	0	0	3
<i>Pheidole</i> sp. 10	0	0	9	27	36
<i>Pheidole</i> sp. 11	4	0	2	0	6
<i>Pheidole</i> sp. 12	18	0	0	0	18
<i>Pheidole</i> sp. 13	37	0	5	0	42
<i>Pheidole</i> sp. 14	26	0	0	0	26
<i>Pheidole</i> sp. 15	0	0	754	670	1424
<i>Pheidole</i> sp. 16	0	0	78	0	78
<i>Pheidole</i> sp. 17	0	3	0	36	39
<i>Pheidole</i> sp. 18	0	0	0	9	9
<i>Pheidologeton affinis</i>	40	2	0	73	115
<i>Pheidologeton silenus</i>	0	0	0	259	259
<i>Philidris</i> sp. 1	64	0	0	0	64
<i>Plagiolepis</i> sp. 1	1	0	0	0	1
<i>Polyrhachis moesta</i>	0	5	0	3	8
<i>Polyrhachis carbonaria</i>	0	8	0	13	21
<i>Ponera</i> sp. 1	12	17	0	12	41
<i>Ponera</i> sp. 2	0	0	0	15	15

(continued)

Table 1 (continued)

Taxon	Regenerating forest		Primary forest		Totals
	Mar.-Apr.	Nov.	Mar.-Apr.	Nov.	
<i>Pristomyrmex pungens</i> (?)	10	10	17	11	48
<i>Pristomyrmex</i> sp. 2	11	0	0	10	21
<i>Proatta butleri</i>	43	5	0	1	49
<i>Protolomyrmex watanabei</i>	0	0	0	1	1
<i>Proceratium stictum</i>	0	3	0	1	4
<i>Proceratium</i> sp. 2	0	0	0	1	1
<i>Pseudolasius</i> sp. 1	1018	393	567	278	2246
<i>Pseudolasius</i> sp. 2	60	0	0	5	65
<i>Pseudolasius</i> sp. 3	0	0	2	0	2
<i>Recirculidris browni</i>	0	6	3	4	13
<i>Secostruma lethifera</i>	0	0	0	2	2
<i>Solenopsis</i> sp. 1	100	52	3	386	541
<i>Strumigenys</i> sp. 1	1	2	3	1	7
<i>Strumigenys signatus</i>	286	11	155	31	483
<i>Strumigenys</i> sp. 3	5	0	0	0	5
<i>Strumigenys juliae</i>	69	0	16	22	107
<i>Strumigenys uichancoi</i>	32	2	17	9	60
<i>Strumigenys</i> sp. 6	0	0	4	2	6
<i>Strumigenys</i> sp. 7	1	0	0	1	2
<i>Strumigenys</i> sp. 8	6	0	0	7	13
<i>Strumigenys</i> sp. 9	0	0	0	2	2
<i>Strumigenys</i> sp. 10	0	1	0	1	2
<i>Strumigenys</i> sp. 11	0	0	0	1	1
<i>Strumigenys godeffroyi</i>	0	0	0	1	1
<i>Technomyrmex</i> sp. 1	62	98	14	55	229
<i>Technomyrmex</i> sp. 2	0	0	6	0	6
<i>Technomyrmex</i> sp. 3	2	15	0	17	34
<i>Tetramorium mashona</i>	55	15	60	23	153
<i>Tetramorium</i> sp. 2	14	7	38	104	163
<i>Tetramorium</i> sp. 3	0	0	1	0	1
<i>Tetramorium kheperai</i>	0	0	9	47	56
<i>Tetramorium senec</i>	0	0	7	0	7
<i>Tetramorium</i> sp. 6	16	17	7	22	62
<i>Tetramorium</i> sp. 7	0	0	8	0	8
<i>Tetramorium</i> sp. 8	0	4	0	5	9
<i>Tetramorium adolphon</i>	0	1	0	2	3
<i>Tetramorium pacificum</i>	0	0	0	1	1
<i>Trichoscapha</i> sp. 1	137	0	0	0	137
<i>Trichoscapha jacobsoni</i>	3	0	1	1	5
<i>Trichoscapha doherthy</i>	1	0	0	0	1
<i>Trichoscapha extensa</i>	0	0	0	2	2
<i>Vollenhovia</i> sp. 1	2	0	8	21	31
<i>Vollenhovia</i> sp. 2	1	0	0	0	1
<i>Vollenhovia</i> sp. 3	0	0	0	1	1
<i>Vombisidris</i> sp. 1	0	0	0	2	2
Totals	6302	2499	4730	4715	18246

Table 2. Canopy fauna. Synopsis of the ant genera and species, and numbers of individuals, from Fogs 1 to 6. Currently unidentified species are represented by a code letter that is duplicated upon the data labels of mounted voucher specimens at FRIM and BMNH

Fog No.	Primary forest		Regenerating forest			Total	
	1	6	2	3	4		5
Taxon							
<i>Aphaenogaster</i> sp. A	12	0	0	0	0	0	12
<i>Bothriomyrmex</i> sp. A	0	0	0	0	0	1	1
<i>Camponotus</i> sp. A	33	314	0	0	0	114	461
<i>Camponotus</i> sp. B	106	456	0	4	0	66	632
<i>Camponotus</i> sp. C	17	0	1	0	0	0	18
<i>Camponotus</i> sp. D	1	0	0	0	0	0	1
<i>Camponotus</i> sp. E	1	0	0	0	0	0	1
<i>Camponotus</i> sp. F	1	0	1	0	1	0	3
<i>Camponotus</i> sp. G	2	0	0	0	7	0	9
<i>Camponotus</i> sp. H	30	0	0	0	0	0	30
<i>Camponotus</i> sp. I	0	2	7	1	0	5	15
<i>Camponotus</i> sp. J	0	0	43	1	125	6	175
<i>Camponotus</i> sp. K	0	0	11	1	4	0	16
<i>Camponotus</i> sp. L	0	0	2	1	0	0	3
<i>Camponotus</i> sp. M	0	0	1	0	3	0	7
<i>Camponotus</i> sp. N	0	2	0	4	0	1	7
<i>Camponotus</i> sp. O	0	1	0	0	0	0	1
<i>Camponotus</i> sp. P	0	1	0	0	0	0	1
<i>Camponotus</i> sp. Q	0	1	0	0	0	0	1
<i>Camponotus</i> sp. R	0	0	0	0	0	1	1
<i>Camponotus</i> sp. S	0	0	0	0	0	1	1
<i>Camponotus</i> sp. T	0	0	0	0	0	2	2
<i>Camponotus</i> sp. U	0	0	0	0	2	0	2
<i>Camponotus</i> sp. V	0	0	0	0	5	0	5
<i>Cardicondyla wroughtonii</i>	3	0	1	0	0	13	17
<i>Cardicondyla</i> sp. B	0	0	76	0	0	0	76
<i>Catantopus horridus</i>	0	0	3	3	0	27	33
<i>Catantopus hispidulus</i>	0	0	2	0	0	0	2
<i>Catantopus latissimus</i>	0	48	0	0	0	0	48
<i>Crematogaster</i> sp. A	243	24	0	128	0	32	427
<i>Crematogaster</i> sp. B	55	16	0	0	0	67	138
<i>Crematogaster</i> sp. C	10	0	17	0	0	0	27
<i>Crematogaster</i> sp. D	25	124	0	0	0	38	187
<i>Crematogaster</i> sp. E	95	0	0	0	0	0	95
<i>Crematogaster</i> sp. F	9	0	0	0	0	0	9
<i>Crematogaster</i> sp. G	0	0	584	1	64	0	649
<i>Crematogaster</i> sp. H	0	0	117	0	0	0	117
<i>Crematogaster</i> sp. I	0	14	0	0	0	0	14
<i>Crematogaster</i> sp. J	0	1	0	0	0	8	9
<i>Crematogaster</i> sp. K	0	1	0	0	0	52	53
<i>Crematogaster</i> sp. L	0	2	0	0	0	0	2
<i>Crematogaster</i> sp. M	0	0	0	0	0	1	1
<i>Crematogaster</i> sp. N	0	0	0	0	0	127	127
<i>Crematogaster</i> sp. O	0	0	0	107	16	16	139
<i>Crematogaster</i> sp. P	0	0	0	0	0	5	5
<i>Crematogaster</i> sp. Q	0	0	0	8	0	0	8
<i>Diacamma rugosum</i>	2	1	6	2	5	1	17
<i>Dilobocandyla borneensis</i>	1	0	0	0	0	0	1
<i>Dilobocandyla</i> sp. B	0	0	1	0	0	2	3

(continued)

Table 2 (continued)

Fog No.	Primary forest		Regenerating forest			Total	
	1	6	2	3	4		5
<i>Dolichoderus thoracicus</i>	2	0	3	0	0	0	5
<i>Dolichoderus</i> sp. B	0	15	167	0	0	0	180
<i>Dolichoderus</i> sp. C	0	0	90	0	0	2	92
<i>Dolichoderus</i> sp. D	0	0	0	0	0	7	7
<i>Echinopla</i> sp. A	0	0	10	0	13	0	23
<i>Echinopla striata</i>	0	3	4	3	4	1	15
<i>Echinopla</i> sp. C	0	5	1	0	0	0	9
<i>Gesomyrmex halshoveni</i>	0	5	0	0	0	0	5
<i>Gnamptogenys menadensis</i>	1	0	0	0	0	0	1
<i>Meranoplus castaneus</i>	0	0	0	0	0	9	9
<i>Monomorium</i> sp. A	15	0	120	8	0	22	165
<i>Monomorium</i> sp. B	5	0	50	0	0	0	55
<i>Monomorium</i> sp. C	0	2	4	0	0	0	6
<i>Monomorium</i> sp. D	0	0	0	0	3	1	4
<i>Monomorium floricola</i>	0	0	0	2	0	0	2
<i>Myrmecarius luteus</i>	0	0	0	0	0	2	2
<i>Oligomyrmex</i> sp. A	1	0	0	0	0	0	1
<i>Pachycondyla darwini</i>	0	1	0	0	0	0	1
<i>Pachycondyla tridentata</i>	0	0	0	0	1	0	1
<i>Paratoponota demota</i>	0	0	0	0	2	1	3
<i>Paratrechina</i> sp. A	1	0	24	0	0	0	25
<i>Paratrechina</i> sp. B	1	3	48	0	0	0	52
<i>Paratrechina</i> sp. C	0	0	0	7	0	0	7
<i>Pheidole</i> sp. A	4	0	0	0	0	0	4
<i>Pheidole</i> sp. B	3	0	0	0	0	0	3
<i>Pheidole</i> sp. C	0	2	0	0	0	0	2
<i>Pheidole</i> sp. D	0	1	0	0	0	0	1
<i>Plagiolepis</i> sp. A	1	1	32	0	0	8	42
<i>Plagiolepis</i> sp. B	0	1	0	0	0	0	1
<i>Platylhyrea</i> sp. A	0	4	0	0	0	0	4
<i>Platylhyrea parallela</i>	0	1	0	1	0	1	3
<i>Polyrhachis illaudata</i>	34	14	0	7	2	1	58
<i>Polyrhachis sumatrensis</i>	4	0	0	0	0	0	4
<i>Polyrhachis</i> sp. C	2	0	2	0	0	0	4
<i>Polyrhachis bicolor</i>	9	65	5	0	0	0	79
<i>Polyrhachis</i> sp. E	28	2	1	0	0	0	31
<i>Polyrhachis abdominalis</i>	1	0	2	0	3	2	8
<i>Polyrhachis</i> sp. G	24	0	1	0	0	0	25
<i>Polyrhachis</i> sp. H	6	0	0	0	0	0	6
<i>Polyrhachis schang</i>	30	0	0	0	0	0	30
<i>Polyrhachis rastellata</i>	10	0	4	0	0	0	14
<i>Polyrhachis</i> sp. K	2	3	0	0	0	0	5
<i>Polyrhachis</i> sp. L	12	0	0	0	0	0	12
<i>Polyrhachis bellicosa</i>	1	0	0	0	0	0	1
<i>Polyrhachis</i> sp. N	0	0	10	0	0	0	10
<i>Polyrhachis</i> sp. O	0	0	6	0	0	0	6
<i>Polyrhachis muelleri</i>	0	0	3	0	0	0	3
<i>Polyrhachis armata</i>	0	0	1	1	3	1	6
<i>Polyrhachis rufipes</i>	0	0	1	0	0	0	1
<i>Polyrhachis boltani</i>	0	20	11	0	33	1	65
<i>Polyrhachis cryptoceroides</i>	0	43	0	0	1	2	46
<i>Polyrhachis</i> sp. U	0	18	0	0	0	0	18
<i>Polyrhachis ypsilon</i>	0	17	0	0	0	0	17
<i>Polyrhachis</i> sp. W	0	19	0	0	0	0	19

(continued)

Table 2 (continued)

Fog No.	Primary forest		Regenerating forest				Total
	1	6	2	3	4	5	
<i>Polyrhachis</i> sp. X	0	66	0	0	0	0	66
<i>Polyrhachis</i> sp. Y	0	5	0	0	0	11	16
<i>Polyrhachis calypso</i>	0	1	0	0	0	0	1
<i>Polyrhachis villipes</i>	0	1	0	0	0	0	1
<i>Polyrhachis</i> sp. AB	0	0	0	0	0	18	18
<i>Polyrhachis nigropilosa</i>	0	0	0	0	0	1	1
<i>Rhopalomastix</i> sp. A	0	0	15	0	1	0	16
<i>Rhopalomastix</i> sp. B	0	0	7	0	0	0	7
<i>Rhopalomastix</i> sp. C	0	0	0	0	1	0	1
<i>Rhoptromyrmex</i> sp. A	4	0	0	0	0	0	4
<i>Rhoptromyrmex wroughtonii</i>	1	0	0	0	0	0	1
<i>Ratastruma retusa</i>	0	0	1	0	0	0	1
<i>Strumigenys</i> sp. A	0	0	1	0	0	0	1
<i>Strumigenys</i> sp. B	0	0	1	0	0	0	1
<i>Strumigenys</i> sp. C	0	0	0	0	0	5	5
<i>Strumigenys</i> sp. D	0	0	0	0	0	3	3
<i>Tapinoma</i> sp. A	2	0	0	0	1	30	33
<i>Tapinoma</i> sp. B	0	0	4	0	0	0	4
<i>Tapinoma</i> sp. C	0	0	4	0	0	0	4
<i>Tapinoma</i> sp. D	0	1	0	0	0	8	9
<i>Technomyrmex</i> sp. A	8	13	170	14	0	4	209
<i>Technomyrmex</i> sp. B	1	0	9	0	0	0	10
<i>Technomyrmex</i> sp. C	0	0	224	0	0	0	224
<i>Technomyrmex</i> sp. D	0	1	43	0	0	88	132
<i>Technomyrmex</i> sp. E	0	0	2	0	0	0	2
<i>Technomyrmex</i> sp. F	0	37	0	0	0	0	37
<i>Technomyrmex</i> sp. G	0	0	0	0	0	12	12
<i>Tetramorium edulis</i>	8	3	2	2	0	17	32
<i>Tetramorium</i> sp. B	1	0	0	0	1	2	4
<i>Tetraponera allaborans</i>	4	1	6	0	3	31	45
<i>Tetraponera attenuata</i>	0	44	91	0	10	2	147
<i>Tetraponera difficilis</i>	0	0	13	0	0	0	13
<i>Tetraponera</i> sp. D	0	0	1	0	0	0	1
<i>Tetraponera modesta</i>	0	1	0	0	0	0	1
<i>Tetraponera</i> sp. F	0	0	0	0	0	4	4
<i>Tetraponera</i> sp. G	0	0	0	0	0	3	3
<i>Tetraponera nigra</i>	0	0	0	4	0	0	4
<i>Vollenhovia</i> sp. A	128	1798	96	0	0	1	2023
<i>Vollenhovia</i> sp. B	3	0	3	0	0	1	7
<i>Vollenhovia</i> sp. C	0	0	0	12	0	0	12
<i>Vombisidris</i> sp. A	0	0	2	0	0	0	2
<i>Vombisidris xylochus</i>	0	3	0	1	0	0	4
<i>Vombisidris harpeza</i>	0	1	0	0	0	0	1
Totals	1003	3230	2171	323	314	888	7929

PUTATIVE ECTOMYCORRHIZAL FUNGI OF PASOH FOREST RESERVE, NEGRI SEMBILAN, MALAYSIA

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The objective of this project was to examine the frequency of ectomycorrhizal fungal sporomes in logged and unlogged forest at Pasoh Forest Reserve with the view of providing data indicative of possible ecosystem disturbance and loss of diversity of these symbiotic fungi as a result of logging activities. A preliminary analysis shows that there is little difference in species diversity between the logged and unlogged areas. Possible reasons for this observation are discussed and recommendations for further study made.

Keywords: Ectomycorrhizal fungi - logged forest - unlogged forest

Introduction

Ectomycorrhizal fungi are essential for the health of most forests. They play important roles as indicators of ecosystem health, monitors of soil disturbance and of environmental pollution. The forests of Malaysia are dominated by the ectomycorrhizal Dipterocarpaceae, one of the most important families of timber trees in South East Asia. Ectomycorrhizal fungi have been demonstrated to significantly enhance uptake of phosphorus and improve seedling growth of some dipterocarp species (Lee & Alexander 1994, Yazid *et al.* 1994). However, little is known of the identity of the associated fungi and how they are affected by forest disturbance, and how this in turn affects dipterocarp seedling survival, regeneration and growth.

This project was carried out to examine the frequency of sporomes of ectomycorrhizal fungi in logged and unlogged forest with the view of providing data indicative of possible ecosystem disturbance and loss of diversity of these symbiotic fungi as a result of logging activities.

Site

The study was conducted in the floristically rich lowland dipterocarp forest of Pasoh Forest Reserve, Negri Sembilan. Pasoh Forest Reserve is located in the rain shadow of the main range and receives relatively low annual rainfall, ranging from 1,727 mm to 3,112 mm per year. The area experiences two relatively dry periods per year with rainfall of 30-100 mm, during the months of February-March and July-August (Soepadmo 1978). The occurrence of the dry periods may, however, vary from year to year, for example, the dry periods in 1992 occurred in March-April and October, while February, June and October were the dry periods in 1993 (Saifuddin Sulaiman *et al.* 1994).

Methods

Sporomes of putative ectomycorrhizal fungi (see Watling & Lee 1995) were collected from beside the major trails in the unlogged and logged forest and in the five one ha plots, A-E, laid out by colleagues from project A2 in the logged over forest (Figure 1). Collections were made twice a year, usually in March-April and at the end of August-beginning of September, to coincide with the fungal fruiting seasons which occur at the end of a prolonged dry spell (Corner 1935, 1962-63). A total of 20 days were spent in collecting from the sample areas. Collecting methods followed those used by agaricologists (Henderson *et al.* 1969) and specimens processed as described in Lee *et al.* (1996b). Processed specimens were sent to the Royal Botanic Garden, Edinburgh, for further study and identification. The material is now housed in the herbarium of the Royal Botanic Garden, Edinburgh (E) with some identified duplicates and voucher specimens kept at FRIM (KEP). Many of the collections are new to science and will probably remain unidentified unless monographic treatments are published in the literature or written by the authors.

The mycelial connections of some fungal sporomes were traced to roots of host trees to confirm their ectomycorrhizal status (see Watling & Lee 1995). However, this was done for only a few collections because it was very time consuming and there were always difficult problems arising from linking an identified sporome with the roots of a specific tree.

Results and discussion

Watling (1995) has outlined the erratic nature of the fruiting of macromycetes and indicated some possible reasons leading to the necessity for long-term studies in temperate communities. He has made a special plea for extended study periods when dealing with these organisms. This is even more paramount in tropical studies when a high percentage of the actual organisms collected are new to science. This present study is of three years duration of which two have been completed. Fortuitously this study has benefited from field results obtained in the two preceeding years. The data so far demonstrates yet again the need for long-term studies when dealing with sporome appearance. Studies over a 20-year

period of the Strathardle Valley in Scotland show that the species area curve for macromycetes continues to rise dramatically for the first ten years only levelling off thereafter, although never truly becoming a symptotic (Watling 1995).

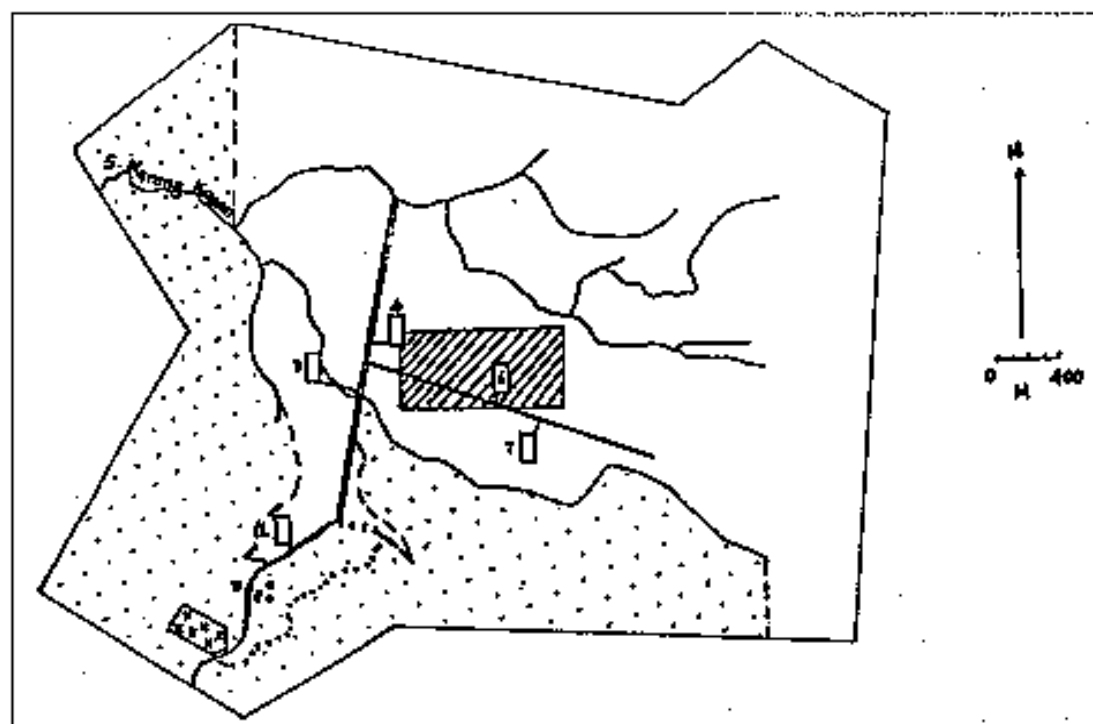


Figure 1. Location of Pasoh Field Research Station and research areas

Legends:

- ==== Main trails
- Nature trail
- ▨ 50-ha plot
- Ecological plots
- XXXX Arboretum
- Buildings
- Logged over forest

Field trips have been made in February, March, April and September to coincide with the local fungal fruiting season. One field trip has just been completed (September 1996) and a final trip will be made in March 1997; it has not been possible to analyse the results of the former for this meeting.

Of over 650 collections and sightings of macromycetes, 460 (71%) were assignable to suspected ectomycorrhizal genera and families. These collections represented 228 distinct taxa (Table 1) and all except members of the genus *Russula* (90 morphotypes) have been examined fully. Only 39 per cent of the species were represented by more than one collection or sighting; very few were represented by more than two collections. Prominent exceptions were *Pulveroboletus frians*, *Rubinoboletus ballouii*, *Cantharellus ianthinus* and *Craterellus cornucopioides* var. *mediosporus*. In this large number of species we have no idea whether there is duplication of ectomycorrhizal activity or indeed if there is redundancy. From

observations elsewhere, we would suggest that this is not the case; a large diversity of ectomycorrhizal fungi would act as a buffer to ecological change. Nor do we know how the ectomycorrhizal fungi in the rain forest interact with organisms other than the host to which they supply nutrients. Gadgil and Gadgil (1975) have offered some clues from studies in plantation areas in New Zealand as to the competition experienced between mycorrhizal and saprophytic entities, *viz.* litter and wood rotters. However, mycelium as well as sporomes are also a source of nutrients for many organisms such as collembola, nematodes and insects in the food-web.

Table 1. Suspected ectomycorrhizal taxa recorded from Pasoh Forest Reserve, Negri Sembilan

Family	Total	Main trail	Number of taxa		
			Logged forest (1)	Unlogged forest (2)	Both logged & unlogged (1), (2)
Amanitaceae	21	11	10	6	3
Boletaceae	25	12	13	13	6
Cantharellaceae	9	1	7	4	2
Cortinariaceae	6	0	5	1	0
Entolomataceae*	9	0	4	6	1
Hydnaceae	1	0	1	0	0
Hydnangiaceae	6	1	3	2	0
Hymenochaetaceae	1	0	1	0	0
Paxillaceae	4	2	3	1	1
Pisolithaceae	1	1	1	0	0
Russulaceae**	128	77	48	31	5
Sclerodermataceae	7	0	4	5	2
Tricholomataceae	9	0	5	4	0
Thelephoraceae	1	0	0	1	0
Total	228	116	98	75	20

* This family has not been truly shown to be ectomycorrhizal in Malaysia (see Rutter & Watling 1977)

** Figures quoted here are only estimates as many members of the genus *Russula* in this family have yet to be identified

Only 60 species have been placed in previously described taxa, that is, 74 per cent of the taxa found are apparently new to science with no more than 13 assignable to the proximity of a known species. This figure agrees with the magnitude in other groups known for the Malaysian region, *e.g.* *Amanita* - 74 per cent (Corner & Bas 1962), *Pleurotus* - 78 per cent (Corner 1981), and falling to 45 per cent for *Cantharellus* and their allies (Corner 1966), 42 per cent in the mycenoid and 47 per cent in the tricholomatoid groups (Corner 1994). *Russula* is obviously the dominant genus and in addition to the more familiar species-facies, a unique growth form has been found - sporomes no bigger than a small thumb nail, in some cases possibly epiphytic. The present study also refutes the claims of the absence of ectomycorrhizal hypogeous fungi in tropical rain forests. At least eight species have now been encountered (Table 2).

Table 2. Suspected hypogeous ectomycorrhizal taxa recorded from Pasoh Forest Reserve, Negri Sembilan to which collections could be assigned

Order & Family	Species	Location collected
Agaricales		
Lepiotaceae?	'Secotiaceae state' sp. 1	Logged forest (1 collection)
	'Secotiaceae state' sp. 2	Logged forest (1 collection)
Boletales		
Chamonixiaceae	<i>Chamonixia mucosa</i>	With <i>Koompassia malaccensis</i> , unlogged forest (1 collection)
Cortinariales		
Gautieriaceae	<i>Gautieria</i> sp. (sp. nov.)	Logged forest (2 collections)
Hymenogastres		
Hymenogastereae	<i>Dendrogaster</i> cf. <i>cambodgensis</i>	Unlogged forest (1 collection)
	<i>Dendrogaster</i> sp. 2	Logged forest (3 collections)
Russulales		
Elasmomycetaceae	<i>Arcangeliiella</i> sp. (sp. nov.)	Ecology plot (1 collection)
Sclerodermatales		
Sclerodermaaceae	<i>Horakiella</i> sp. (sp. nov.)	Unlogged forest (4 collections) Logged forest (2 collections)
Total	8 taxa	16 collections

Undoubtedly the main ectomycorrhizal trees in Pasoh are the Dipterocarpaceae, for example, 47 ectomycorrhizal fungal-dipterocarp associations were obtained from the regenerated Plots A-E during the March 1996 collection. There is evidence for at least some of the ectomycorrhizal Cortinariaceae, a rather rare or restricted group in the tropics, being associated with *Castanopsis* (Fagaceae), viz. *Cortinarius* sp. found along the Nature Trail. Results also confirm the long suspected relationship between some putative mycorrhizal taxa and members of the genus *Eugenia* (Myrtaceae) of which there are 45 species in the 50-ha plot alone. *Russula crustosa* was associated with *Eugenia prainiana* in Plot C while a member of *Russula* sect. *Ilicinae* and an undertermined *Russula* species were associated with *Eugenia ridleyi* in Plot E. *Intsia palembanica*, a Caesalpinoid legume has been shown to form both ectomycorrhizas as well as arbuscular mycorrhizas (Norani 1996). We suspect that *Koompassia malaccensis*, another Caesalpinoid legume, is probably also ectomycorrhizal as it has been found in association with *Chamonixia mucosa* (Table 2) in the unlogged area at Pasoh.

A preliminary analysis of the data shows that there is a similar magnitude of species diversity between the logged and unlogged areas visited with many species being found in both (Table 1). This is probably due to the low intensity of logging carried out in the 1950's where many smaller sized dipterocarp trees were left behind and/or because of the existence in the logged areas of volunteer plants which may act as hosts after the removal of a local ectomycorrhizal dominant (Watling 1981). In fact there is evidence that there may even be an increase in the number of individuals of potential ectomycorrhizal hosts in second growth from

the application of the Malayan Uniform System (MUS) silvicultural technique as exemplified by Manokaran (in this publication).

Most fruitings have been found in clearings and along trails in both logged and unlogged areas. Indicator species have not been identified so far, because of the necessity in the first instance to define the taxa involved and inventorize the mycobiota. With the incredible mixture of arborescent plants at Pasoh as exemplified by the data from the 50-ha plot (Manokaran *et al.* 1992), it is more often than not impossible to say which fungus is associated with which host. Indeed in broad-leaved forests of mid-west North America, Kauffman (1906) suggests that mycorrhizas can be linked by mycelial cords to different hosts, even hosts in different families. It is because of this complexity that comparative data from the policies at FRIM have been greatly valued (Watling 1994, Watling & Lee 1995, Watling & Lee in press). A small attempt at physically linking sporomes to root systems has been independently undertaken by Dr. A. Taylor. Although Becker (1983) had earlier shown the widespread nature of ectomycorrhizas in Pasoh, his results need careful reassessment and as we believe sporome appearance does not reflect what is growing below ground; this is an area which must be addressed in the future. Some species, *e.g.* *Craterellus cornucopioides* var. *mediosporus*, *Rubinoboletus ballouii* and *Cantharellus ianthinus* are widespread in both logged and unlogged areas, whereas other species, *e.g.* *Scleroderma sinnamariense* and *Tricholoma mons-fraseri*, have so far been found in the logged areas only. From observations at Bukit Lagong, Kepong (Watling & Lee 1995), a plantation environment of mixed timber trees including dipterocarps, the former category of fungi would very probably increase. Any loss or reduction of lianas from the community does not appear to have any effect on the ectomycorrhizal diversity; if anything, the number of collections of fungi increases probably because of the ease of spotting single sporomes in the clearer areas. We have, however, no evidence that lianas are ectomycorrhizal. There are several species of ectomycorrhizal fungi found in logged areas in Pasoh which are not found at Kepong, *e.g.* *Scleroderma echinatum*. Other species confined to the unlogged areas of Pasoh might not be expected at Kepong, *e.g.* *Sartodon thwaitsei*, and may represent possible indicator species for future monitoring. From other observations (Lee *et al.* 1996a) there is evidence of a greater diversity of ectomycorrhizas in unlogged forests although they may be represented by single populations. A single or number of sporomes could represent such a population whereas a single sporome could equally well represent the dominant taxon (Dahlberg 1991).

In order to understand how the intensity of logging affects the mycobiota of ectomycorrhizal taxa, comparisons in the future will have to be made with areas before and immediately after felling operations and during plant recolonization. This can only be carried out successfully in areas of similar vegetation as there is every indication that with even slight changes in community structure slight differences exist in the fungi recorded between localities; this may indicate that there is a geographical parameter involved. Thus the mycobiota of ectomycorrhizal fungi so far known from lowland forest in Pasoh, replanted communities in the Greater Templar Park area, the hill forests of Hutan Simpan Semangkok, the upper

hill forest around the Awana Golf and Country Resort in Genting Highlands, and the lowland forests of Sungai Lalang, Ulu Langat and Bukit Lagong are all slightly different, e.g. *Boletus rufocaudatus* from Templar Park (Watling 1994) and *Boletus corrugatus* from Gombak (Watling & Lee 1995). A possible indicator to any pattern arising may probably be seen if forests are clear felled drawing parallels to those found in the largely non-ectomycorrhizal rainforest of El Verde in Puerto Rico which was devastated by Hurricane Hugo. Judging from European studies, some groups of non-mycorrhizal fungi, especially the wood rotters may be better indicators of forest change after logging (Renvall 1995). However, it is not known whether a similar situation occurs in tropical rainforests.

Six articles incorporating some of the data from this project have already been published; four further articles are in various stages of production.

References

- BECKER, P. 1983. Ectomycorrhizae on Shorea (Dipterocarpaceae) seedlings in a lowland Malaysian rainforest. *The Malaysian Forester* 46(2): 146 - 170.
- CORNER, E.J.H. 1935. The seasonal fruiting of Agarics in Malaya. *Gardens' Bulletin, Strait Settlements* 9: 79 - 88.
- CORNER, E.J.H. 1962-63. Fungi. Royal Society Expedition to North Borneo 1961. *Proceedings of the Linnean Society of London* 175: 40 - 42.
- CORNER, E.J.H. 1966. *A Monograph of Cantharellus-like Fungi*, 255 pp. Oxford University Press, London.
- CORNER, E.J.H. 1981. The Agaric Genera *Lentinus*, *Panus* and *Pleurotus* with particular reference to Malaysian species. 169 pp. *Nova Hedwigia* Heft 69. J. Cramer: Vaduz.
- CORNER, E.J.H. 1994. Agarics in Malesia: I Tricholomatoid, II Mycenoid. 271 pp. *Nova Hedwigia* Beiheft 109. J. Cramer: Vaduz.
- CORNER E.J.H. & BAS, C. 1962. The genus *Amanita* in Singapore and Malaya. *Persoonia* 2(3): 241 - 304.
- DAHLBERG, A. 1991. *Ectomycorrhiza in coniferous forest: structure and dynamics of populations and communities*. 38 pp. Swedish University of Agricultural Sciences, Uppsala.
- GADGIL, R.L. & GADGIL, P.D. 1975. Suppression of litter decomposition by mycorrhizal roots of *Pinus radiata*. *New Zealand Journal of Forest Science* 5: 33 - 41.
- HENDERSON, D.M., ORTON, P.D. & WATLING, R. 1969. *British Fungus Flora: Agarics and Boleti: Introduction*. 58 pp. HMSO, Edinburgh.
- KAUFFMAN, D.H. 1906. *Cortinarius* as a mycorrhiza producing fungus. *Botanical Gazette* 42: 208 - 214.
- LEE, S.S. & ALEXANDER, I.J. 1994. The response of seedlings of two dipterocarp species to nutrient additions and ectomycorrhizal infection. *Plant and Soil* 163: 299 - 306.
- LEE, S.S., ALEXANDER, I.J., MOURA-COSTA, P. & YAP, S.W. 1996a. Mycorrhizal infection of dipterocarp seedlings in logged and undisturbed forests. Pp. 157-164 in Appanah, S. & Khoo, K.C. (Eds.) *Proceedings of the Fifth Round-Table Conference on Dipterocarpaceae*. 7-10 November 1994, Chiang Mai, Thailand. FRIM.
- LEE, S.S., WATLING, R. & TURNBULL, E. 1996b. Ectomycorrhizal fungi as possible bioindicators in forest management. Pp. 63-68 in Norhara Hussein, Bacon, P.S. & Khoo, K.C. (Eds.) *Proceedings of the Third Conference on Forestry and Forest Products Research Vol. 1 (CFFPR)* 1995, 3-4 October 1995, FRIM, Kpong.
- MANOJARAN, N., LAFRANKIE, J.V., KOCHUMMEN, K.M., QUAH, E.S., KLAHN, J.E., ASHTON, P.S. & HUBBELL, S.P. 1992. *Stand table and distribution of species in the fifty hectare research plot at Pasoh Forest Reserve*. 454 pp. FRIM Research Data No.1.
- NORANTAHMAD. 1996. The role of mycorrhizas in the regeneration of some Malaysian lowland rain forest trees of Jengka. *Journal of Tropical Forest Science* 8(4): 441- 448.
- RENVALL, R. 1995. Community structure and dynamics of wood rotting Basidiomycetes on decomposing conifer trunks in North Finland. *Karstenia* 35: 1 - 51.

- RUTTER, G. & WATLING, R. 1997. Taxonomic and floristic notes on some larger Malaysian fungi II. *The Malayan Nature Journal* 50(4): 229 - 234.
- SAIFUDDIN SULAIMAN, ABDUL RAHIM NIK & LAFRANKIE, J.V. 1994. *Pasoh climatic summary (1991-1993)*. FRIM Research Data No. 3.
- SOEPADMO, E. 1978. Introduction to the Malesian IBP Synthesis Meetings. *The Malayan Nature Journal* 30(2): 119 - 124.
- WATLING, R. 1981. Relationship between macromycetes in the development of higher plant communities. Pp. 427-459 in Carroll, G. & Wicklow, D. (Eds.) *Fungal Community Origins and Role of Fungi in the Ecosystem*. Marcel Dekker, New York.
- WATLING, R. 1994. Taxonomic and floristic notes on some larger Malaysian fungi. *The Malayan Nature Journal* 48(2) : 67 - 78.
- WATLING, R. 1995. Assessment of fungal diversity: macromycetes, the problems. *Canadian Journal of Botany* 73 (Suppl. 1): S15-S24.
- WATLING, R. & LEE, S.S. 1995. Ectomycorrhizal fungi associated with members of the Dipterocarpaceae in Peninsular Malaysia - I. *Journal of Tropical Forest Science* 7(4): 657 - 669.
- WATLING, R. & LEE, S.S. Ectomycorrhizal fungi associated with members of the Dipterocarpaceae in Peninsular Malaysia - II. *Journal of Tropical Forest Science* (in press).
- YAZID, M.S., LEE, S.S. & LAPYRIE, F. 1994. Growth stimulation of *Hopea* spp. (Dipterocarpaceae) seedlings following ectomycorrhizal inoculation with an exotic strain of *Pisolithus tinctorius*. *Forest Ecology and Management* 67: 339 - 343.

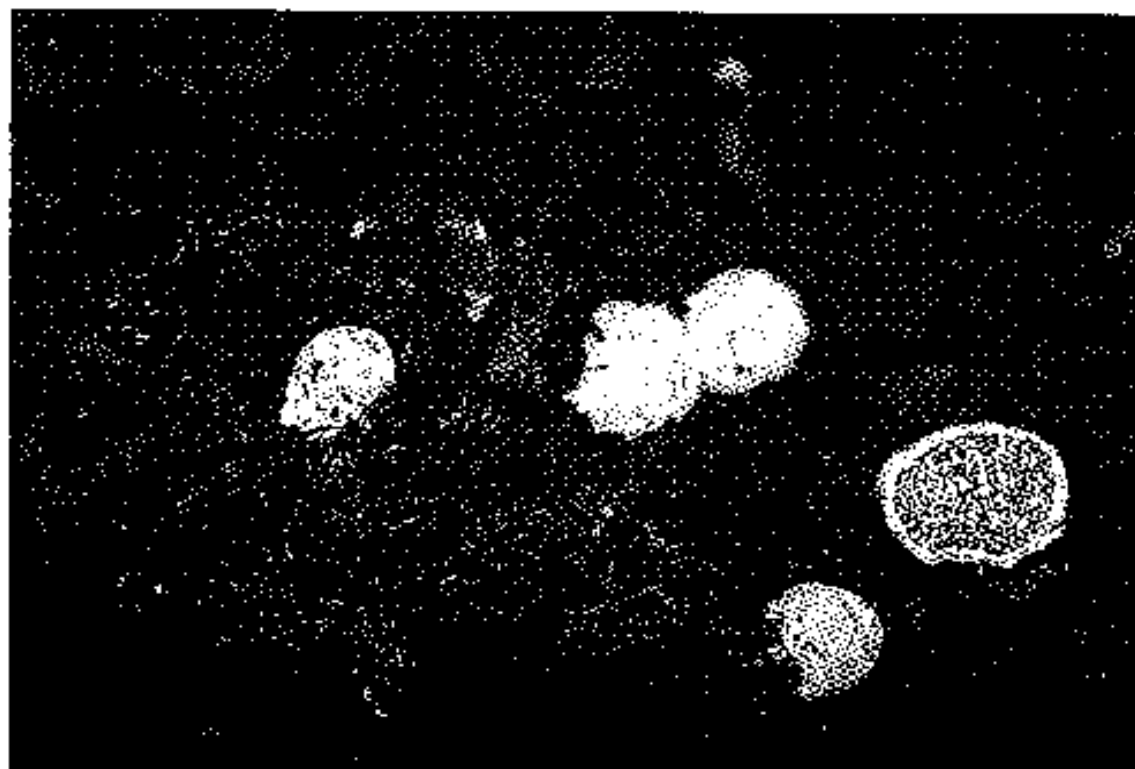


Plate 1. The hypogeous fungus, *Horakiella* sp. buried among the buttresses and soil at the base of trees. This fungus was found in both the logged and unlogged forest at Pasoh. Photo: S.S. Lee



Plate 2. A member of the dominant genus, *Russula*, found in Pasoh. This species has not yet been identified. Photo: S.S. Lee



Plate 3. Different developmental stages of *Amanita* cf. *virginia* found in the unlogged forest in Pasoh. Photo: S.S. Lee

PRELIMINARY OBSERVATIONS ON THE SPECIES DIVERSITY OF PALMS IN PASOH FOREST RESERVE, NEGRI SEMBILAN

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A study on the species richness and abundance of palms is currently being undertaken in the lowland forest of Pasoh Forest Reserve, Negri Sembilan. The objective of the study is to examine the diversity of palms within and between undisturbed forest and forest logged approximately 40 years ago. Preliminary observations revealed that edaphic factors have an influence on palm species diversity in the unlogged forest. However, other factors need to be examined to determine the differences that were observed within a particular soil type. The logged forest is located on lateritic soil, and is less diverse than that in the unlogged forest on similar soil. This may indicate that forest disturbance has had a long-term effect on the diversity of palms in the study area. However, further work is necessary to determine if there are other factors that contribute to the reduction of the richness and abundance of palm species.

Keywords: Palms - species diversity - logged forest - unlogged forest

Introduction

The Pasoh project was set up to gather from one carefully selected site data which would be relevant to the general question of whether logging of the lowland dipterocarp forests of South East Asia has deleterious long-term effects on their biodiversity. The palms in Pasoh Forest Reserve are a particularly interesting group to study for three reasons. Firstly, they are diverse in habit. Some, such as the rattans, are climbers, others are acaulescent understorey species, and still others are arborescent species. Species in these different habit groups may be affected to different extents by logging. Secondly, mature individuals grow at a relatively constant rate, characteristic of each particular species. Once the growth rate is known, the age of an individual can be determined relatively easily. This is of obvious interest in studying species composition at the present day of forest logged at a known date in the past. Thirdly, some species of palms, in particular the rattans, have considerable commercial

value. This makes it possible to quantify the value obtained by sustainable exploitation of palms in unlogged forest. Furthermore, the palms at Pasoh are taxonomically well known and, except for seedlings of some species of *Licuala*, are readily identifiable, facilitating the completion of full censuses.

The Pasoh Forest Reserve contains, in one broadly similar ecological environment, unlogged forest, logged forest regenerating after selective logging, and a small area of forest regenerating after clear felling. The whole area has been described by Kochummen *et al.* (1990) and Manokaran and La Frankie (1990). The unlogged forest contains a 50-ha (1000 × 500 m) demographic plot in which all trees with a diameter greater than 1 cm diameter at breast height (dbh) have been identified, mapped and entered into a database. The logged forest is located about 1.6 km south-west of the 50-ha plot, on slopes which were logged in 1955 under the Malayan Uniform System (MUS). The clear-felled forest consists of a strip 100 × 20 m from which unlogged forest was totally cleared for a biomass study by Japanese scientists in the early 1970's (Kira 1978). It had then been left to regenerate naturally.

Most of the disturbed forest is on lateritic soils which are not subject to flooding. Lateritic soils, and soils derived from shale, occur also in the more elevated parts of the 50 ha plot, but much of this plot is relatively low-lying and of alluvial soils. Two types of disturbed forest can be distinguished: those that are reasonably well-drained and those that are prone to flooding. Soil factors are known to influence the distribution and abundance of certain species of palms (*e.g.*, Saw 1995). It was therefore necessary to examine species diversity on different types of soil within the unlogged forest before attempting to make valid comparisons between the unlogged forest, the logged forest and the clear-felled forest.

As a first step, species inventory lists were compiled for the unlogged forest on the different soil types and for the two types of disturbed forest. Preliminary results from these studies are presented here. More elaborate analyses will follow later, when the data are more complete.

Methods

Plot Layout

Four soil types occur within the 50-ha plot of unlogged forest: laterite, shale, alluvium A (well-drained) and alluvium B (prone to flooding) (Adzmi Yaacob & Suhaimi Wan Chik 1996). On each soil type, four quadrats each measuring 0.12 ha were established and the palms therein assessed. These quadrats were large enough to contain at least eight species of palms per quadrat, which is the minimum necessary for meaningful plant community studies in the tropical rain forest (Swaine, pers. comm.). A total of 16 quadrats will be demarcated in the logged forest. The shape of the quadrats was designed to ensure that each quadrat was confined to a single soil type and did not overlap a boundary between different soil types. Quadrats were positioned to include areas with different densities of trees, degrees of slope and aspect.

Sampling

Palms growing in a cluster or solitarily are each considered as an individual. Data collected are species name and the growth classes of each stem. The growth classes, adapted from Stockdale (1994) are as follows:

- seedling - stemless, with seedling leaf
- juvenile - stemless, with older leaf morphology (for climbing palms, with short stem but without climbing organ)
- intermediate - a small/short stem (for rattans, with climbing organs)
- mature - a big/long stem (for rattans, with climbing organs).

Results and observations

Unlogged Forest

Thirty-two species of palms belonging to ten genera were recorded. The species richness and species abundance of palms differ between soil types. There are more species in areas located on alluvial soils that are prone to flooding (Alluvium B) (Table 1). Twenty-nine of the 32 species assessed can be found on these soils. Here the density of palms is estimated at 7,228 individuals per hectare. Well-drained alluvial soil (Alluvium A) has the least number of palm species (16 species, 2,164 individuals/ha). It was observed that there was much wild pig (*Sus scrofa*) activity in this area. Pigs uproot palm seedlings as they forage in the leaf litter and surface soil, churning up the soil to a considerable depth. They also utilise palm leaves as bedding in the construction of 'nests'. Some palm species, particularly acaulescent individuals of *Licuala*, may be effectively defoliated by pigs. It appears that pig activity has increased dramatically in the 50 ha plot (Saw, pers. comm.) and undoubtedly this will have some effect on the populations of palms. This will, however, require further assessment.

Forest on elevated areas with soils derived from laterite and shale, both have 24 palm species. The abundance of palms on these soil types are 6,296 and 10,307 individuals per hectare, respectively (Table 2). The abundance of palms on shale is due to the large number of individuals of *Daemonorops verticillaris*, which is also abundant on other soil types. More than 60 per cent of the palm individuals in the unlogged forest belong to this solitary climbing palm species. Other species that are found in great abundance are *Calamus diepenhorstii* which has a high concentration on the seasonally flooded alluvial soils, and *Pinanga simplicifrons*, which prefers lateritic soils.

A few species show a marked preference for a particular soil type. *Caryota mitis*, *Daemonorops grandis*, *D. macrophylla* and *Salacca affinis* are only found on the flooded alluvial soil. *Iguanura wallichiana* subsp. *wallichiana* is also found on this soil type, but a small number of individuals of this species exist on the lower slopes on shale. *Daemonorops kunstleri* and *Pinanga disticha* are not found on alluvial soils.

Growth forms

There are three species of arborescent palms, 18 species of climbing palms and 11 species of acaulescent, short-stemmed palms in the understorey of the unlogged forest (Table 1). Altogether there are 22 species belonging to the Calamoideae sub-family, including all the climbing palms or rattans. This group is most abundant on all the soil types (Table 2), making up about 56 per cent of the total number of species and about 90 per cent of the number of individuals.

Table 1. Species of palms and their abundance (individuals/ha) on the four soil types in the unlogged forest of Pasoh Forest Reserve

Palm species	Laterite	Shale	Alluv. A	Alluv. B
<u>Acaulescent and short-stemmed undergrowth palms</u>				
<i>Calamus castaneus</i>	25	58	14	141
<i>Daemonorops culcarpa</i>	219	294	47	95
<i>D. kunsteri</i>	17	17	0	0
<i>Iguanura wallichiana</i> subsp. <i>wallichiana</i>	0	2	0	50
<i>Licuala ferruginea</i>	108	144	28	112
<i>L. kunsteri</i>	36	33	0	33
<i>L. longipes</i>	106	88	42	41
<i>L. triphylla</i>	3	0	0	8
<i>Pinanga disticha</i>	17	14	0	0
<i>P. simplicifrons</i>	419	144	33	8
<i>Salacca affinis</i>	0	0	0	41
Number of Species	9	9	5	9
Individuals/ha	945	789	164	529
<u>Moderate to tall arborescent palms</u>				
<i>Caryota mitis</i>	0	0	0	67
<i>Nenga pumila</i> var. <i>pachystachya</i>	0	0	0	4
<i>Oncosperma haridum</i>	19	0	0	8
Number of Species	1	0	0	3
Individuals/ha	19	0	0	79
<u>Moderate to high climbing palms</u>				
<i>C. densiflorus</i>	0	83	0	0
<i>C. dipeunhorstii</i>	275	386	585	746
<i>C. insignis</i> var. <i>insignis</i>	133	128	339	151
<i>C. javensis</i>	14	14	0	242
<i>C. laevigatus</i>	94	44	25	425
<i>C. speciosissimus</i>	64	50	6	4
<i>C. tumidus</i>	53	53	28	21
<i>D. didymorphylla</i>	0	3	0	41
<i>D. gemiculata</i>	261	278	6	117
<i>D. grandis</i>	0	0	0	16
<i>D. hystrix</i>	219	328	22	79
<i>D. leptopus</i>	6	0	0	16
<i>D. macrophylla</i>	0	0	3	246
<i>D. micracantha</i>	8	128	51	21
<i>D. verticillaris</i>	4158	7992	928	4475
<i>Korthalsia laciniata</i>	8	14	0	4
<i>K. rigida</i>	28	11	6	4
<i>K. scortechinii</i>	11	6	0	12
Number of Species	24	24	16	17
Individuals/ha	5332	9518	2000	6620

Table 2. The number of species and individuals per hectare for different growth forms of palms on four soil types in the unlogged forest at Pasoh Forest Reserve

Soils	Acaulescents		Aborescents		Climbers	
	Species	Number	Species	Number	Species	Number
Laterite	9	945	1	19	14	5332
Shale	9	789	0	0	15	9518
Alluvium A	5	164	0	0	11	2000
Alluvium B	9	529	3	79	17	6620
All soil types	11	2427	3	98	18	23470

Growth stages

More than 60 per cent of the individuals found in the unlogged forest are still in the seedling stage (Table 3). The ratio of seedlings to mature palms is high (23.6 seedlings per mature palm) on shale and low (13.2 seedlings per mature palm) on the well-drained alluvial soil (Alluvium A). On average, there are only 222 mature palms per hectare.

Table 3. The number of individuals per hectare and ratio of different growth stages to mature palms in the unlogged forest of Pasoh Forest Reserve

Soil type		Seedlings	Juveniles	Intermediates	Mature palms	Total
Laterite	no.	3947	1802	333	214	6296
	ratio	18.4	8.4	1.6	1	
Shale	no.	6878	2872	266	291	10907
	ratio	23.6	9.9	0.9	1	
Alluvium A	no.	1430	485	148	101	2164
	ratio	13.2	4.4	1.4	1	
Alluvium B	no.	4487	2110	319	282	7228
	ratio	15.9	7.5	1.2	1	

Variation within soil type

It was observed that within one soil type, the numbers of species and individuals varied. This was obvious on laterite, shale and alluvial soil where there was a difference of seven species (laterite and shale) and six species (alluvial soil) between the quadrats with the greatest and least number of species (Table 4). The variation between the greatest and least number of species in quadrats located on flood-prone alluvial soil was four.

Table 4. Variation in species number within one soil type in the unlogged forest. Figures given for quadrats measuring 0.12 ha with greatest and least number of species

Soil Types	Quadrat with greatest no. of species		Quadrat with least no. of species	
	No. of Species	No. of individuals	No. of Species	No. of individuals
Laterite	22	709	15	662
Shale	24	2162	17	649
Alluvium A	14	412	8	194
Alluvium B	28	821	24	914

Logged forest

Only two (A and B) of the five one hectare blocks in the logged forest were assessed. For comparison purposes, only quadrats located on lateritic soils were used in the analysis. Fourteen palm species were found in the two blocks (Table 5), four of which are understorey species and ten climbing palms. There are more species in Block B than in Block A. However, there are more individuals in Block A. The number of species per quadrat varied from nine to 12.

Table 5. The number of species and individuals (per hectare) for different palm growth stages in Blocks A and B of the logged forest of Pasoh Forest Reserve

	BLOCK A					BLOCK B				
	Seed-lings	Juveniles	Inter-mediate	Mature	Total	Seed-lings	Juveniles	Inter-mediate	Mature	Total
<u>Acaulescent and short-stemmed undergrowth palms</u>										
<i>Licuala ferruginea</i>	0	0	0	0	0	0	15	28	3	46
<i>L. kunthii</i>	0	8	0	0	8	0	10	18	0	28
<i>L. longipes</i>	4	4	8	0	16	0	0	5	2	5
<i>Pinanga simplicifrons</i>	0	0	0	0	0	0	2	0	0	2
Subtotal:	4	12	8	0	24	0	27	49	5	81
<u>Moderate to high climbing palms</u>										
<i>Calamus densiflorus</i>	29	13	0	0	42	7	17	0	0	24
<i>C. diepenhorstii</i>	8	8	8	0	24	20	63	2	0	85
<i>C. insignis</i> var. <i>insignis</i>	42	33	0	21	96	3	10	8	0	21
<i>C. javensis</i>	4	4	0	0	8	0	2	0	0	2
<i>C. laevigatus</i>	0	4	0	4	8	22	52	0	0	74
<i>C. speciosissimus</i>	0	17	0	0	17	3	7	2	0	12
<i>C. tumidus</i>	4	0	0	0	4	3	0	0	0	3
<i>Daemonorops geniculata</i>	0	0	0	0	0	8	27	7	0	42
<i>D. hystrix</i>	17	25	0	0	42	18	40	7	0	65
<i>D. verticillaris</i>	313	271	4	0	588	175	172	3	5	355
Subtotal:	417	375	12	25	899	259	390	29	5	683
No. of species:	8	10	3	2	11	9	12	9	3	14
Total individuals:	421	388	21	25	853	260	415	78	10	764

Impact of forest disturbance on palm species diversity

Comparisons were made between the quadrats on lateritic soils in the unlogged forest and the logged forest. The number of species and their abundance in the logged forest are much less than that in the unlogged forest. There are 812 palm individuals per hectare belonging to 14 palm species (in four genera) in the logged forest compared to 6,296 individuals per ha from 24 species (in six genera) in the unlogged forest (Table 6).

Table 6. The species of palms and their abundance (individuals/ha) in the unlogged and logged forests located on lateritic soils in Pasoh Forest Reserve

	Unlogged	Logged
<u>Acaulescent and short-stemmed undergrowth palms</u>		
<i>Calamus castaneus</i>	25	0
<i>Daemonorops calcarpa</i>	219	0
<i>D. hunsleri</i>	17	0
<i>Licuala ferruginea</i>	103	23
<i>L. hunsleri</i>	36	18
<i>L. longipes</i>	106	11
<i>L. triphylla</i>	3	0
<i>Pinanga disticha</i>	17	0
<i>P. simplicifrons</i>	419	1
Number of species	9	4
Individuals/ha	945	53
<u>Moderate to tall arborescent palms</u>		
<i>Oncospermum horridum</i>	19	0
Number of species	1	0
Individuals/ha	19	0
<u>Moderate to high climbing palms</u>		
<i>C. densiflorus</i>	0	38
<i>C. diepenhorstii</i>	275	55
<i>C. insignis</i>	133	59
<i>C. javensis</i>	14	5
<i>C. laevigatus</i>	94	41
<i>C. speciosissimus</i>	61	15
<i>C. timidus</i>	53	4
<i>D. geniculata</i>	261	21
<i>D. hystrix</i>	219	54
<i>D. leptopus</i>	6	0
<i>D. microcarpa</i>	8	75
<i>D. verticillaris</i>	4158	472
<i>Korthalsia laciniata</i>	8	0
<i>K. rigida</i>	28	0
<i>K. scortechinii</i>	11	0
Number of species	14	11
Individuals/ha	5332	832
Total no. of species	24	14
Total no. of individuals/ha	6296	887

The number of individuals for all the growth stages is much smaller in the logged forest than in the unlogged forest. However, in terms of ratios, the proportion of juveniles and intermediates to mature palms is much higher in the logged forest (Table 7). *Daemonorops verticillaris* is the most abundant palm species in both forest types with seedlings and juveniles making up about 97 per cent of the individuals. The second most important palm in terms of abundance in both forest types is *Calamus diepenhorstii*. Two species, *D. kunstleri* and *P. disticha* are found on lateritic soil in the unlogged forest but are absent in the logged forest.

Table 7. Abundance (number per ha) of individuals and ratio of different growth stages to mature palms in two forest types at Pasoh Forest Reserve

Forest Types		Seedlings	Juveniles	Intermediates	Mature	Total
Unlogged forest	No.	3947	1802	933	214	6296
	ratio	18.4	8.4	1.6	1	
Logged forest	No.	340	402	49	18	809
	ratio	18.9	22.3	2.8	1	

Discussion

Forty-three species of palms from 15 genera were found in the lowland forest of Pasoh. Nine species present but not included in the quadrats are *Arenga oblongifolia*, *Calamus ornatus*, *C. scipionum*, *C. oxleyanus*, *Daemonorops angustifolia*, *Eleiodoxa conferta*, *Korthalsia flagellaris*, *Orania sylvicola*, *Pinanga malaiana*, *Pholidocarpus macrocarpus* and *Plectocomiopsis geminiflora*.

Preliminary results show that species richness and species density vary not only between the unlogged and logged forest, but also within a forest type. The difference in number of species and individuals in an unlogged forest and a forest logged about 40 years previously, is obvious. Log production records from the area which could be related to the intensity of the logging operation are not available. The study should thus look into other possible factors that could have contributed to the decrease in the palm species number and densities.

In terms of the various palm growth forms, the most obvious differences between the unlogged and logged forest is a marked decrease in the number of species of acaulescent and short-stemmed undergrowth species and an absence of tree palms in the logged forest. The statistical significance of these differences has not yet been tested. The moderate to high-climbing rattans seem to fare better. One species, *Calamus densiflorus*, is present in the logged forest but not in the unlogged forest; there is no obvious explanation for this.

Soils seem to have an influence on the diversity of palms in the unlogged forest. However, it was observed that within a soil type variation still exists. These differences need to be examined before we can determine the factors that are involved. Analyses of soil physical and chemical properties are necessary, but other factors such as the presence of light gaps, pig activity or other non-soil factors may be involved.

Further work needs to be conducted before thorough analyses of the data can be carried out. The relationship of tree densities and canopy cover to palm species distribution needs to be examined. Information on wild pig activity and other information related to the dispersal of palm seeds and their survival will assist in the understanding of palm species diversity.

A quadrat on a strip of forest clear-felled some 20 years ago has also been assessed. This succession plot can provide valuable information on the invasion of a clear-felled forest by palm species. An adjacent plot will be assessed to compare the degree of invasion and succession. Growth studies in these plots and those in the unlogged forest should provide a good estimate of the function of time in the diversity of palms in Pasoh.

This study is the first of its kind in Peninsular Malaysia. Information gathered will be useful for future studies on palm ecology. Research plots established in Pasoh will be reassessed to look at the changes in diversity in three to five years. Studies on a few commercial rattan species, such as *D. verticillaris* and *C. diepenhorstii* will be undertaken.

The methods used in this study may be adapted and/or modified for similar studies in the hill forests. Studies on the effect of different degrees of forest disturbance on the diversity of palms are expected to provide valuable indicators for environmental impact assessment of tropical rain forests.

Conclusion

The preliminary results indicate that forest logging has an impact, detectable even after 40 to 50 years, on the species richness and species density of palms in the Pasoh Forest Reserve. However, further work needs to be carried out to determine other influential factors, as variation in palm diversity was also observed within a forest type. Soils were observed to have an influence on species diversity. In-depth studies to correlate these factors are necessary.

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References

- ADZMI YAACOB & SUHAIMI WAN CHIK. 1996. Detailed soil survey report of part of the 50 ha plot in Pasoh Forest Reserve. Soil Science Unit, FRIM (unpublished).
- KIRA, T. 1978. Community architecture and organic matter dynamics in tropical lowland forests of Southeast Asia with special reference to Pasoh, West Malaysia. Pp. 561-590 in Tomlinson, P.B. & Zimmerman, M.H. (Eds.) *Tropical Trees as Living Systems*. Proceedings of the Cobolt Symposium. Cambridge University Press, Cambridge.

- KOCHUMMEN, K.M., LA FRANKIE, J.V. & MANOKARAN, N. 1990. Floristic composition of Pasoh Forest Reserve, a lowland rain forest in Peninsular Malaysia. *Journal of Tropical Forest Science* 3(1): 1-13.
- MANOKARAN, N. & LA FRANKIE, J.V. 1990. Stand structure of Pasoh Forest Reserve, a lowland rain forest in Peninsular Malaysia. *Journal of Tropical Forest Science* 3(1):14-24.
- SAW, L.G. 1995. *Taxonomy and Ecology of Licuala in Peninsular Malaysia*. Ph.D. thesis. The University of Reading.
- STOCKDALE, M.C. 1994. *Inventory methods and ecological studies relevant to the management of wild populations of ruffian*. Ph.D. thesis. University of Oxford.

THE EFFECT OF SELECTIVE TIMBER LOGGING ON THE DIVERSITY OF WOODY CLIMBERS AT PASOH

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The diversity of woody climbers at Pasoh Forest Reserve is very high with 35 families being represented in the lowlands and up to 40 families being present in the hills. The total number of species (excluding small climbers, rattans and herbaceous vines) found in the area was 220. Woody climber species-richness was not significantly different between the logged and the unlogged forests sites, but there was a strong difference in the frequency distribution of various size classes in the logged and unlogged rainforest. Large climbers are absent in the logged sites, but in these sites there is an abundance of small sized stems with a high proportion of ramified stems. The greatest diversity is found in plots with a large number of stems (at their base) irrespective of the disturbance history. The species composition of logged and unlogged plots is quite different. Families dispersed by birds or mammals are under-represented in logged rain forest sites. It is recommended that if it is necessary to remove climbers to prevent them pulling down other trees during log extraction then the cutting of climbers should be restricted to a few individual commercially important trees before and after felling. Otherwise, these practices could affect the ecosystem for a considerable period by promoting fast-growing liana species at the expense of others usually represented by a few individuals per hectare.

Keywords: Liana - logged rain forest - distribution

Introduction

Climbers are an important component of the structure and dynamics of tropical rain forests but their significance in tropical rain forest ecology has only recently begun to be investigated in detail (Putz 1984, 1985, Putz & Chai 1987), possibly because of the practical difficulty of reaching them. The pattern of distribution, means of dispersal, and other ecological interactions of most species remain unknown (Gentry 1991). Climbers interact both with the trees on which they find support, and with other plants, as well as with elements of the fauna by, for example, providing natural pathways through the canopy. However, the available data on woody climbers is very scant, and as a group, they present considerable taxonomic problems. A few families of lianas have been revised in the *Flora Malesiana*, but more information is needed to be able to identify many others to species level.

The primary objectives of this study were firstly, to document the species-richness of woody climbers at Pasoh Forest Reserve and in the surrounding forest estate, and secondly, to determine the effect of selective timber logging on that diversity. This was undertaken by comparison of the species composition and size classes present in two sites, one pristine and one logged, approximately 40 years ago. A subsidiary objective

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of the work was to suggest ways of minimising any adverse impact on climbers by management practices, bearing in mind that the logging system used in the past differs from the one used today, that Pasoh is not a very representative forest type, and that most logging is being conducted in hill forest rather than in the lowlands. However, despite these limitations some results have been obtained which have relevance to extraction practices in all forest sites.

The present study makes use of original data as well as information gathered by J.V. LaFrankie in 1990 and the late A.H. Gentry in the 50-hectare plot established under the sponsorship of the Smithsonian Institution.

Sites, materials and methods

This study was carried out in the Pasoh Forest Reserve in Negri Sembilan, 180 km south-east of Kuala Lumpur, in the remnants of a lowland rain forest surrounded by a buffer zone of logged rain forest. The use of rope techniques to gain access to the canopy, combined with the natural skills of the orang asli have allowed the application of a different methodology for assessing the diversity of climbers in primary forest and to evaluate the extent of their loss in logged plots. Existing data on lianas are mostly based on 0.1-ha data sets of plots for lianas >2.5 cm in diameter at breast height (dbh). The generally clumped distribution of lianas is a useful characteristic when conducting investigations on a small scale, but not all families of lianas are clumped (Putz 1984, Gentry 1985). Thus, in order to better document the diversity of lianas and to assess the effect of logging on this group, a different methodology was chosen. Following Gentry's investigation on the size of sampling plots, the size of the plot was enlarged to 100 × 50 m, corresponding to 0.5-ha, and several plots were randomly chosen. The lianas, between 1.0 and 2.0 cm dbh, were considered in 100 × 10 m plots to assess and inventory small woody climbers which rarely reach big diameter sizes. Individual plants were defined as stems with their own root system.

Results

Only the data from six 0.5-ha plots have been processed. Plots numbered 1 to 3 in the primary rain forest yielded 1,012 lianas and plots A, C and E in the logged forest yielded 904 lianas, that is to say, data on 1,916 climbers are presented.

Gentry, working in Pasoh in 1990, recorded the presence of 56 or 57 species of climbers (excluding small climbers, belonging to the families Araceae, Asclepiadaceae, Palms, etc.). The present study has found over 220 species representing 35 families in the lowland compartment and 40 families in the hill forest. These figures are fairly high in comparison to the other permanent lowland study sites, such as Barro Colorado Island, Panama, and Mokokou, Gabon. It is expected that overall climber species-richness at Pasoh will be around 300 species, including small climbers, herbaceous vines and the species occurring in the neighbouring hills.

Number of species per family in Pasoh

The three major families were found to be Annonaceae (32 species), Connaraceae (26 species) and Leguminosae (24 species) (Figure 1). Five families are moderately species-rich: Moraceae (14 species), Rubiaceae (14 species), Apocynaceae (14 species), Convolvulaceae (11 species) and Menispermaceae (eight species). Some families, such as the Loganiaceae, Celastraceae and Myrsinaceae have fewer representatives, but a large number of families, such as Linaceae, Sterculiaceae and Combretaceae, are only represented by one or two species. A few families, such as Euphorbiaceae or Moraceae, have species with a variable status. For example, one species of Euphorbiaceae may be a shrub or have the distinct features of a climber depending upon habitat circumstances, while some *Ficus* are both hemiepiphytic and climbing.

A putative new species of Connaraceae was found and new records of locality for Peninsular Malaysia were established.

Number of individuals per family in Pasoh

In Figure 2 it can be seen that although the most species-rich families are also those with the greatest number of individual specimens, a few families with one or a few species also have a large number of individual stems. These include the Sterculiaceae (*Byttneria maingayi*), Combretaceae (*Combretum nigrescens*), Verbenaceae (*Sphenodesme pentandra*) and Rhamnaceae. Among the Leguminosae, one species (*Caesalpinia parviflora*), is very abundant, and it produces millions of seedlings in Pasoh. In the Annonaceae, *Mitrella kentii* is also very abundant and it shows a distinct clumped distribution. *Dichapetalum griffithii* is also very abundant as a small climber or at younger stages (seedlings) but it is very rare to find a large specimen. A few families, such as the Aristolochiaceae and the Dichapetalaceae are only represented by one to two stems in all the six 0.5-ha plots.

Size structure in unlogged and logged plots

The number of individuals with the same dbh in the three primary plots shows the same trend curve in spite of the different overall number of stems in the samples varying from around 250 to 500 (Figure 3). These plots have a large number of small sized stems but they also have some large sized climbers reaching to between 20 and 35 cm dbh. The three logged plots show a similar trend curve, but with fewer large climbers (Figure 4). One can also observe great heterogeneity in the number of lianas in each plot.

The preliminary results suggest great heterogeneity in the distribution of woody climbers in both unlogged and logged rain forest plots. However, the distribution of size classes in the primary rain forest differs significantly from that of the secondary forest as the latter lacks the large mature climbers.

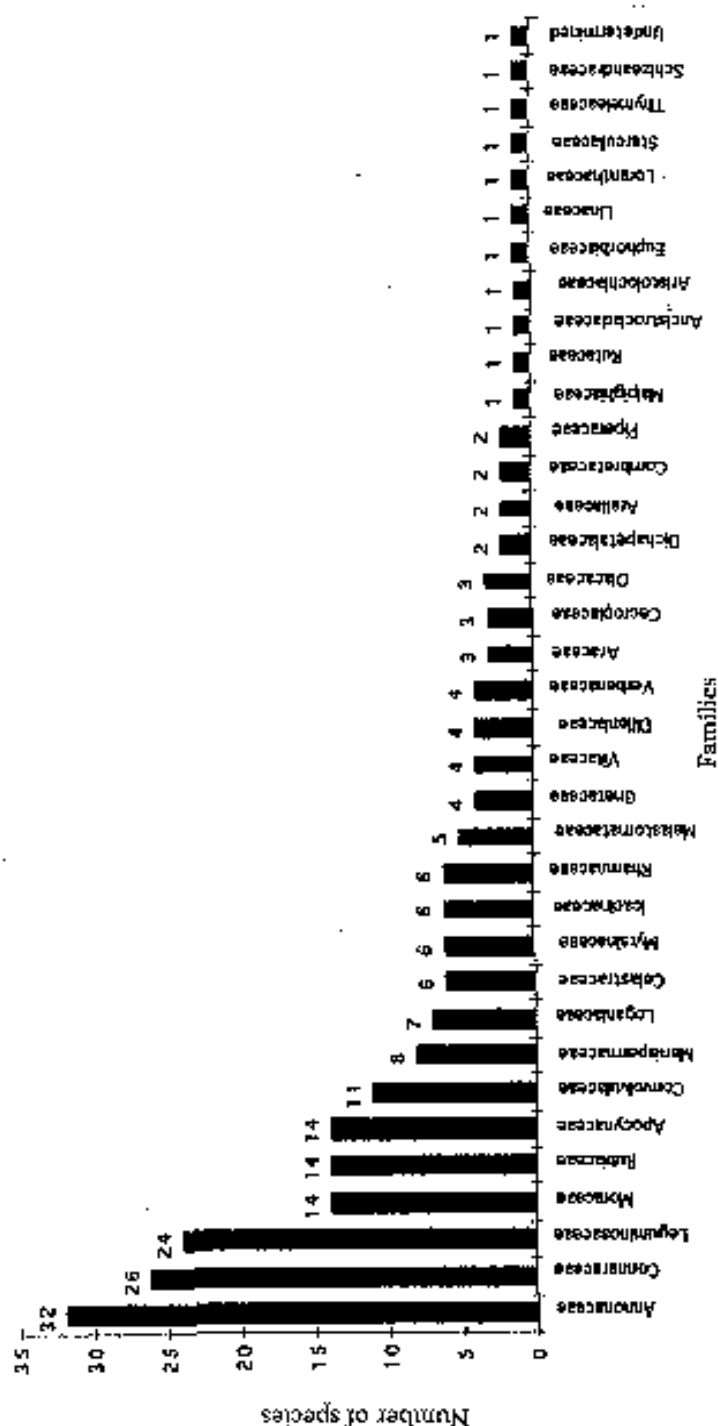


Figure 1. Number of species per family in eight half hectare plots, Pasoh Forest Reserve, Negri Sembilan

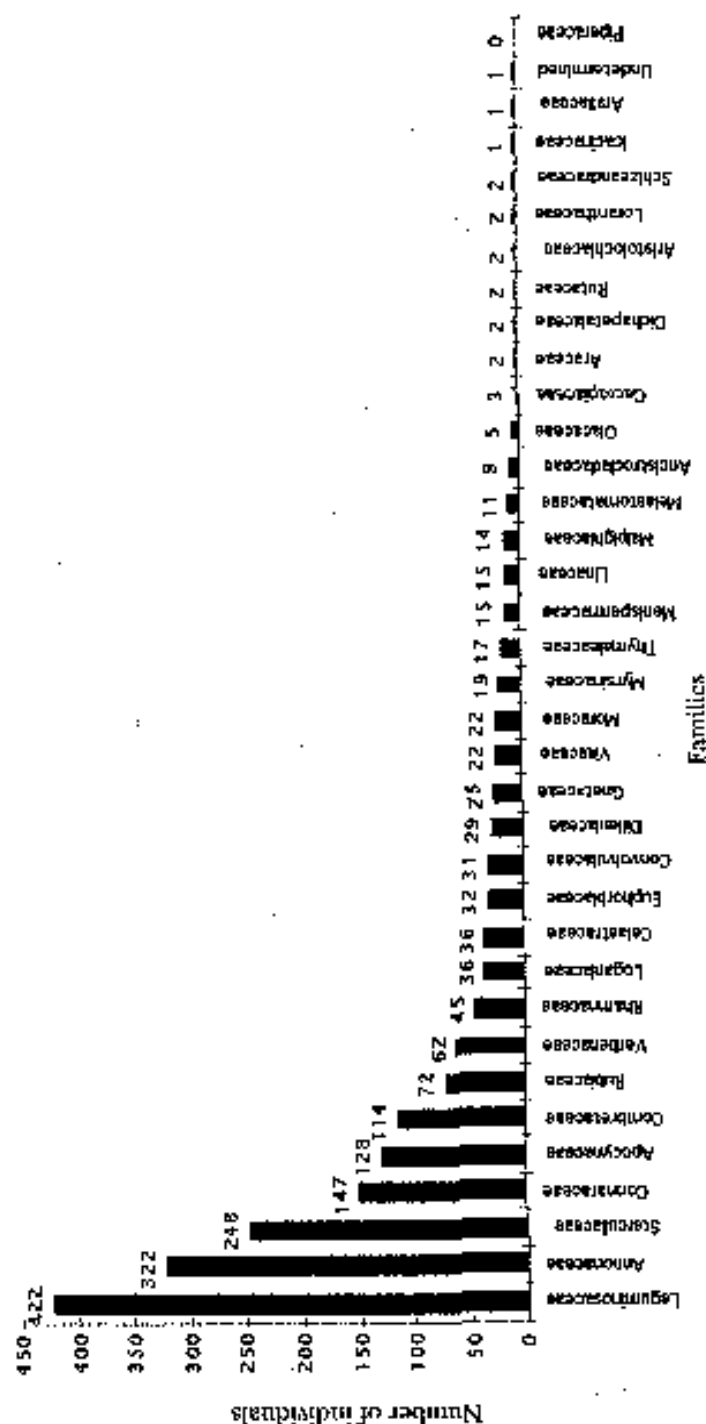


Figure 2. Number of individuals per family in eight half hectare plots, Pasoh Forest Reserve, Negri Sembilan

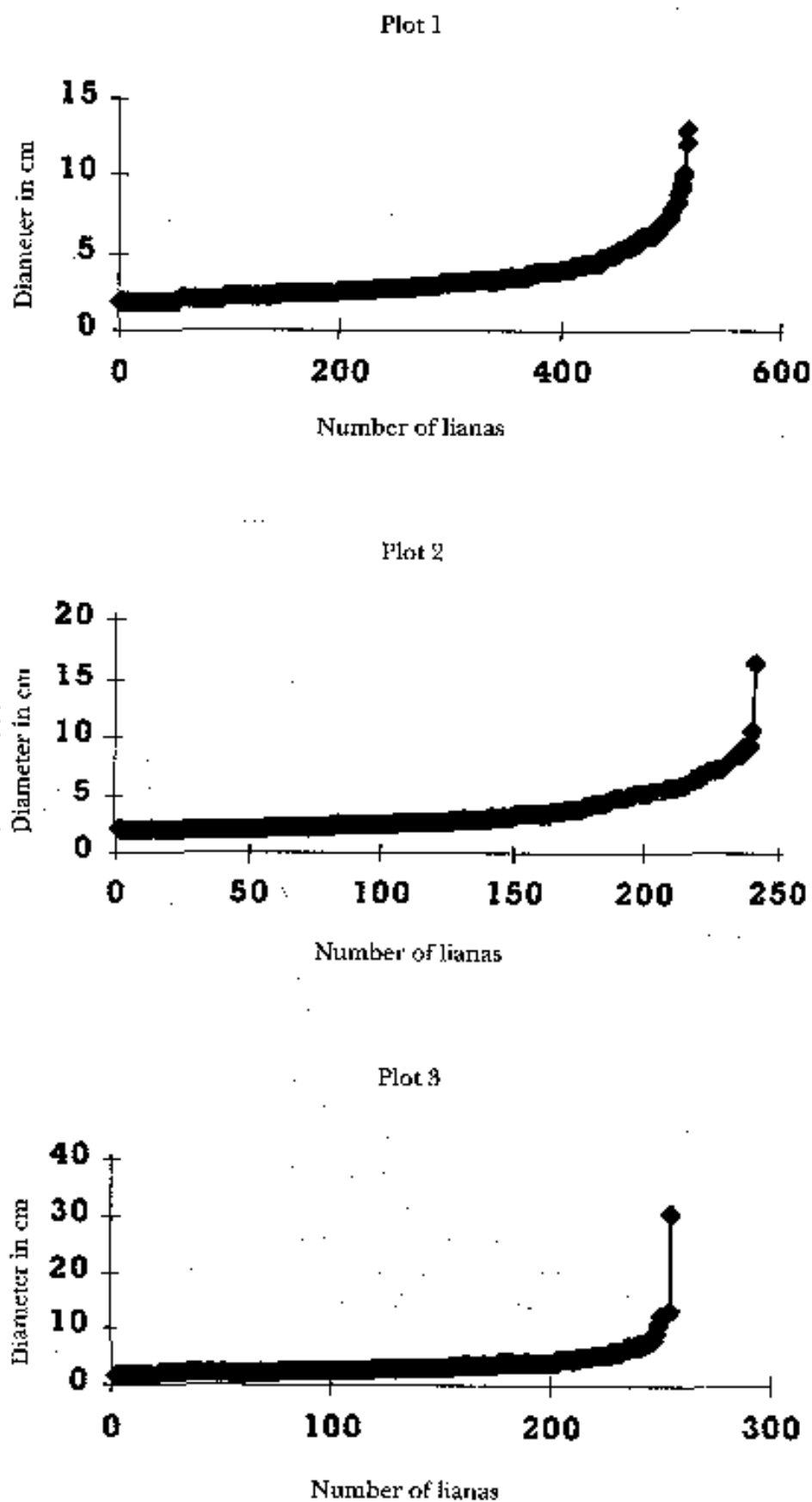


Figure 3. Size structure of climbers over 2 cm dbh in the unlogged plots, 1, 2 and 3, Pasoh Forest Reserve, Negri Sembilan

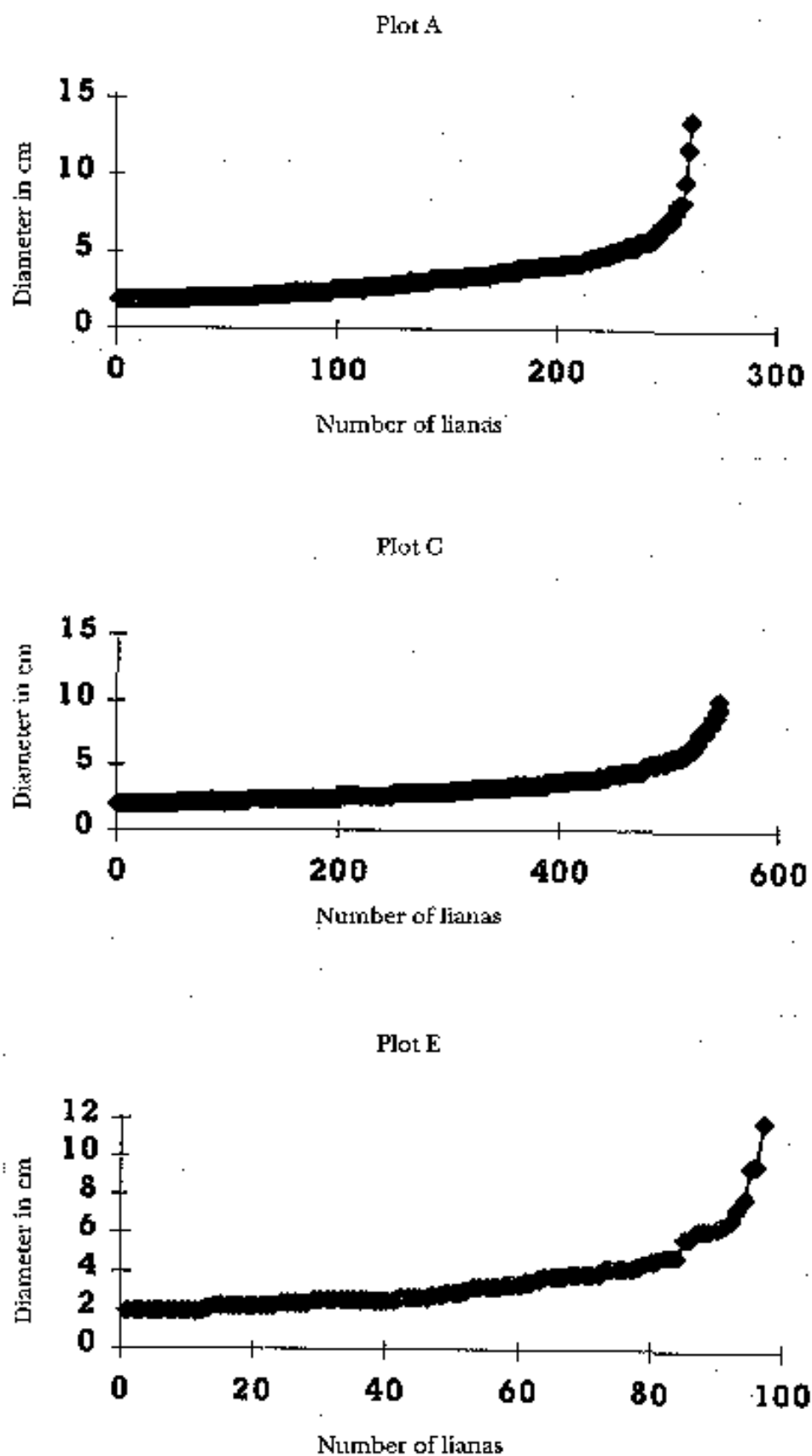


Figure 4. Size structure of climbers over 2 cm dbh in the logged plots, A, C and E, Pasoh Forest Reserve, Negri Sembilan

Total number of families and species per plot

From Table 1 it can be seen that one of the plots in the primary rain forest (Plot 1) is the richest in terms of number of families (29) and species (103). This plot contains 25 more species than Plot C, the richest logged plot (24 families, 78 species) even though both plots have very similar numbers of individual stems (515 for Plot 1, 546 for Plot C). The two remaining primary forest plots (Plot 2 and Plot 3 with 22 families/70 species and 25 families/73 species, respectively) are very similar in overall richness to the logged plots A and C (with 22 families/68 species, and 24 families/78 species, respectively). One plot in the logged area, Plot E, has very low species-richness (16 families/37 species), with half of the species of most of the other plots. This is thought to be related to the fact that the forest structure in Plot E was particularly severely modified, with many big trees difficult for lianas to access. It is noted that the plots with the highest number of lianas are also those with a higher diversity.

Table 1. List of common species classified according to their number of individuals in decreasing frequency, Pasoh Forest Reserve, Negri Sembilan

Number of species Families	Plot A	Plot C	Plot E	Plot 1	Plot 2	Plot 3
Annonaceae	15	19	10	13	17	15
Conmaraceae	9	9	3	12	10	6
Leguminosae	8	12	6	13	6	8
Moraceae	2	1	3	6	1	2
Rubiaceae	2	4	1	6	3	3
Apocynaceae	5	6	2	7	4	7
Convolvulaceae	2	4	1	5	3	4
Menispermaceae	2	0	1	5	2	3
Loganiaceae	3	3	0	3	5	5
Celastraceae	3	1	2	3	1	2
Melastomataceae	0	0	0	0	2	0
Dichapetalaceae	1	1	0	0	0	0
Ginetaceae	1	2	1	3	0	2
Myrsinaceae	1	1	1	2	2	1
Vitaceae	2	1	1	2	2	1
Araceae	0	0	0	2	1	0
Cecropiaceae	1	0	0	1	1	1
Dilleniaceae	2	1	2	2	2	3
Icacinaceae	0	0	0	0	0	1
Oleaceae	0	1	0	2	1	0
Rhamnaceae	3	3	0	3	1	1
Verbenaceae	2	2	1	2	2	1
Araliaceae	0	0	0	1	0	0
Combretaceae	0	1	0	1	0	1
Malpighiaceae	1	1	0	2	0	1
Piperaceae	0	0	0	0	0	0
Rutaceae	0	0	0	1	0	1
Ancistrocladaceae	0	0	0	1	0	1
Aristolochiaceae	0	1	0	0	0	0
Clusiaceae	0	0	0	0	0	0
Euphorbiaceae	1	1	0	1	0	1
Linaceae	1	1	0	1	1	1
Loranthaceae	0	1	0	1	0	0
Sterculiaceae	1	1	1	1	1	1
Undetermined	0	0	1	1	2	0
Total of species	68	78	37	103	70	73

Total number of individuals per plot

It can be seen from Table 2 that the number of individuals in any one family varies considerably between different plots, although some of the best represented families in any one plot (Annonaceae, Leguminosae and Sterculiaceae) tend to be well represented in all plots. The Annonaceae show a fairly constant number of individuals per plot. However, one species may be common in one plot and almost rare in another, for instance Sterculiaceae (*Byttneria maingayi*), Combretaceae (*Combretum nigrescens*), Verbenaceae (*Sphenodesme pentandra*), and Melastomataceae. A few families, such as Connaraceae, Moraceae and Apocynaceae, have markedly fewer individuals in the logged rain forest plots than in the pristine forest, whereas the Euphorbiaceae are more numerous in disturbed forest.

Table 2. List of individuals over 5 cm dbh classified in decreasing frequency, Pasoh Forest Reserve, Negri Sembilan

Number of individuals Families	Plot A	Plot C	Plot E	Plot I	Plot 2	Plot 3
Annonaceae	51	86	17	75	60	33
Connaraceae	17	17	5	40	30	29
Leguminosae	58	138	33	90	42	59
Moraceae	2	1	3	10	2	3
Rubiaceae	4	13	1	32	12	10
Apocynaceae	15	45	2	28	15	22
Convolvulaceae	3	6	1	10	3	7
Menispermaceae	2	0	1	6	2	5
Loganiaceae	3	7	0	9	6	11
Celastraceae	4	1	3	11	2	13
Melastomataceae	0	0	0	1	10	0
Dichapetalaceae	1	1	0	0	0	0
Gnetaceae	4	6	1	11	0	3
Myrsinaceae	3	6	1	4	3	2
Vitaceae	4	1	4	10	2	1
Araceae	0	0	0	2	1	0
Cecropiaceae	1	0	0	3	0	1
Dilleniaceae	9	3	3	6	4	4
Icacinaeae	0	0	0	0	0	1
Oleaceae	0	1	0	4	1	0
Rhamnaceae	4	14	0	19	5	1
Verbenaceae	13	20	9	3	11	5
Araliaceae	0	0	0	1	0	0
Combretaceae	0	37	0	62	1	14
Malpighiaceae	1	3	0	16	4	2
Piperaceae	0	0	0	0	0	0
Rutaceae	0	0	0	1	0	1
Ancistrocladaceae	0	0	0	6	0	1
Aristolochiaceae	0	2	0	0	0	0
Clusiaceae	0	0	0	0	0	0
Euphorbiaceae	14	15	0	1	0	2
Linaceae	2	3	0	3	3	2
Loranthaceae	0	1	0	1	0	0
Sterculiaceae	46	119	12	32	17	22
Undetermined	0	0	1	20	4	1
Total of individuals	261	546	97	515	242	255

Conclusions

The differences in terms of number of individuals are not significant between logged and unlogged rainforest (40 years after logging). The number of species present per plot varies considerably between plots, but if one excludes the exceptionally species-rich Plot 1 and the particularly species-poor Plot E, then there is no significant difference in species-richness between the logged and unlogged plots. There is a marked difference in the size classes present in logged and unlogged plots, with an abundance of larger diameter (10 cm+) climbers in unlogged plots. Usually a few species are abundant in logged rain forest as they overgrow the others by producing numerous shoots and thus have better chances of dispersal. All the primary rain forest plots show a high species-richness in Connaraceae, Moraceae, Loganiaceae, Apocynaceae and Menispermaceae. Mature specimens of species of all of these families have fruit that are eaten by animals and so it is possible that logging may have had an adverse impact on this frugivore fauna. These families also have a low potential of reiteration (to produce extra shoots at the base of the parent stem), so the potential reduction in fruit dispersers may have further adverse effects.

The major factors that contribute to a high species-richness or great abundance of climbers are the presence of many supports of different height classes and the proximity of climber parents. Some species appear to be more frequent in logged rain forests than in pristine rain forests, especially those which reiterate copiously and grow rapidly. In this investigation, it was observed that lianas prefer to exploit the crown surface between 10 to 25 metres high so that the trees with long trunks (where the first branching starts above 25 metres) are free of lianas. Those trees belong to the categories of commercial timber trees. As the highest supports, exploited for timber, are usually free of lianas, the widespread practice of climber cutting is probably not particularly important. The cutting of climbers will increase the abundance of the species which reiterate and grow fast at the expense of others which are potential food sources for the fauna.

The species composition of woody climbers is not strictly different between logged and unlogged plots although the primary forest plots are the richest in number of families and species. Nevertheless 40 years after logging, the importance of Connaraceae, Menispermaceae, Loganiaceae and Apocynaceae is still minor in the logged area although they are quite common in primary rain forest.

It is not possible to assess, in a one year programme, the economic importance of woody climbers as it requires a specific inquiry of the local uses by the indigenous inhabitants and a chemical investigation of the compounds present in the leaves, the stems, the bark or the sap of the selected species. There are certainly tens of potential key molecules to discover for medicinal uses.

Acknowledgments

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References

- GENTRY, A.H. 1985. An ecotaxonomic survey of Panamanian lianas. Pp. 29-42 in D'Arcy, W.G. & Correa, M. (Eds.) *Historia Natural de Panama*, Missouri Botanical Garden, St Louis.
- GENTRY, A.H. 1991. The distribution and evolution of climbing plants. Pp. 3-42 in Putz, F.E. & Mooney, H.A. (Ed.) *The Biology of Vines*. Cambridge University Press, Cambridge.
- PUTZ, F.E. 1984. The natural history of lianas on Barro Colorado Island, Panama. *Ecology* 65: 1713-1724.
- PUTZ, F.E. 1985. Woody lianas and forest management in Malaysia. *Commonwealth Forestry Review* 64: 359-365.
- PUTZ, F.E. & CHAI, P. 1987. Ecological studies of lianas in Lambir National Park, Sarawak, Malaysia. *Journal of Ecology* 75: 523-531.

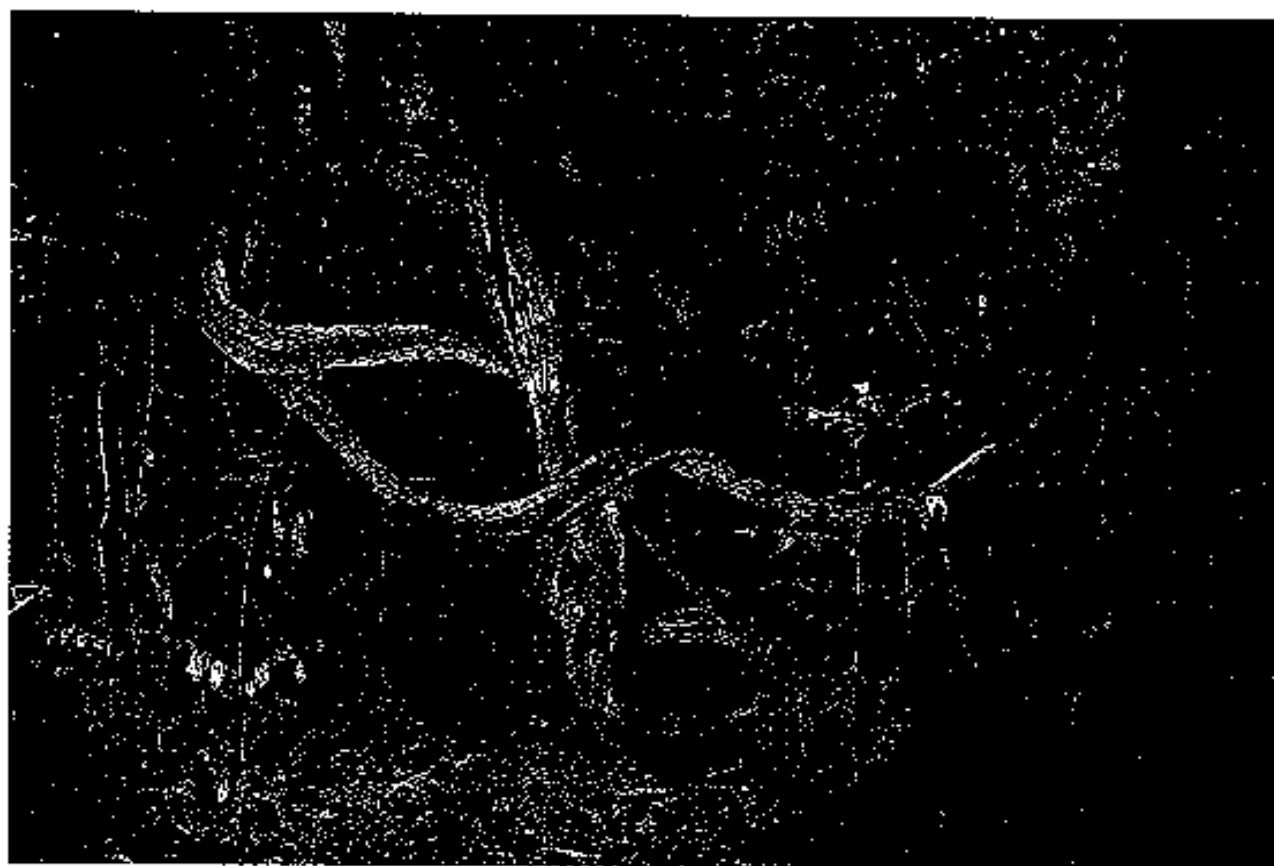


Plate 1. A *Bauhinia* liana, one of the climbers commonly found in Malaysian lowland forests.
Photo: L.S.L. Chua

TO DETERMINE THE EFFECTS OF LOGGING AND CONVERSION OF PRIMARY FOREST TO TREE CROP PLANTATIONS, ON HERPETOFAUNAL DIVERSITY IN PENINSULAR MALAYSIA

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A research programme to determine the effects of logging and timber extraction, and conversion of primary forest to tree crop plantations, on herpetofaunal diversity in Peninsular Malaysia was proposed during discussions and site visits, 26 February-26 March 1995. A list of expected amphibian and reptile fauna (65 and 138 species, respectively) was drawn up for primary and logged-over (secondary) forests, forest plantations - *Acacia* or *Pinus*, rubber estate and oil palm plantations. The programme with three constituents depended on specific surveying precepts that were incorporated with the methodology. Thirteen amphibians and 14 reptiles were recorded during March 1995 in primary and secondary forest (including cleared Rest House area), and oil palm plantation within the Pasoh Forest area near Simpang Pertang (Negri Sembilan). Four amphibians (*Bufo melanostictus*, *Rana erythraea*, *R. limnocharis* and *Microhyla hutchinsi*) were indicator species of man-changed habitats, and two (*Rana chalconota*, *R. hosi*) indicator species of forests were absent from plantations. Of 23 amphibians listed for Pasoh primary forest, *R. chalconota* was most frequently recorded (20% of sightings), followed by *B. parvus* and *R. blythi* (14%), and *B. asper* (11%). *Rana erythraea* and *Polypedates leucomystax* were the amphibians most frequently recorded in the Rest House area (after darkness, and following rain); while of reptiles, frequent barks of *Gekko smithi* were heard in both Pasoh forest and plantation, and *Draco volans* were observed on trees edging the Rest House area. *Varanus nebulosa* was a large, conspicuous plantation species.

Keywords: Reptile - amphibian - herpetofaunal diversity - primary forest - plantations

Introduction

The aim of this research programme was to compare the herpetofaunal diversity in primary forest before intervention and after logging (with regard for the method of

timber extraction and time expired), with the herpetofaunal diversity in forest areas converted to oil palm, rubber and forest tree plantations. Species surveys were therefore conducted in primary forest for direct comparison with each of the tree crop plantation types, and in secondary forest of known logging history.

In addition to the pre-logging survey in the Serling Forest Reserve Extension not far from Pasoh Forest Reserve, a survey was conducted in primary forest within a 50-ha study plot that had been established at Pasoh Forest Reserve. A list of the amphibians expected to occur there had been prepared by Kiew (1978) for the International Biological Programme, and a list of species expected to occur in forests and plantations of Malaysia was prepared by Kiew B.H. (Appendix: Table 1). Numbers observed incidental to investigations on vertebrates generally were recorded by Lim and Lambert (Appendix: Tables 2 and 3). The list, detailing species richness and relative abundance (composition and frequency), provides useful preliminary information on herpetofaunal diversity.

Background literature

Montane amphibians and reptiles in Pahang were examined by Grandison (1972) and in northern Trengganu by Dring (1979). The snakes of Malaysia were detailed by Tweedie (1961) and subsequently, using further information mostly provided by Lim B.L., revised and updated (Tweedie 1983). Additional papers were published by Lim in the *Malayan Nature Journal* culminating in a comprehensive guide (Lim 1991). Berry (1973) prepared a bibliography on the ectothermic vertebrate groups, and her definitive work on the amphibians of Peninsular Malaysia followed later (Berry 1975). A useful field guide with colour photographs of amphibian and reptile species occurring on Singapore island, relevant also to Peninsular Malaysia where all the species occur, was produced by Lim and Lim (1992). With such works as Inger (1979, 1980) to hand, the conservation status of amphibians in Malaysia was given in a list by Kiew (1984), who also produced a small educational booklet on Malaysian frogs (Kiew 1989). There is no comprehensive listing to date of the crocodilians and lizards of Peninsular Malaysia, and one, especially for the latter group, is urgently required. Kiew *et al.* (1996) provide information on the effects of logging and conversion on the herpetofauna in Peninsular Malaysian forests.

A research programme

Three constituents to the programme were drawn up to address the project's aims:

- A comparison of amphibian diversity (species composition, per cent frequency and relative density as numbers ha⁻¹) in primary forest before and after logging, and in relation to post-logging changes/recovery with time.
- Phase I. A comparison of herpetofaunal diversity in primary forest with that in forest converted to oil palm, rubber and forest tree plantations (static diversity).

- Phase II. Recording changes in herpetofaunal diversity in logged forest in relation to method of timber extraction and time since logging activities took place (dynamic diversity).

Surveying precepts

Primary rain forest (trees up to 30 or 35 m) has a strong vertical component compared with oil palm, rubber and forest tree plantations (on a more horizontal plane).

Forest tree plantation should be included with surveys of other plantation types, for some believe that this vegetation type and habitat differs little from that of primary or secondary forest, which can therefore be replaced with little ecological damage.

Secondary forest results from the logging of primary forest. Timber extraction can range from selection only of economic species removed by animal traction to wholesale removal (in recent years) of all sizeable trunks with very destructive mechanical methods of extraction. Thus extraction method and time since logging took place needs to be taken into account.

Primary forest yields many species, especially amphibians, at low density while plantations yield a lower number of species (a greater proportion of reptiles) at higher densities.

Because amphibians, representing the main herpetofaunal component in primary forest, are mainly active at night, surveys must be conducted during the first two or three hours of darkness, as well as during the day. For comparison, night surveys must also be undertaken in plantation habitats and aim to spend equal proportions of time in daylight and darkness.

Diurnal reptiles in primary forest emerge to bask and hunt during the hottest two or three hours of the day, when the sun is vertically overhead and can penetrate the canopy layer to the ground litter surface. In plantations, reptiles emerge with warmth of morning sunshine about two hours after sunrise, or after the sun has emerged from cloud later in the day.

With distinct dry and wet seasons, behaviour and population structure of forest amphibians may change.

Amphibians tend to congregate at pond and stream edges in primary forest, especially at night, and so facilitate species recording; a correction factor may have to be introduced for size of catchment area represented.

Amphibians are an important herpetofaunal component in primary rain forest; and therefore high competence in species recognition is required during surveys. Ability to recognise amphibians in plantations is less acute. Reptile species recognition in both habitats is also required. Ability to recognise tadpole species in forest streams and pools is also needed.

Oil palm plantations occur on drained soil, usually on slopes intersected by stream valleys, supporting riparian vegetation. Surveys should include riparian habitat.

Surveys in plantation types need to take distance from primary and logged forest into account, since forest habitat provides a harbour from which species can to varying degrees of ability invade.

To yield sufficient numbers for statistical purposes, the survey area in primary forest will need to be five, ten or more times that of plantation habitats, in which two or four hectares should suffice. An area of 50 ha, with a proportionally longer surveying time, may be required in primary forest in order to yield a cumulative number of 300 records desired for statistical comparisons.

Surveying methodology

Primary and secondary forest

To ensure that sufficient numbers of amphibians in particular, are recorded, 50-ha plots would be subdivided into 1 ha plots. Five field assistants trained in amphibian identification will walk in straight lines through each plot with 10 m separating observers. Each assistant would therefore be responsible for 5 m either side. The basic method will be visual encounter survey at night, supplemented by aural census for animals identified by their calls but not seen (note that unidentifiable calls can be tape recorded). Position relative to any nearby breeding site or water body will be noted. The date and time of each survey, weather conditions, phase of the moon, temperature and relative humidity will be recorded at each study site. The team would cover five 1 ha plots per night for ten nights. Night surveys will be supplemented by 2-3 hour day surveys between 0800 and 1100 h, depending on sunshine, in order to record also diurnal species and basking reptiles. Bodies of water will be examined by day or night for the presence and abundance of amphibian larvae and eggs - number of larvae and eggs to be estimated (giving an indication of the number of adult females laying them). Identification will be carried out in the field wherever possible. If tadpoles or adults cannot be identified, samples will be collected and brought back to the laboratory for identification (voucher specimens of unidentified material to be preserved). Tadpoles may also be reared in the laboratory for positive species identification.

Oil palm, rubber and forest tree plantations

One to four or five randomly selected 1-ha sub-plots within a 10-ha plot in each plantation type would be equal-effort sampled initially. For direct comparison with forest species, the same surveying method during the night and day would be carried out as in forests. The number of sub-plots in plantation types will be increased if numbers of animals sighted remain low.

Timing

To account for seasonal and weather changes, surveys covering wet and dry seasons would be carried out during four different times of the year.

Species richness

From species and the numbers recorded in each of the habitats, the aim would be to determine species composition, percentage frequency and relative density (no. ha⁻¹) in order to make direct comparisons. It may also be possible to compare the data for present day assemblages with those of similar forest habitats recorded by Inger (e.g. 1980) some 30 years ago.

Surveying Serling Forest Reserve Extension

A herpetofaunal survey of primary forest in the Serling Forest Reserve Extension may have two options. One may simply involve following the river course through the length of the forest during the hours of darkness and daylight recording species visually and by call. The other may be to record species in three or four 100 m transects established to include forest on either side of the river.

Herpetofauna observed during a visit to the Pasoh Forest Reserve, Negri Sembilan

A list of the species observed in the Pasoh Forest Reserve area during March 1995 was prepared (Appendix: Table 2). Sightings were additionally made by Lambert on 6-7 March and 15-18 March 1995.

Pasoh primary forest

Species were recorded in the Pasoh 50-ha plot. Among Amphibia were included *Rana chalconata* (tadpoles of spawn from a single female in small pool, 25 counted when larger eight days later, 15 March) and *Leptophryne borbonica* (one resting on trunk-base buttress of dipterocarp, *Shorea maxwelliana*; not previously recorded at Pasoh). Among Reptilia were *Varanus salvator* (immature, basking on a fallen log; 1430 h); *Gekko smithi* (bark heard); *Mabuya multifasciata* (immature, basking on leaf patch; 1200 h), and *Macrophisthodon rhodomelas* (ca. 50 cm long opisthoglyph; sighted on partly obscured track in dense vegetation, 1000 h).

Oil palm plantation, Pasoh

Adjacent to logged forest, species were recorded during searches of 111 min (1127-1316 h, 16 March) and 24 min (1507-1531 h, 17 March). The only amphibian was *Rana limnocharis* (four on dry ground vegetation, resting, 16 March). Among Reptilia were *Varanus nebulosa* (three disturbed while basking, 16 and 17 March; one 2 m long individual on track near stream re-entered secondary forest at 1318 h; frequently seen on main track passing through the plantation); *Gekko smithi* (bark heard, 17 March); *Mabuya multifasciata* (immature skink on stem of palm frond, 17 March), and *Naja sumatrana* (snake under dipterocarp log, 16 March; an active predator of plantation rats).

Pasoh secondary forest

Species were recorded on and by the track to the Office and Rest House area amidst secondary forest (selective timber removal by animal traction in the 1950's). Among Amphibia were *Kaloula pulchra* (newly metamorphosed, 1800 h, 6 March); *Polypedates leucomystax* (foam nest with eggs attached under beam above water in butt of bungalow; 6 March; and after overnight rain, three on porch of building the following night and foam nest on grass, 2330 h, 17 March; a common species and indicator of human-disturbed habitat), and *Nyctixalus pictus* (two on porch of building at night, 2330 h, 17 March). Among Reptilia were *Mabuya multifasciata* (dark adult basking on rotten stump, 1230 h, 7 March), and one immature on grass, 17 March); *Hemidactylus frenatus* (on walls of wooden buildings, 17 March); *Gekko smithi* (frequent barks heard, and individual geckos seen, 17 March); *Draco volans* (flying lizards on trunks and branches at edge of residential area; general report), and *Cuora amboinensis* (terrapin probably of this species - yellow lines on the neck and head - basking on branches of tree by pond, 17 March). A number of other species (listed in Table 1) were also reported by independent observers during March.

References

- BERRY, P.Y. 1973. Annotated bibliography for amphibians, reptiles and fishes. *The Malayan Nature Journal* 2: 48 - 61.
- BERRY, P.Y. 1975. *The Amphibian Fauna of Peninsular Malaysia*. 130 pp. Tropical Press, Kuala Lumpur.
- DIUNG, J.C.M. 1979. Amphibians and reptiles from northern Trengganu, Malaysia, with descriptions of two new geckos: *Cnemaspis* and *Cyrtodactylus*. *Bulletin of the British Museum of Natural History (Zoology)* 34: 181 - 241.
- GRANDISON, A.G.C. 1972. The Gunong Benom Expedition, 1967. 5. Reptiles and amphibians of Gunong Benom with a description of a new species of *Macrocalamus*. *Bulletin of the British Museum of Natural History (Zoology)* 23(4): 45 - 101.
- INGER, R.F. 1979. Abundances of amphibians and reptiles in tropical forests of South-east Asia. Pp. 93-110 in Marshall, A.G. (Ed.) *Transactions of the 6th Aberdeen-Hull Symposium on Malaysian Ecology*. Department of Geography, University of Hull, Miscellaneous Series no. 22.
- INGER, R.F. 1980. Relative abundances of frogs and lizards in forests of Southeast Asia. *Biotropica* 12(1): 14 - 22.
- KIEW, B.H. 1978. List of Amphibians of the Pasoh Forest Reserve [prepared for IBP]. Pasoh Newsletter, cyclostyled.
- KIEW, B.H. 1984. Conservation status of Malaysian amphibians. *Malayan Naturalist*, May 1984: 7 - 10.
- KIEW, B.H. 1989. *Malaysian Frogs & Toads*. 41 pp. Malayan Nature Society, Kuala Lumpur.
- KIEW, B.H., Lim B.L. & Lambert M.R.K. 1996. To determine the effects of logging and timber extraction, and conversion of primary forest to tree crop plantations, on herpetofaunal diversity in Peninsular Malaysia. *British Herpetological Society Bulletin* 57: 2 - 20.
- LIM, B.L. 1991. *Poisonous Snakes of Peninsular Malaysia*. 74 pp. Malayan Nature Society, Kuala Lumpur.
- LIM, K.K.P. & Lim F.L.K. 1992. *A Guide to the Amphibians and Reptiles of Singapore*. 160 pp. Singapore Science Centre.
- TWEEDIE, M.W.F. 1961. *The Snakes of Malaya*. 2nd edition (reprinted). Government Printing Office, Singapore.
- TWEEDIE, M.W.F. 1983. *The Snakes of Malaya*. 3rd edition. 167 pp. Singapore National Printers (Pte) Ltd.

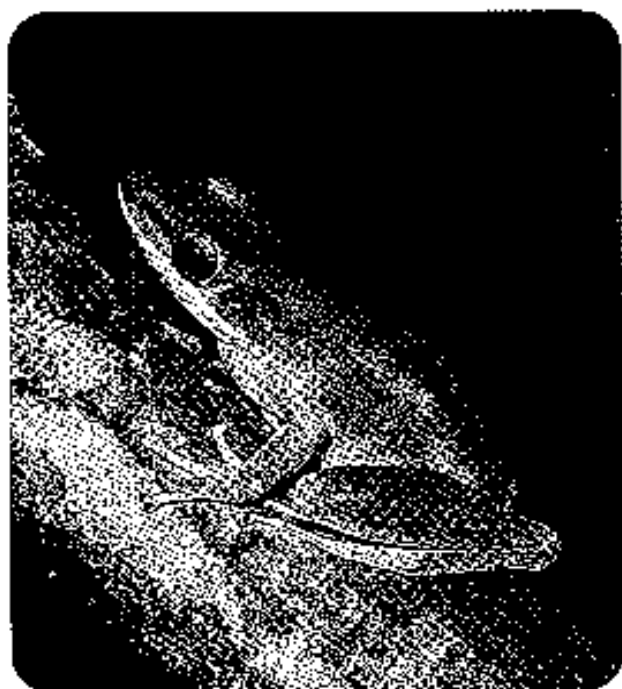


Plate 1. *Rana chalconota*, a small forest frog (32 - 60 mm) in Malaysia, whose relative abundance is increased by selective timber extraction.
Photo: C.H. Diong



Plate 2. *Rana hosi*, a small forest frog (42 - 98 mm) in Malaysia, whose relative abundance is higher in primary forest.
Photo: C.H. Diong



Plate 3. *Rana blythi*, a forest frog (c. 100 mm) whose relative abundance in Malaysia is highest in forests, but is also found in tree crop plantations.
Photo: C.H. Diong



Plate 4. *Cyrtodactylus quadrivirgatus*, a gecko not uncommon in forests of Malaysia, and found in forest tree and rubber plantations, but not in oil palm plantations.
Photo: C.H. Diong

Appendix

Table 1. Checklist, with relative abundance, of expected amphibian and reptile fauna in primary (PF) and logged-over (secondary) forests (LF), forest plantations - *Acacia* or *Pinus* (FP), rubber estate (RU) and oil palm plantations (OP) in Peninsular Malaysia. Prepared by Kiew Bong Heng, March 1995. [Note that a list of amphibians and reptiles in forests of Peninsular Malaysia, and their relative abundance, has not been drawn up before, and this is the first listing of Malaysian lizards].

Key:

- 0 Not likely to be present at all.
- 1 Rare; Not likely to be encountered owing to behaviour, low numbers and/or very restricted distribution.
- 2 Number is extremely low, estimated at 1 per 50 hectares; chance of encounter in a day/night search is negligible.
- 3 Number low, estimated at 1 per 10 hectares; chance of encounter in a day/night search is slight.
- 4 Number poor, estimated at 1 per 5 hectares; chance of encounter in a day/night search is poor.
- 5 Number high, estimated at 1 or more per hectare; chance of encounter in a day/night search is good.

Species	Vegetation type				
	PF	LF	FP	RU	OP
AMPHIBIA					
Caeciliidae					
<i>Caudacaecilia nigroflavus</i>	2	2	0	0	0
<i>Ichthyophis monochrous</i>	2	2	0	0	0
Scaphiophrynidae					
<i>Leptobrachium hendricksoni</i>	4	3	2	3	2
<i>Leptobrachium nigroops</i>	2	2	2	2	0
<i>Megophrys monticola nasuta</i>	3	3	0	0	0
Bufonidae					
<i>Ansonia longidigita</i>	2	2	0	0	0
<i>Ansonia malayana</i>	1	1	0	0	0
<i>Bufo asper</i>	4	4	2	0	0
<i>Bufo biporcatus</i>	2	2	0	0	0
<i>Bufo macrinis</i>	1	1	0	0	0
<i>Bufo melanostictus</i>	0	0	0	3	3
<i>Bufo parvus</i>	4	4	3	3	2
<i>Bufo quadriporcatus</i>	1	1	0	0	0
<i>Leptophryne borbonica</i>	2	2	0	0	0
<i>Pedostibes hosei</i>	3	2	0	0	0
<i>Pelophryne brevipes</i>	1	1	0	0	0
Ranidae					
<i>Ociodoxyga laevis</i>	3	4	1	1	1
<i>Rana baramica</i>	2	2	0	0	0
<i>Rana blythi</i>	4	4	3	3	3
<i>Rana chalconota</i>	4	4	0	0	0
<i>Rana erythraea</i>	0	2	2	3	5
<i>Rana glandulosa</i>	2	2	2	2	2

Appendix 1 continued

<i>Rana hirsuta</i>	3	2	0	0	0
<i>Rana kuhlii</i>	2	2	0	0	0
<i>Rana laticeps</i>	2	2	0	0	0
<i>Rana limnocharis</i>	0	2	3	4	4
<i>Rana luctuosa</i>	2	2	0	0	0
<i>Rana malesiana</i>	2	2	2	3	1
<i>Rana micropus</i>	2	2	2	2	2
<i>Rana microbariensis</i>	2	3	3	2	2
<i>Rana paramacrodon</i>	2	2	0	0	0
<i>Rana plicatella</i>	2	2	0	0	0
<i>Rana signata</i>	3	2	0	0	0
<i>Staurois larutensis</i>	2	2	0	0	0
Rhacophoridae					
<i>Nyctixalus picta</i>	2	2	0	0	0
<i>Polypedates colletti</i>	2	2	0	0	0
<i>Polypedates leucomystax</i>	0	2	4	1	4
<i>Polypedates linki</i>	0	2	2	2	2
<i>Polypedates macrotis</i>	3	3	0	0	0
<i>Rhacophorus appendiculatus</i>	2	3	0	0	0
<i>Rhacophorus bimaculatus</i>	1	1	0	0	0
<i>Rhacophorus nigropalmatus</i>	1	1	0	0	0
<i>Rhacophorus pardalis</i>	1	1	0	0	0
<i>Rhacophorus promianus</i>	2	2	0	0	0
<i>Rhacophorus reinwardti</i>	1	1	0	0	0
<i>Rhacophorus robinsoni</i>	1	1	0	0	0
<i>Theloderma asper</i>	1	1	0	0	0
<i>Theloderma horridus</i>	1	1	0	0	0
<i>Theloderma leprosa</i>	1	1	0	0	0
Microhylidae					
<i>Calluella volzi</i>	1	1	0	0	0
<i>Chaperina fusca</i>	1	2	0	0	0
<i>Kalophrynus palmatissimus</i>	2	1	0	0	0
<i>Kalophrynus pleurostigma</i>	1	2	0	0	0
<i>Kalophrynus robinsoni</i>	1	1	0	0	0
<i>Kaloula baleata</i>	1	1	0	0	0
<i>Kaloula pulchra</i>	0	0	1	2	2
<i>Microhyla annectens</i>	1	1	0	0	0
<i>Microhyla berlaimorei</i>	2	2	0	0	0
<i>Microhyla bornensis</i>	2	2	0	0	0
<i>Microhyla butleri</i>	1	2	3	3	3
<i>Microhyla heymonsi</i>	2	3	3	3	3
<i>Microhyla inornata</i>	1	1	0	0	0
<i>Microhyla ornata</i>	1	1	0	0	0
<i>Microhyla palmipes</i>	1	1	0	0	0
<i>Microhyla superciliosa</i>	1	1	0	0	0

Appendix I continued

REPTILIA

Chelonia

Emydidae

<i>Cuora amboinensis</i>	1	2	2	2	2
<i>Cyclemys dentata</i>	1	1	1	1	1
<i>Hoesemys spinosa</i>	1	1	0	0	0
<i>Notochelys platynota</i>	2	2	0	0	0

Testudinidae

<i>Geochelone elongata</i>	1	1	1	1	1
<i>Geochelone emys</i>	1	1	2	2	2

Trionychidae

<i>Dogania subplana</i>	2	2	1	1	1
<i>Amyda cartilagineus</i>	1	1	1	1	1

Sauria

Agamidae

<i>Acanthosaura armata</i>	2	2	0	0	0
<i>Aphaniotis fusca</i>	2	2	0	0	0
<i>Bronchocela cristatella</i>	0	0	1	2	2
<i>Bronchocela emma</i>	0	0	1	1	1
<i>Calotes versicolor</i>	2	2	2	2	2
<i>Draco fimbriatus</i>	1	1	0	0	0
<i>Draco formosus</i>	1	1	0	0	0
<i>Draco maculatus</i>	1	1	0	0	0
<i>Draco maximus</i>	1	1	0	0	0
<i>Draco melanopogon</i>	2	2	1	1	1
<i>Draco volans</i>	3	3	2	2	2
<i>Gonocephalus borneensis</i>	1	1	0	0	0
<i>Gonocephalus grandis</i>	1	1	0	0	0
<i>Gonocephalus herveyi</i>	1	1	0	0	0

Gekkonidae

<i>Aerulascababotes jelineus</i>	1	1	0	0	0
<i>Cnemaspis affinis</i>	1	1	0	0	0
<i>Cnemaspis kendalli</i>	1	1	0	0	0
<i>Cosymbotes platyrus</i>	0	0	1	1	1
<i>Cyrtodactylus consobrinus</i>	1	1	0	0	0
<i>Cyrtodactylus malayanus</i>	1	1	0	0	0
<i>Cyrtodactylus pulchellus</i>	1	1	0	0	0
<i>Cyrtodactylus quadrivirgatus</i>	2	2	1	1	0
<i>Gehyra mutilata</i>	0	0	0	1	0
<i>Gekko gekko</i>	0	0	0	1	0
<i>Gekko monarchus</i>	0	0	0	1	0
<i>Gekko smithi</i>	2	2	0	0	0
<i>Hemidactylus brookii</i>	0	0	0	1	0
<i>Hemidactylus frenatus</i>	0	0	0	1	0

Appendix 1 continued

<i>Hemidactylus garnottii</i>	0	0	0	1	0
<i>Lepidodactylus lugubris</i>	0	0	0	1	0
<i>Minetozoon craspedotus</i>	1	1	0	0	0
<i>Ptychozoon horsfieldii</i>	1	1	0	0	0
<i>Ptychozoon kuhli</i>	1	1	0	0	0
Scincidae					
<i>Dasia olivacea</i>	2	2	1	0	0
<i>Emoia atrocostata</i>	2	2	1	0	0
<i>Mabuya longicaudata</i>	1	1	1	1	1
<i>Mabuya multifasciata</i>	2	3	3	3	3
<i>Mabuya rugifera</i>	1	1	1	1	1
<i>Mochlus boweringi</i>	0	0	1	2	2
<i>Sphenomorphus indicus</i>	1	1	0	0	0
<i>Sphenomorphus praesigne</i>	1	1	0	0	0
<i>Sphenomorphus scotophilus</i>	1	1	0	0	0
<i>Sphenomorphus stellatus</i>	2	2	1	0	0
Varanidae					
<i>Varanus nebulosa</i>	1	1	2	2	2
<i>Varanus rudicollis</i>	1	1	1	2	3
<i>Varanus salvator</i>	1	1	1	2	3
Serpentes					
Typhlopidae					
<i>Ramphotyphlops alticeps</i>	1	1	0	0	0
<i>Ramphotyphlops braminus</i>	1	1	1	1	1
<i>Typhlops diardi</i>	1	1	1	1	1
Aniliidae					
<i>Anomochilus leonardi</i>	1	1	1	1	1
<i>Cylindrophis rufus</i>	1	1	1	1	1
Xenopeltidae					
<i>Xenopeltis unicolor</i>	1	1	1	1	1
Boidae					
<i>Python curtus</i>	1	1	1	1	1
<i>Python reticulatus</i>	1	1	1	1	2
Colubridae					
<i>Ahaetulla fasciolata</i>	1	1	1	1	1
<i>Ahaetulla mycterizans</i>	1	1	1	1	1
<i>Ahaetulla prasina</i>	1	1	1	1	1
<i>Amphiesma conspicillata</i>	1	1	1	1	1
<i>Amphiesma peterii</i>	1	1	1	1	1
<i>Aplopeltura boa</i>	1	1	0	0	0

Appendix 1 continued

<i>Boiga cynodon</i>	1	1	1	1	1
<i>Boiga dendrophila</i>	1	1	1	1	1
<i>Boiga drapiezii</i>	1	1	1	1	1
<i>Boiga jaspidea</i>	1	1	1	1	1
<i>Calamaria albiventer</i>	1	1	1	1	1
<i>Calamaria pavimentata</i>	1	1	1	1	1
<i>Calamaria schlegelii</i>	1	1	1	1	1
<i>Chrysopelea ornata</i>	1	1	1	1	1
<i>Chrysopelea paradisi</i>	1	1	1	1	1
<i>Chrysopelea petas</i>	1	1	1	1	1
<i>Dendrelaphis caudolineatus</i>	1	1	1	1	1
<i>Dendrelaphis pictus</i>	1	1	1	1	1
<i>Dendrelaphis formosus</i>	1	1	1	1	1
<i>Dendrelaphis striatus</i>	1	1	1	1	1
<i>Dryocalamus subannulatus</i>	1	1	1	1	1
<i>Dryophiops rubescens</i>	1	1	1	1	1
<i>Elaphe flavolineata</i>	1	1	1	1	1
<i>Elaphe taeniura</i>	1	1	1	1	1
<i>Elaphe radiata</i>	1	1	1	1	1
<i>Elaphe prasina</i>	1	1	1	1	1
<i>Gonyophis margaritatus</i>	1	1	0	0	0
<i>Gonyosoma oxycephalum</i>	1	1	1	1	1
<i>Homalopsis buccata</i>	1	1	1	1	1
<i>Lepturophis borneensis</i>	1	1	1	1	1
<i>Liopeltis baliodendra</i>	1	1	1	1	1
<i>Liopeltis longicauda</i>	1	1	1	1	1
<i>Liopeltis tricolor</i>	1	1	1	1	1
<i>Lycodon aulicus</i>	1	1	1	1	1
<i>Lycodon butleri</i>	1	1	1	1	1
<i>Lycodon effraenis</i>	1	1	1	1	1
<i>Lycodon subcinetus</i>	1	1	1	1	1
<i>Macrophisthodon flaviceps</i>	1	1	1	1	1
<i>Macrophisthodon rhodometus</i>	1	1	1	1	1
<i>Macropophis maculatus</i>	1	1	1	1	1
<i>Natrix trianguligera</i>	1	1	1	1	1
<i>Oligodon octolineatus</i>	1	1	1	1	1
<i>Oligodon purpurascens</i>	1	1	1	1	1
<i>Oligodon signatus</i>	1	1	1	1	1
<i>Pareas carinatus</i>	1	1	1	1	1
<i>Pareas laevis</i>	1	1	1	1	1
<i>Pareas malaccanus</i>	1	1	1	1	1
<i>Pareas margaritophorus</i>	1	1	1	1	1
<i>Psammodynastes pictus</i>	1	1	1	1	1
<i>Psammodynastes pulverulentus</i>	1	1	1	1	1
<i>Pseudorhabdion longiceps</i>	1	1	1	1	1
<i>Ptyas carinatus</i>	1	1	1	1	1
<i>Ptyas fuscus</i>	1	1	1	1	1
<i>Ptyas korros</i>	1	1	1	1	1

Appendix 1 continued

<i>Rhabdophis chrysargus</i>	1	1	1	1	1
<i>Rhabdophis subminiatus</i>	1	1	1	1	1
<i>Sibynophis collaris</i>	1	1	1	1	1
<i>Sibynophis melanocephalus</i>	1	1	1	1	1
<i>Xenelaphis hexagonatus</i>	1	1	1	1	1
<i>Xenochrophis piscator</i>	1	1	1	1	1
<i>Xenodermus javanicus</i>	1	1	1	1	1
Elapidae					
<i>Bungarus candidus</i>	1	1	1	1	1
<i>Bungarus fasciatus</i>	1	1	1	1	1
<i>Bungarus flaviceps</i>	1	1	1	1	1
<i>Calliophis gracilis</i>	1	1	1	1	1
<i>Calliophis maculiceps</i>	1	1	1	1	1
<i>Maticora bivirgata</i>	1	1	1	1	1
<i>Maticora intestinalis</i>	1	1	1	1	1
<i>Naja kaouthia</i>	0	0	0	1	1
<i>Naja sumatrana</i>	1	1	1	1	2
<i>Ophiophagus hannah</i>	1	1	1	1	1
Viperidae					
<i>Agkistrodon rhodostoma</i>	0	0	0	1	1
<i>Trimeresurus hageni</i>	1	1	0	0	0
<i>Trimeresurus puniceus</i>	1	1	0	0	0
<i>Trimeresurus sumatranus</i>	1	1	0	0	0
<i>Trimeresurus wagleri</i>	1	1	0	0	0

Table 2. Amphibians and reptiles recorded in Pasoh Forest area, near Simpang Pertang (Negri Sembilan), Malaysia, March 1995, including those observed outside primary forest previously. Figures in parentheses based on verbal reports only.

Key: 1) primary forest; 2) secondary forest; 3) Rest House area (within secondary forest) and other human dwellings, and 4) oil palm plantation with riparian valley vegetation

Species	1	2	3	4	Comments
AMPHIBIA					
Bufonidae					
<i>Bufo melanostictus</i>	1	-	-	8	-
<i>Leptophryne borbonica</i>	1	-	-	-	-
Ranidae					
<i>Ocicodyga larvis</i>	-	-	(5)	-	-
<i>Rana chalconota</i> ²	25	-	2	-	In small pool (larvae) at 1
<i>Rana erythraea</i> ²	-	-	25	-	-
<i>Rana glandulosa</i>	-	-	+	-	At 3 by Kiew (1978)
<i>Rana hoesei</i> ²	-	-	(1)	-	-
<i>Rana limnocorais</i> ¹	-	-	11	4	-
Rhacophoridae					
<i>Nyctixalus pictus</i>	-	-	2	-	-
<i>Polypedates leucomystax</i>	-	-	13	-	Includes two foam SLI nests
Microhylidae					
<i>Kaloula pulchra</i>	-	1	2	-	-
<i>Microhyla butleri</i> ²	-	3	-	-	-
<i>Microhyla heymonsi</i>	-	-	5	-	-
REPTILIA					
Chelonia					
Emydidae					
<i>Cuora amboinensis</i>	-	1	-	-	In pond
<i>Heosemys spinosa</i>	-	-	(1)	-	During heavy rain
Sauria					
Agamidae					
<i>Bronchocele cristatella</i>	-	-	(1)	-	-
<i>Draco volans</i>	-	-	(3)	-	-
Gekkonidae					
<i>Gekko smithi</i>	4	1	3	2	All but one (at 3) heard only
<i>Hemidactylus frenatus</i>	-	-	5	-	-
Scincidae					
<i>Mabuya multifasciata</i>	1	2	-	1	-
Varanidae					
<i>Varanus nebulosa</i>	2	-	-	7	-
<i>Varanus salvator</i>	-	1(?)	-	-	-
Serpentes					
Boidae					
<i>Python reticulatus</i>	(1)	-	-	-	180 mm diameter
Colubridae					
<i>Baigu dendrophila</i>	-	-	(5)	-	-
<i>Gonyosoma oxycephala</i>	(3)	-	-	-	-
<i>Macrophisthodon rhodomelas</i>	2	-	-	-	-
Elapidae					
<i>Naja sumatrana</i>	-	-	-	1	-

¹Indicator species of man-changed habitat

²Forest species - absent from plantations

Table 3. Records of amphibians, and frequency (%), in primary forest of Pasoh Forest Reserve, near Simpang Pertang (Negri Sembilan), Malaysia

Species	Kiew (1978)	Lim (in prep.) ¹	% (n = 65)
Polobatrachidae			
<i>Leptobrachium hendricksoni</i>	+	4	6.2
<i>Leptobrachium nigrops</i>	+	2	3.1
<i>Megophrys nasuta</i>	+	2	3.1
Bufonidae			
<i>Leptophryne borbonica</i>	-	-(+1) ²	1.5
<i>Bufo asper</i>	+	7	10.8
<i>Bufo parvus</i>	+	9	13.8
Ranidae			
<i>Occidozyga laevis</i>	+	2	3.1
<i>Rana blythi</i>	+	9	13.8
<i>Rana chalconota</i>	+	12 (+1) ²	20.0
<i>Rana glandulosa</i>	+	2	3.1
<i>Rana hosei</i>	+	-	0
<i>Rana laticeps</i>	+	1	1.5
<i>Rana paramacrodon</i>	+	-	0
<i>Rana stignata</i>	+	2	3.1
Rhacophoridae			
<i>Polypedates culicatus</i>	+	1	1.5
<i>Rhacophorus appendiculatus</i>	+	-	0
<i>Rhacophorus bimaculatus</i>	+	3	4.6
<i>Rhacophorus nigropalmatus</i>	+	-	0
<i>Rhacophorus prasinus</i>	-	2	3.1
Microhylidae			
<i>Chaperina fusca</i>	+	1	1.5
<i>Microhyla inornata</i>	+	3	4.6
<i>Microhyla superciliaris</i>	-	1	1.5
(? = palmatus)			
<i>Kalophrynus pleurostigmata</i>	+	-	0

¹ List of Lim Boo Liat compiled from incidental collections on 10-19 January 1968, 13 April - 2 May 1969, 2-12 December 1972 and FRIM Sains Alam Sekitar 1989-91 (identifications by P.Y. Berry, pers. comm., after Berry, 1975).

² Recorded by Lambert, 7 and 14-19 March 1995.

A COMPARISON BETWEEN POPULATIONS OF PRIMATES, SQUIRRELS, TREE SHREWS AND OTHER MAMMALS INHABITING VIRGIN, LOGGED, FRAGMENTED AND PLANTATION FORESTS IN MALAYSIA

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This paper compares populations of primates, squirrels, treeshrews and other mammals inhabiting virgin, logged, fragmented and plantation forests within the Permanent Forest Estate in Peninsular Malaysia. Results presented in this study indicate that: (a) conversion to plantation resulted in a massive loss of diversity, only a few of the most adaptable species were seen to make use of plantation forest; (b) the smallest areas of natural forest (≤ 164 ha) had the lowest diversity of mammal species, compared to the larger areas of natural forest ($\geq 10,000$ ha) because certain of the rarer, least abundant species, including some of the largest, most wide-ranging and/or specialist species were apparently unable to cope with habitat fragmentation; and (c) most species were able to survive at least one commercial felling. However, mammal diversity and densities changed in logged forest compared with virgin forest. Some species showed a preference for virgin forest and appeared adversely affected by the effects associated with logging. Other species, however, (in particular those associated with disturbed vegetation) were seen to react favourably. Recommendations are made for a two-part management strategy which enables economic use of forest resources, as follows: (1) wherever possible, continuous areas of natural forest should be retained in preference to permitting fragmentation of areas of natural forest; and (2) the existing Virgin Jungle Reserve (VJR) system within Peninsular Malaysia should be strengthened, by declaring and maintaining units of virgin/relatively undisturbed forest within productive forest as VJRs. This two-part strategy is achievable at minimum cost, by using existing Forestry policy and updating management structures/systems which are already in place.

Keywords: Mammals - primates - squirrels - treeshrews - VJRs.

Introduction

The land area covered by forest in Peninsular Malaysia continues to be reduced and fragmented, and also converted from virgin to logged forest. Results from studies on habitat disturbance and loss are pivotal for future planning of biodiversity conservation and forest management. The objective of this paper, therefore, is to compare populations of primates, squirrels, treeshrews and other mammals from seven sites representing four forest categories within the Permanent Forest Estate (PFE) in Peninsular Malaysia, namely virgin, logged, fragmented and plantation forests.

Logging

Numerous studies have examined the effects of habitat disturbance, including logging activities, on wildlife, in particular primates. For example, Martin and Asibey (1979), Murayak (1981), Skorupa (1987), Thiollay (1992), Plumptre and Reynolds (1994) in Africa, and Johns (1986) in Brazilian Amazonia. Most of the work, however, has been carried out in South East Asia (Johns & Skorupa 1987). These include studies by Southwick and Cadigan (1972), Marsh and Wilson (1981), Wong (1982), Johns (1983, 1987), Lambert (1987) and Laidlaw (1994) in Peninsular Malaysia; Wilson and Wilson (1975), Davies and Payne (1982), Wilson and Johns (1982), Johns (1988), Lambert (1990) and Dahaban (1996) in Borneo; and Wilson and Wilson (1976) and Rijksen (1978) in Sumatra. Reviews on primates and habitat disturbance have been published by Johns and Skorupa (1987) and Marsh *et al.* (1987).

Results from the above studies indicate that the effects of logging on wildlife vary from one species to another and from one locality to another. Malaysian studies have shown that certain species become locally extinct after logging, others decline in numbers, whereas a few do well in logged forest. In general, these short-term studies illustrate that most species can persist in logged forest. However, the long-term effects on wildlife of repeated logging (and silvicultural) activities are not yet known. This is partly because the rate of converting logged forest into agricultural land/plantation has largely outstripped the rate of relogging old managed forest.

Habitat fragmentation

The fragmentation of forest has increasing relevance for Peninsular Malaysia. Reduction of total forest area and natural forest (*i.e.* conversion to plantation within the PFE), in the more accessible forests, where the productive forest is situated, results in a second form of wildlife habitat disturbance, which is habitat fragmentation. Habitat fragmentation results in the loss of habitat continuity, so that a continuous area of habitat is both reduced in area and divided into two or more fragments (Wilcove *et al.* 1986, Lovejoy *et al.* 1986, Lord & Norton 1990, Primack 1993). Fragmentation is not a random process. It results from the incursion of economic and political forces into the natural landscape so that the fragmented natural vegetation tends to be located on more marginal land (Terborgh 1992). In Peninsular Malaysia a map of the forested areas is now seen to coincide with a map of the more hilly/upland areas. Sixty per cent of land in Peninsular Malaysia is in the lowlands and lowland dipterocarp forest (LDF) once covered much of this area. However, most of the LDF has been converted for agriculture or infrastructural development (Lim 1991) and the remaining LDF is mostly fragmented.

Fragmentation has different implications for different species. After isolation, there is an overall loss of existing diversity (faunal relaxation) in the resulting fragment (see for example, Willis 1974, 1979, Wilson & Willis 1975, Matthiae & Stearns 1981, Whitcomb *et al.* 1981, Karr 1982, Lovejoy *et al.* 1983, 1986, Wilcove *et al.* 1986, Pahl *et al.* 1988, Terborgh 1989, Laurance 1990, 1991, Newmark 1991). The extent of faunal relaxation/collapse, and the probability of a species being present in a

fragment, therefore depends on a number of factors including the size of the fragment, habitat quality, degree of isolation, and time since isolation. Of these, fragment size has been shown to be of critical importance. Decreases in diversity have been positively correlated with decreasing fragment size (Matthiae & Stearns 1981, Soul *et al.* 1992). However, in spite of the importance of fragment size, little is known about the area requirements of the majority of species. In the Neotropics it is thought that forest fragments of less than 10,000 ha suffer the instantaneous loss of a whole array of area-demanding species (Terborgh 1992). In addition, studies on populations of birds have shown that the rate of extinction rises steeply when the area drops below 100 ha (Wilson 1988). Circular reserves smaller than 100 ha are thought to contain no true forest interior (Wilcove *et al.* 1986).

Methods

The seven sites considered in this paper are located in lowland and hill dipterocarp forest (LDF and HDF), since these types of forest, in particular LDF, are valued for commercial timber extraction. One of these sites (Bukit Tarek plantation) has been converted from LDF into an *Acacia mangium* plantation. Sites considered in this paper are the following:

- Virgin forest: two sites in Lesong Forest Reserve (FR), Pahang, and Sungai Lalang FR, Selangor. The Lesong site (Lesong VJR) was a 146 ha compartment in a tract of virgin forest in a 63,645 ha FR. The Sungai Lalang site (Sungai Lalang VJR) was an 82 ha compartment surrounded by logged forest in the Main Range of mountains which are largely forested.
- Logged forest: two sites in Sungai Lalang FR, Selangor, and Kemasul FR, Pahang. The Sungai Lalang site was logged once between 1955-1964 under the Malayan Uniform System (MUS). It was adjacent to the virgin site described above and had some regeneration problems. The Kemasul site had been commercially logged twice, first in the 1960's followed by a second felling in 1987-1988. The Kemasul site was in an area of natural forest of about 10,000 ha.
- Relic forest fragments: two sites in Paya Pasir FR, Pahang, and Bukit Tarek FR, Selangor. The Paya Pasir site (Paya Pasir VJR/FR) comprising 164 ha, was an isolated patch of forest on a hill. The surrounding land had been partly converted to agricultural use and contained some poorly maintained smallholdings which were thought to be fairly long term. The Bukit Tarek site (Bukit Tarek VJR) was a 70 ha forested hillside surrounded by plantation, with *A. mangium* inside the FR and *Hevea brasiliensis* outside the FR. The Bukit Tarek FR was 9,163 ha.
- Plantation forest: one site in Bukit Tarek FR adjacent to the fragmented site described above. This site was located in the *A. mangium* plantation which largely surrounds Bukit Tarek VJR. Conversion was thought to have taken place approximately nine years before this present survey.

Of the seven study sites, the continuous virgin site (Lesong), the two forest fragments and the plantation forest (Paya Pasir and Bukit Tarek) were each surveyed

once. The virgin compartment and the two logged forest sites (Sungai Lalang and Kemasul) were surveyed five times each. All surveys took place over the course of 13 months (see Laidlaw 1994 for details).

The density/km² of diurnal primates, squirrels and treeshrews was calculated from field data collected in the seven selected study sites, using line transect surveys. Surveys closely followed the recommendations of Burnham *et al.* (1980), Brockelman and Ali (1987), and the methods of Marsh and Wilson (1981). Vegetation data were also collected from the freshly-cut transects.

Morning census walks were used to calculate density of certain species. In order to compare diversity, *i.e.* number of species of primates, squirrels and treeshrews, more extensive walks, which did not strictly follow the transects, were also conducted in the afternoons in the seven sites. In addition, data from these walks (and infrequent walks at night) were used to compare overall mammal diversity between the areas of natural vegetation in Lesong FR (>10,000 ha), Sungai Lalang FR (>10,000 ha), Kemasul FR ($\approx$ 10,000 ha), Paya Pasir FR (164 ha), Bukit Tarek VJR (70 ha) and the Bukit Tarek *A. mangium* plantation.

Data analysis included the use of non-parametric multivariate technique (Clarke 1993). Forest structure and composition data were ordinated using a correlation-based Principal Components Analysis (PCA) (Goodall 1954). Animal data analysis included the use of an expanded Fourier series programme to calculate density in all sites except Lesong where King's method was used for primates due to a small sample size. Data from the same sites were combined for (a) primates and (b) for squirrels and treeshrews to calculate strip widths (data not truncated).

Similarities in primate density and squirrel and treeshrew density were analysed by constructing a ranked lower triangular similarity matrix using the Bray-Curtis similarity measure (Bray & Curtis 1957) and by constructing a dendrogram using hierarchical agglomerative clustering and group average linkage.

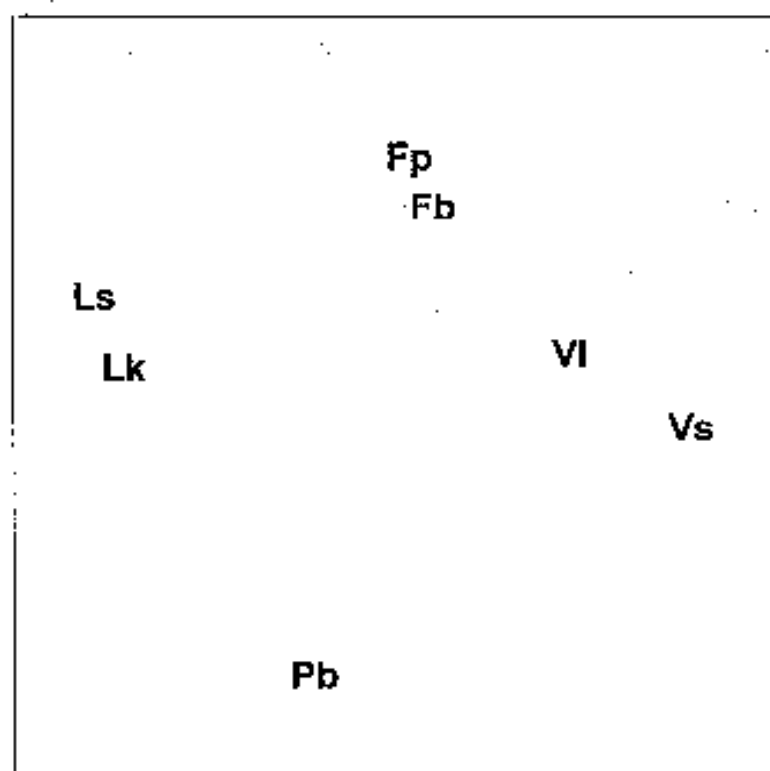
Results

Vegetation

Similarities were apparent between sites of the same vegetation type. The virgin sites were characterised by the largest basal areas, the logged forest sites by the lowest tree densities and the highest percentage Dipterocarpaceae, and the forest fragments by the highest representation of Moraceae and the lowest representation of Dipterocarpaceae (Table 1, see Laidlaw 1994 for further details). On analysis, each pair of these three site types was grouped together (Figure 1). The most strikingly different site was the plantation forest in Bukit Tarek FR. In Figure 1, therefore, this site has been separated from the other sites. There has been a huge loss of diversity in this site in that 97 per cent of its composition was made up of one species, *i.e.* *A. mangium*.

Table 1. Summary of the forest structure and composition in all study sites for trees ≥ 30 cm gbh (n=2,488 trees). Key: dipts: Dipterocarpaceae, euphorb: Euphorbiaceae

Site	tree density /ha	basal area (m ² /ha)	max girth (cm)	% trees with lianas	dips as % of total composition	Moraceae as % of total composition	euphorb basal area ranking as % of total basal area
Virgin							
Lesong	485	35.0	450	41.5	9.0	2.0	15
Sg. Lalang	538	39.4	400	26.3	7.3	2.0	4
Logged							
Sg. Lalang	332	20.0	250	12.0	24.7	5.3	2
Kemasul	396	12.3	155	24.3	12.7	5.3	2
Fragment							
Paya Pasir	426	33.0	502	35.0	5.0	6.0	2
Bukit Tarek	472	29.0	500	34.0	2.5	6.0	1
Plantation							
Bukit Tarek	505	12.5	87	-	0	0.4	2

**Figure 1.** Site grouping from tree structure and composition data using PCA

Key: VI: Lesong Virgin Forest; Vs: Sungai Lalang Virgin Forest;
 Ls: Sungai Lalang Logged Forest; Lk: Kemasul Logged Forest;
 Fp: Paya Pasir Forest Fragment; Fb: Bukit Tarek Forest Fragment;
 Pb: Bukit Tarek Plantation Forest

Primates

Primates are very successful forest dwellers and one of the most widespread and common orders of mammals in the Peninsula. They are also one of the most versatile in their considerable ability to change their diet and feeding behaviour (Johns 1986, Johns & Skorupa 1987). Thus, differences in diversity are subtle in comparison to other groups of mammals, unless the vegetation where they occur has been drastically altered. For example, diversity in terms of species numbers, in all the study sites with natural vegetation, was consistent, regardless of disturbance or size of area, i.e. all sites except Bukit Tarek plantation contained a range of between four and six primate species. The Bukit Tarek plantation was the least diverse of all the sites (Table 2). *Macaca fascicularis* was the only primate recorded inside the *A. mangium* plantation. Even this species, however, was only encountered after extensive searching and never during census walks.

The highest densities (≥ 16.0 groups/km²) occurred in the two forest fragments. Excluding the *A. mangium* plantation in Bukit Tarek FR, the lowest densities (≥ 7.5 groups/km²) occurred in the two logged forest sites (Figure 2). Differences were noted in that the macaques seemed to be more tolerant of disturbance (excluding conversion) than either *Hylobates* spp. or colobines species (Figure 2). The greatest similarities in primate density were between sites of the same vegetation type (Figure 3). There was an additional grouping between the virgin sites and the forest fragments (Figure 3).

Table 2. Comparison of primate diversity in all study sites

Key: *H.s.*: *Hylobates syndactylus*; *H.l.*: *Hylobates lar*; *P.m.*: *Presbytis melalophos*;
T.o.: *Trachypithecus obscurus*; *M.f.*: *Macaca fascicularis*; *M.n.*: *Macaca nemestrina*.
 p : present
 ? : not recorded but thought to use the site surveyed

FR	<i>H.s.</i>	<i>H.l.</i>	<i>P.m.</i>	<i>T.o.</i>	<i>M.f.</i>	<i>M.n.</i>	Total
Virgin							
Lesong	-	p	p	p	p	p	5
Sg. Lalang	-	p	p	p	-	p	4
Logged							
Sg. Lalang	-	p	p	p	-	p	4
Kemasul	p	p	p	p	p	p	6
Fragment							
Paya Pasir	-	p	p	p	?	p	4
Bt. Tarek	-	p	p	p	p	p	5
Plantation							
Bt. Tarek	-	-	-	-	p	-	1
Total	1	6	6	6	4	6	

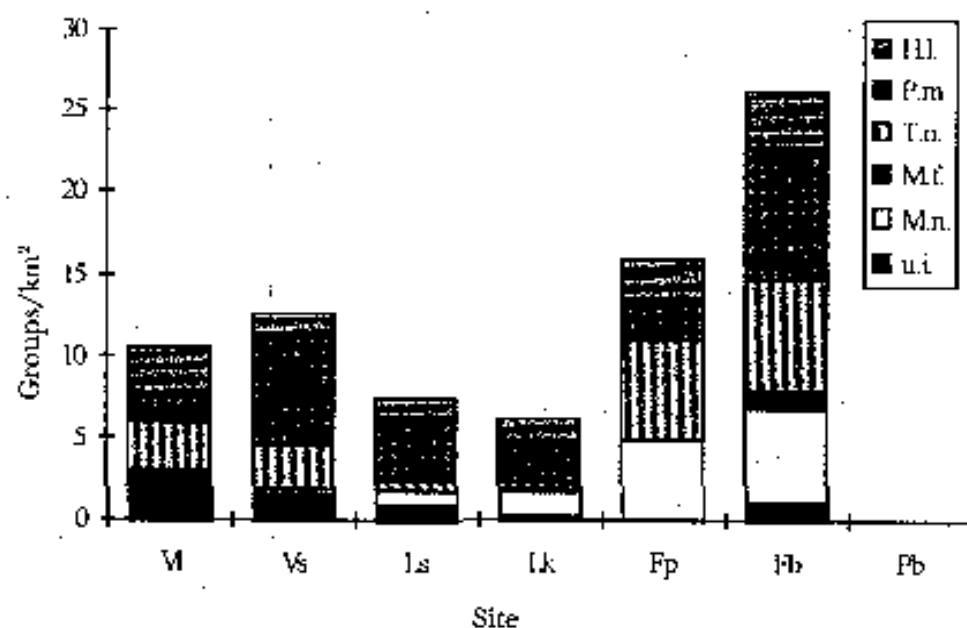


Figure 2. Comparison of primate group density/km² between all study sites
Key: As in Table 2 and Figure 1

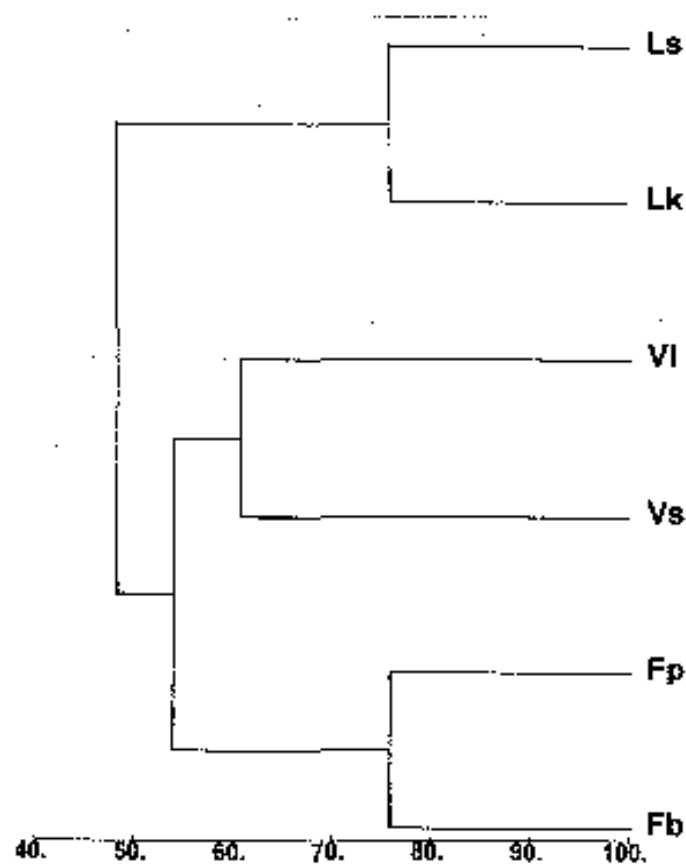


Figure 3. Site grouping from primate group density data using Bray-Curtis similarity measure (all sites except the plantation)
Key: As in Figure 1

Squirrels and treeshrews

Disturbance, in particular selective logging, has been shown to affect the diversity of certain sections of the animal community, e.g. avifauna (Johns 1986a, 1987b, Wong 1986, Lambert 1990, 1992, Thiollay 1992). It was noted that only *Callosciurus notatus* and *Tupaia glis*, the most versatile species, were encountered in every study site (including the plantation forest in Bukit Tarek FR where the lowest number of species occurred), regardless of the type of disturbance experienced (Table 3). In contrast to the primates (Table 2), diversity of squirrels and treeshrews differed noticeably between sites (Table 3). It appeared that some of the species were more sensitive to habitat change than the primates, e.g. *Sundasciurus hippurus* was apparently restricted to virgin forest. Other species were more tolerant e.g. *Sundasciurus tenuis*, which was widespread in natural forest sites, but, even so, was apparently unable to tolerate the *A. mangium* plantation. Certain species, e.g. *Tupaia minor* seemed to have a preference for logged forest.

Certain similarities were noted between the disturbed sites which contained natural vegetation (Figure 5). This was largely because *Callosciurus* spp., on the whole, seemed to respond favourably to disturbance though not to total forest conversion as in the Bukit Tarek plantation (where the lowest density of species was found) (Figure 4). In addition, *Tupaia* spp., notably *Tupaia glis*, although relatively common in all sites, tended to respond favourably to disturbance, in particular, logging disturbance (Figure 4). In keeping with the primate data, the virgin sites were noted as being similar to each other but distinct from the other sites (Figure 5).

Table 3. Comparison of squirrel and treeshrew diversity in all study sites

Key: R.a.: *Ratufa affinis*; R.b.: *Ratufa bicolor*; C.c.: *Callosciurus caniceps*; C.n.: *Callosciurus notatus*; C.ng.: *Callosciurus nigrovittatus*; C.p.: *Callosciurus prenestii*; S.h.: *Sundasciurus hippurus*; S.l.: *Sundasciurus lowii*; S.t.: *Sundasciurus tenuis*; L.i.: *Lorisius insignis*; R.l.: *Rhinosciurus laticaudatus*; T.g.: *Tupaia glis*; T.m.: *Tupaia minor*.
p : present

Site	R.a.	R.b.	C.c.	C.n.	C.ng.	C.p.	S.h.	S.l.	S.t.	L.i.	R.l.	T.g.	T.m.	Total
Virgin														
Lesong	p	p	-	p	-	-	p	-	p	-	-	p	-	6
Sg. Lalang	p	p	p	p	p	-	p	-	p	-	p	p	-	9
Logged														
Sg. Lalang	-	p	p	p	p	-	-	-	p	-	p	p	p	8
Kemasul	p	-	p	p	p	-	-	p	p	p	p	p	p	10
Fragment														
Paya Pasir	-	p	p	p	p	-	-	-	p	p	-	p	-	7
Bukit Tarek	-	-	-	p	-	p	-	-	p	-	-	p	-	4
Plantation														
Bukit Tarek	-	-	-	p	-	-	-	-	-	-	-	p	-	2
Total	3	4	4	7	4	1	2	1	6	2	3	7	2	

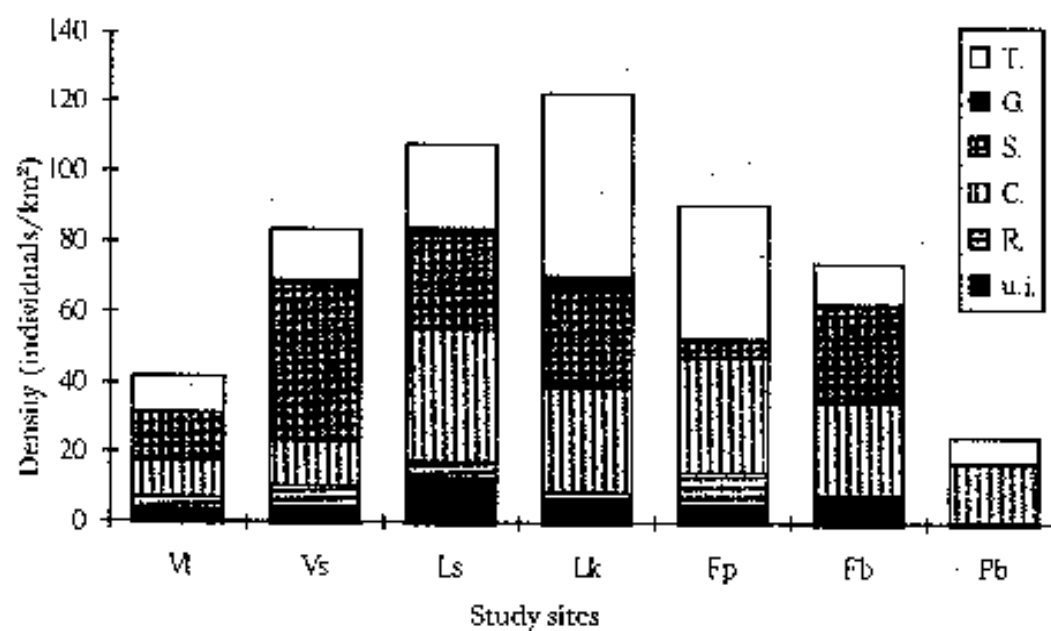


Figure 4. Comparison of squirrel and treeshrew density/km² in all sites (level: genus)
Key: As in Table 3 and Figure 1

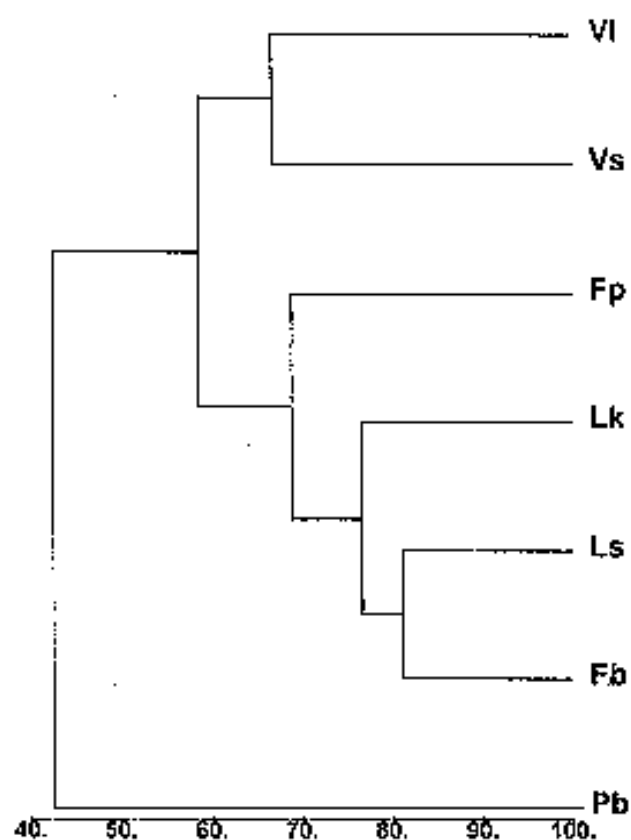


Figure 5. Site groupings from squirrel and treeshrew density data using Bray-Curtis similarity measure
Key: As in Figure 1

Table 4. Mammal diversity in all FRs/areas of natural vegetation and in the *Acacia mangium* plantation. Key: P: present

SPECIES		SITE					
		<i>A. mangium</i> Plantation	Bkt. Tarek 70ha	Paya Pasir 164ha	Kemasul >10,000ha	Sg. Lalang >10,000ha	Lesong >10,000ha
<i>Callosciurus notatus</i>	(6)	P	P	P	P	P	P
<i>Sus scrofa</i>		P	P	P	P	P	P
<i>Tragulus spp.</i>		P	P	P	P	P	P
<i>Muntiacus muntjak</i>		P	P	P	P	P	P
<i>Tupaia glis</i>		P	P	P	P	P	P
<i>Macaca nemestrina</i>	(5)	-	P	P	P	P	P
<i>Presbytis melalophos</i>		-	P	P	P	P	P
<i>Trachypithecus obscurus</i>		-	P	P	P	P	P
<i>Hylobates lar</i>		-	P	P	P	P	P
<i>Sundasciurus tenasis</i>		-	P	P	P	P	P
<i>Tapirus indicus</i>		-	P	P	P	P	P
<i>Macaca fascicularis</i>	(4)	P	P	-	P	-	P
<i>Manis flavigula</i>		-	-	P	P	P	P
<i>Callosciurus caniceps</i>	(3)	-	-	P	P	P	-
<i>Callosciurus nigrovittatus</i>		-	-	P	P	P	-
<i>Civet spp.</i>		-	-	P	P	P	-
<i>Helarctos malejanus</i>		-	-	-	P	P	P
<i>Hyrrix brachyura</i>		-	-	-	P	P	P
<i>Ratusa affinis</i>		-	-	-	P	P	P
<i>Ratusa bicolor</i>		-	-	P	-	P	P
Small flying squirrel spp.		-	-	-	P	P	P
<i>Tupaia minor</i>		-	-	-	P	P	P
<i>Callosciurus prevasii</i>	(2)	-	P	-	P	-	-
<i>Elephas maximus</i>		-	-	-	P	-	P
<i>Felis spp.</i>		-	-	-	P	P	-
<i>Hylotes spadicus</i>		-	-	-	P	P	-
<i>Lariscus insignis</i>		-	-	P	P	-	-
<i>Paguma larvata</i>		-	-	-	-	P	P
<i>Rhinosciurus laticaudatus</i>		-	-	-	P	P	-
<i>Sundasciurus hippurus</i>		-	-	-	-	P	P
<i>Arctitis binturong</i>	(1)	-	-	-	-	P	-
<i>Bos gaurus</i>		-	-	-	P	-	-
<i>Cervus unicolor</i>		-	-	-	-	-	P
<i>Cynocephalus variegatus</i>		-	-	-	-	P	-
<i>Felis marmorata</i>		-	-	-	-	P	-
<i>Herpestes sp.</i>		-	-	-	P	-	-
<i>Hylobates syndactylus</i>		-	-	-	P	-	-
<i>Manis javanica</i>		-	-	-	-	P	-
<i>Neofelis nebulosa</i>		-	-	-	P	-	-
Otter spp.		-	-	-	P	-	-
<i>Panthera tigris</i>		-	-	-	-	-	P
<i>Petaurista petaurista</i>		-	-	-	P	-	-
<i>Ptilocercus lowii</i>		-	-	-	-	P	-
<i>Sundasciurus lowii</i>		-	-	-	P	-	-
Total P (44)		6	18	17	34	31	24

Mammals and habitat fragmentation

The list of species in Table 4 is headed by species/species groups that were recorded in the five forest reserves and one plantation, *i.e.* in all six forests, followed by those that were recorded in five forests, four forests and so on. The list ends with species that were recorded in only one forest. Species are laid out alphabetically in each section. Data for Lesong, Sungai Lalang and Kemasul FRs include both relatively undisturbed/virgin forest and logged forest. The order Chiroptera and family Muridae have been excluded. The most striking aspect of the data presented in Table 4 concerns the trend in species composition in the smallest and the largest areas of natural forest. A gradation is immediately obvious from left to right of the Table, in that species encountered in the smallest areas of natural forest *i.e.* Bukit Tarek VJR (70 ha), tend to be the most widespread overall. Specifically, 85 per cent of the species that were recorded in that area were also recorded in every other FR sampled.

The rarest species were encountered only in the three largest areas (Lesong, Sungai Lalang and Kemasul FRs), *i.e.* 57 per cent of species were only recorded in FRs of $\geq 10,000$ ha. This is reflected in Figure 6 where a similarity measure presents the three largest areas as entirely separate from the remaining, relic areas. In addition, 86 per cent of the species were not recorded in the plantation, *i.e.* the conversion to plantation has resulted in a massive loss of species diversity.

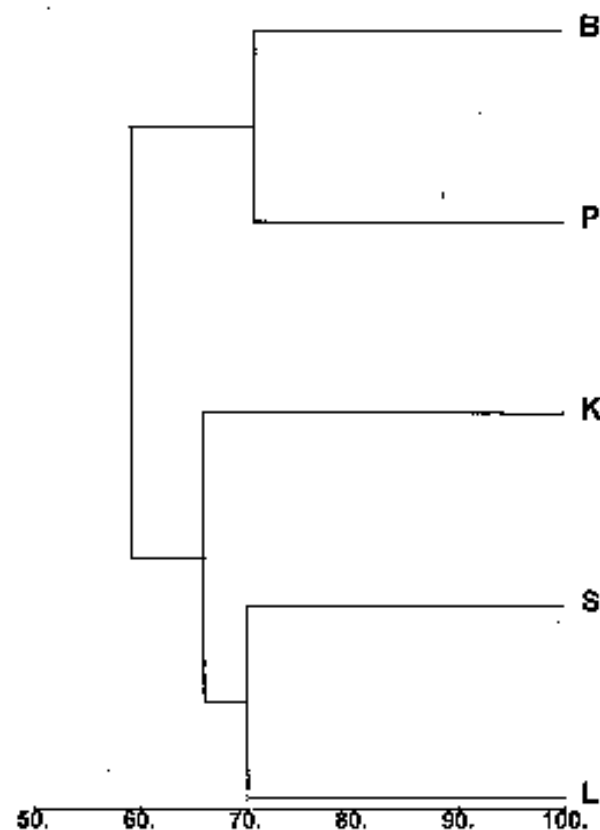


Figure 6. Site grouping from mammal diversity data for all FRs/areas of natural vegetation using Bray-Curtis similarity measure (excluding the plantation)

Key: L: Lesong FR; S: Sungai Lalang FR; K: Kemasul FR; P: Paya Pasir VJR; B: Bukit Tarek VJR

Discussion

Virgin forest sites

The communities of primates, squirrels and treeshrews in the virgin sites were different from those in the other sites sampled. The virgin sites were characterised by a relatively low primate density. This was expected, mostly because of the composition of the forests, the relatively low densities of Moraceae (which are important sources of food for certain mammals) and relatively high densities of Dipterocarpaceae. Likewise, the species densities of squirrels and treeshrews were relatively low, in particular, those that were apparently associated with disturbance (e.g. *Callosciurus notatus* and *Tupaia glis*). However, total primate density was higher in the virgin forest sites than in the logged forest sites. Certain species were only recorded in the virgin forest sites (e.g. *Sundasciurus hippurus*) or showed an apparent preference for virgin forest.

Logged forest sites

In comparison with the virgin forest sites, the most striking effects of logging on primates, squirrels and treeshrews, were a decrease in primate densities and a change in the diversity of squirrels and treeshrews. Certain species either have a habitat preference for disturbed vegetation (e.g. *Callosciurus caniceps*) or are better adapted to cope with the effects of logging disturbance (e.g. *Macaca nemestrina*). *Hylobates* spp. and the colobine species appeared to be less tolerant of commercial logging (and silvicultural treatment). The repeated logging of an area is likely to exacerbate these responses. Diversity of primates, may ultimately be affected. In the short-term, however, logged forest can provide a variety of habitats for small mammals such as squirrels and treeshrews. This is thought to be reflected in the high diversity of such mammals recorded in logged forest in comparison with both virgin and fragmented sites.

Fragmented forest sites

An area of natural forest which survives conversion, may be affected by increased competition for existing resources by immigrants fleeing conversion. In view of the long period since conversion took place at both Paya Pasir and Bukit Tarek (more than nine years), the effects of an initial increase in population were probably less important than the carrying capacity of the remaining forest fragment and the nature of the adjoining land-use. The latter may have been enhanced by chronic low-intensity human disturbance and/or increased exposure to light, and the primates may be able to supplement their diet by foraging outside the fragment.

The nature of the disturbance, therefore, in Paya Pasir VJR (164 ha) and Bukit Tarek VJR (70 ha) relic sites has apparently resulted in a favourable habitat for primates, in that primate density at both sites was the highest in comparison with the

other sites, especially in terms of *Macaca* spp. Species diversity had also been maintained. Diversity of squirrels and treeshrews in Paya Pasir VJR was comparable with the other sites surveyed in this study (excluding the plantation). Diversity in Bukit Tarek VJR, however, was markedly lower. This may suggest that the 70 ha site is now only capable of sustaining four species of what was originally a more diverse population; an alternative explanation would be the regional distribution of squirrels meaning that only four such species were ever present in this site. In the absence of data before conversion, it is now impossible to be sure. Squirrel and treeshrew densities in the relic sites were less than in the logged forest and similar to virgin forest, perhaps indicating less use of the surrounding matrix and/or movement between the relic and the matrix, than primates.

Fragmentation of natural forest resulted in differences in the diversity of the mammal communities in the five FRs. The most impressive difference between the large ($\geq 10,000$ ha) and small areas (≤ 164 ha) of natural forest was that the rarer, least abundant species with more specialised and less flexible requirements (in terms of behaviour and diet), were only recorded in the largest areas of natural forest (Lesong, Sungai Lalang and Kemasul - all $\geq 10,000$ ha) whereas the most flexible, widespread and abundant species were recorded in all forest reserves. The survival of mammal populations in small forest fragments is substantially affected by outside factors. The long-term survival of those species which are not adapted to the particular conditions of forest fragments is in doubt. The communities in such fragments, therefore, cannot be regarded as stable.

Plantation forest

In stark contrast to all of the other sites, the structure and composition of the *A. mangium* plantation was uniform, as is to be expected of a plantation. The effects of land conversion from natural forest to plantation are dramatic and generally detrimental for forest mammals. In the area undergoing conversion, forest mammals either die (e.g. through a fall, starvation or fire) or individuals may move away into adjoining areas of natural vegetation (if they exist) (Green 1978, Marsh *et al.* 1987). The ability of certain mammals to recolonise the converted area will depend on their ability to make use of the plantation and in certain cases, proximity to natural vegetation.

Conversion to plantation is the most extreme form of habitat disturbance and the *A. mangium* plantation was seen to have a dramatic negative effect on mammal diversity. In the natural forest sites in this study, primate diversity was relatively unaffected by the types of disturbance encountered. In comparison, the monoculture of *A. mangium* resulted in an almost total absence of primates with only one species (*Macaca fascicularis*) being recorded. Squirrel and treeshrew diversity was also dramatically affected in that only one species of squirrel (*Callosciurus notatus*) and one species of treeshrew (*Tupaia glis*) were encountered. Overall, only the most adaptable species were able to make use of the plantation.

Conclusion

Some species in the present study apparently react favourably to logging and/or fragmentation. Other mammal species, however, are adversely affected, for example, certain of the rarer, least abundant species, including some of the largest, most wide-ranging and/or specialist species are apparently unable to cope with habitat fragmentation. Commercial logging, however, does not present as severe a problem for these species. Most species are able to survive at least one commercial felling although diversity and densities change; and some species are seen to react favourably to the effects associated with this type of habitat disturbance. Other species, however, are seen to show a preference for the least disturbed and/or virgin sites. Conversion to plantation results in a massive loss of diversity. Only a few of the most adaptable species were seen to make use of plantation forest.

It is expected that by the end of the 1990's all remaining natural forest in Peninsular Malaysia will be included in the PFE (and some TPAs) and will therefore be under increased pressure for exploitation. LDF, in particular, is under threat. Bearing this in mind, in order to conserve a full range of species diversity in Peninsular Malaysia, special attention must be given to the habitat requirements of those species worst affected by habitat fragmentation and/or logging and other forms of disturbance. Those species which are seen to thrive in disturbed habitats do not need such special measures.

Conservation efforts in Peninsular Malaysia should therefore be devoted to conserving large areas of continuous natural (although not necessarily virgin) forest; and to conserving areas of virgin forest. The main points to bear in mind are as follows:

Avoiding fragmentation

A figure of 10,000 ha has been suggested as a minimum area below which the instantaneous loss of certain area-demanding species will result. In this study, the greatest diversity, including some of the largest mammals in the Peninsula, occurred in FRs exceeding 10,000 ha. A primary conservation objective in Peninsular Malaysia, therefore, should seek to avoid fragmentation and to conserve large areas of continuous, productive, natural forest. This should be made a conscious priority in forest management policy, so that when forest exploitation involves a choice between a course which would result in fragmenting an area of continuous natural forest, and not doing so, the non-fragmenting course should invariably be followed.

Conserving virgin forest

The diversity of primates, squirrels and treeshrews was similar in the two virgin forest sites, but was dissimilar to logged and fragmented forests. This was true even though one of the sites was only one compartment in the middle of a large logged forest and the other was part of an area of continuous virgin forest. This shows that even a small area (82 ha) of virgin forest, when surrounded by a large area of natural forest, is effective in conserving a substantial part of the characteristics of virgin forest. Even

relatively small areas of virgin forest, therefore, provided that they are within a much larger area of natural forest, are effective in enhancing the survival of certain species. In view of this, attention should be given to whether it is practical to preserve areas of virgin forest within the logged (and increasingly fragmented) productive natural forest.

Peninsular Malaysia is fortunate in that it has an established system of Virgin Jungle Reserves (VJR) which are basically small, theoretically undisturbed, compact samples of forest generally located in commercially productive forest (Laidlaw 1994). This network was designed to maintain areas of virgin forest within productive forest (Wyatt-Smith 1950, 1963). Size is an important factor when considering a patch of virgin forest within logged forest. The (non-statutory) Guidelines for VJRs suggest a minimum size of 259 ha (one square mile, *i.e.* one compartment) and a minimum number of one VJR in each large Forest Reserve of economic value (Wyatt-Smith 1963). It should be noted, however, that in Sabah, the VJRs are on the whole considerably larger than those in the Peninsula; the average size of VJRs in Sabah is 1,802 ha (IUCN 1985) compared with 244 ha in the Peninsula (Laidlaw 1994) and in this respect the Sabah model is to be preferred. In practice, at the moment, the VJR network in the Peninsula falls short of meeting even the existing criteria.

Laidlaw (1994) made an assessment of the VJR network and concluded that in terms of management and survival, VJRs can be viable and that they can be effective to enhance vegetation and certain mammal communities in managed forest. A positive management strategy is, however, essential for their survival and the success of any expansion of the existing system. As in the case of avoiding fragmentation of natural forest (see above), recognition and support at the highest levels are needed, if the existing VJR network is to form the basis of an expanded system of protected virgin forest areas in the future.

Conserving natural forest fragments

It is realistic to assume that natural forest in Peninsular Malaysia, in particular LDF, will continue to become fragmented. Declaring virgin, or the most undisturbed remaining areas as VJRs has the additional but essentially fall-back benefit, that if properly maintained, the VJR may survive as a patch of natural forest even though the surrounding natural forest has been converted into plantation. An example of this in the present study is Bukit Tarek VJR. As such, even under the worst possible conditions, the VJR can continue to have a conservation benefit. It should be emphasised, however, that this is very much less than optimum (see above), particularly in the long-term. When the possibility of a protected virgin area becoming a forest fragment is considered, size assumes critical importance. Results from this study show a difference between areas of 70 ha and 164 ha; and whilst the Guidelines for the VJRs suggest a minimum area of 259 ha, still larger areas are likely to prove more beneficial for mammal populations.

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References

- BRAY, J.R. & CURTIS, J.T. 1957. A ordination of the upper land forest communities of southern Wisconsin. *Ecological Monographs* 27: 325-349.
- BROCKELMAN, W.Y. & ALI, R. 1987. Methods of surveying and sampling forest primate populations. Pp. 23-62 in Marsh, C.W. & Mittermeier, R.A. (Eds.) *Primate Conservation in the Tropical Rain Forest*. 365 pp. Alan R. Liss Inc., New York.
- BURNHAM, K.P., ANDERSON, D.R. & LAKE, J.L. 1980. Estimation of density from line transect sampling of biological populations. *Wildlife Monograph Number* 72.
- CLARKE, K.R. 1993. Non-parametric multivariate analyses of changes in community structure. *Australian Journal of Ecology* 18: 117-143.
- DAHABAN, Z. 1996. *Wildlife Conservation in Hill Dipterocarp Forest in Sarawak*. Unpubl. doctoral dissertation, 260 pp. Universiti Kebangsaan Malaysia.
- DAVIES, A.G. & PAYNE, J.B. 1982. *A Faunal Survey of Sabah*. World Wildlife Fund Malaysia, Kuala Lumpur.
- GOODALL, D.W. 1954. Objective methods for the classification of vegetation. III. An essay in the use of factor analysis. *Australian Journal of Botany* 2: 304-324.
- GREEN, K.M. 1978. Primates of Bangladesh: a preliminary survey of population and habitat. *Biological Conservation* 13: 141-160.
- IUCN. 1985. *Directory of Indomalayan Protected Areas*. Draft prepared by the Protected Areas Data Unit, Conservation Monitoring Centre, Cambridge.
- JOHNS, A.D. 1983. *Ecological Effects of Selective Logging in a West Malaysian Rain forest*. Unpubl. doctoral dissertation, 356 pp. University of Cambridge.
- JOHNS, A.D. 1986. *Effects of Habitat Disturbance on Rain Forest Wildlife in Brazilian Amazonia*. Unpublished report to World Wildlife Fund US, Washington DC, USA.
- JOHNS, A.D. 1987. The use of primary and selectively logged rainforest by Malaysian hornbills (Bucerotidae) and implications for their conservation. *Biological Conservation* 40: 179-190.
- JOHNS, A.D. 1987. *Long-term Effects of Selective Logging Operations on Malaysian Wildlife: A Case Study in the Tekam Forest Reserve, Pahang, Peninsular Malaysia*. 18 pp. Unpublished report to the Forest Research Institute of Malaysia and the Socio-Economic Research Unit of the Prime Minister's Department.

- JOHNS, A.D. 1988. *Long-term Effects of Selective Logging Operations on Malaysian Wildlife. II. Case Studies in the Ulu Segama Forest Reserve, Danum Valley and Tabin Conservation Areas, Sabah, East Malaysia*. 28 pp. Unpublished report to the Danum Valley Management Committee, Sabah Foundation and the Socio-Economic Research Unit of the Prime Minister's Department.
- JOHNS, A.D. & SKORUPA, J.P. 1987. Responses of rain forest primates to habitat disturbance: a review. *International Journal of Primatology* 8: 157-191.
- KARR, J.R. 1982. Avian extinction on Barro Colorado Island, Panama: a reassessment. *American Naturalist* 119: 220-239.
- LADDLAW, R.K. 1991. *The Virgin Jungle Reserves of Peninsular Malaysia: The Ecology and Dynamics of Small Protected Areas in Managed Forest*. 304 pp. Unpubl. doctoral dissertation, University of Cambridge.
- LAMBERT, F.R. 1987. *Fig-eating and Seed Dispersal by Birds in a Malaysian Lowland Rain Forest*. Unpubl. doctoral dissertation, University of Aberdeen.
- LAMBERT, F.R. 1990. *Antifungal Changes Following Selective Logging of a North Bornean Rain Forest*. 59 pp. Unpublished report to the Danum Valley Management Committee, Sabah Foundation and the Socio-Economic Research Unit of the Prime Minister's Department. Institute of Tropical Biology, University of Aberdeen.
- LAMBERT, F.R. 1992. The consequences of selective logging for Bornean lowland forest birds. *Philosophical Transactions of the Royal Society, London B* 335: 443-457.
- LAURANCE, W.F. 1990. Comparative responses of five arboreal marsupials to tropical forest fragmentation. *Journal of Mammalogy* 71: 641-653.
- LAURANCE, W.F. 1991. Ecological correlates of extinction proneness in Australian tropical rain forest mammals. *Conservation Biology* 5: 79-89.
- LIM, M. T. 1991. Lowland and hill forests. Pp. 19-21 in Kiew, R. (Ed.) *The State of Nature Conservation in Malaysia*. 237 pp. Malayan Nature Society.
- LORD, J.M. & NORTON, D.A. 1990. Scale and the spatial concept of fragmentation. *Conservation Biology* 4: 197-202.
- LOVEJOY, T.E., BIERREGAARD, R.O., RANKIN, J.M. & SCHUBART, O.R. 1983. Ecological dynamics of tropical forest fragments. Pp. 377-384 in Sutton, S.L., Whitmore, T.C. & Chadwick, A.C. (Eds.) *Tropical Rain Forest: Ecology and Management*. Blackwell, Oxford.
- LOVEJOY, T.E., BIERREGAARD, R.O., RYLANDS, J.R., MALCOLM, G.E., QUINTELA, C.E., HARPER, L.H., BROWN, K.S., POWELL, A.H., POWELL, G.V.H., SCHUBART, H.O.R. & JAWS, M.B. 1986. Edge and other effects of isolation on Amazon forest fragments. Pp. 251-285 in Soul, M.E. (Ed.) *Conservation Biology: The Science of Scarcity and Diversity*. 584 pp. Sinauer Associates, Inc., Sunderland, Mass.
- MARSH, C.W., JOHNS, A.D. & AMES, J.M. 1987. Effects of habitat disturbance on rainforest primates. Pp. 83-107 in Marsh, C.W. & Mittermeier, R.A. (Eds.) *Primate Conservation in the Tropical Rain Forest*. 365 pp. Alan R. Liss, Inc., New York.
- MARSH, C.W. & WILSON, W.L. 1981. *A Survey of Primates in Peninsular Malaysian Forests*. 107 pp. Universiti Kebangsaan Malaysia and Cambridge University, Cambridge.
- MARTIN, C. & ASHREY, E.O.A. 1979. Effect of timber exploitation on primate populations and distribution in the Bia rap forest area of Ghana. Paper presented to 7th IPS Congress, Bangalore, India.
- MATTHIAS, P.E. & STEARNS, F. 1981. Mammals in forest islands in southeastern Wisconsin. Pp. 55-66 in Burgess, R.L. & Sharp, D.M. (Eds.) *Forest Island Dynamics in Man-dominated Landscapes*. 296 pp. Springer-Verlag, New York.
- MURRAY, D.F. 1981. Censusing the gorillas in Kahuzi-Biega National Park. *Biological Conservation* 21: 163-176.
- NEWMARK, W.D. 1991. Tropical forest fragmentation and the local extinction of understory birds in the eastern Usambara Mountains, Tanzania. *Conservation Biology* 5: 67-78.
- PAHL, L.I., WINTER, J.W. & HEINSHOK, G. 1988. Variation in responses of arboreal marsupials to fragmentation of tropical rainforest in North Eastern Australia. *Biological Conservation* 46: 71-82.
- PLUMPTRE, A.J. & REYNOLDS, V. 1994. The effect of selective logging on the primate populations in the Budongo Forest Reserve, Uganda. *Journal of Applied Ecology* 31: 631-641.
- PRIMACK, R.B. 1993. *Essentials of Conservation Biology*. 564 pp. Sinauer Associates, Inc., Sunderland, Mass.
- RJRSSEN, H.D. 1978. *A Field Study of Sumatran Orang-Utans (Pongo pygmaeus abelii), Lesson 1827: Ecology, Behaviour and Conservation*. H. Veerinan and B.V. Zonen, Wageningen, Netherlands.
- SKORUPA, J.P. 1987. *Effects of Selective Timber Harvesting on Rain Forest Primates in Kibale Forest, Uganda*. Unpubl. doctoral dissertation, University of California.
- SOUL, M.E., ALBERTS, A.C. & BOLGER, D.T. 1992. The effects of habitat fragmentation on chaparral plants and vertebrates. *Oikos* 63: 39-47.
- SOUTHWICK, C.H. & CARDIGAN, F.C. 1972. Population studies of Malaysian primates. *Primates* 13: 1-19.

- TERBORGH, J. 1989. *Where Have All the Birds Gone?* Princeton University Press, Princeton.
- TERBORGH, J. 1992. Maintenance of diversity in tropical forests. *Biotropica* 24: 283-292.
- THOLLAY, J.M. 1992. Influence of selective logging on bird species diversity in a Guianan rain forest. *Conservation Biology* 6: 47-63.
- WHITCOMB, R.F., ROBBINS, C.S., LYNCH, J.F., WHITCOMB, B.L., KLIMKIEWICZ, M.C. & BYSTRAL, D. 1981. Effects of forest fragmentation on avifauna of the eastern deciduous forest. Pp. 125-205 in Burgess, R.L. & Sharp, D.M. (Eds.) *Forest Island Dynamics in Man-dominated Landscapes*. 293 pp. Springer-Verlag, New York.
- WILCOVE, D.S., McLELLAN, C.H. & DOBSON, A.P. 1986. Habitat fragmentation in the temperate zone. Pp. 237-256 in Soul, M.E. (Ed.) *Conservation Biology: The Science of Scarcity and Diversity*. 584 pp. Sinauer Associates, Inc., Sunderland, Mass.
- WILLIS, E.O. 1974. Populations and local extinctions of birds on Barro Colorado Island, Panama. *Ecological Monographs* 44: 153-169.
- WILLIS, E.O. 1979. The composition of avian communities in reminiscent woodlots in southern Brazil. *Papeis Avulsas Zoológicas* 33: 1-25.
- WILSON, C.C. & WILSON, W.L. 1975. The influence of selective logging on primates and some other animals in East Kalimantan. *Folia Primatologica* 23: 245-274.
- WILSON, C.C. & WILSON, W.L. 1976. Behavioral and morphological variation among primate populations in Sumatra. *Yearbook of Physical Anthropology* 20: 207-233.
- WILSON, W.L. & JOHNS, A.D. 1982. Diversity and abundance of selected animal species in undisturbed forest, selectively logged forest and plantations in East Kalimantan, Indonesia. *Biological Conservation* 24: 205-218.
- WILSON, E.O. 1988. The current state of biological diversity. Pp. 3-18 in Wilson, E.O. (Ed.) *Biodiversity*. 521 pp. National Academy Press, Washington, D.C.
- WILSON, E.O. & WILLIS, E.O. 1975. Applied biogeography. Pp. 522-534 in Cody M.L. & Diamond, J.M. (Eds.) *Ecology and Evolution of Communities*. Harvard University Press, Cambridge, Mass.
- WONG, M. 1982. *Patterns of Food Availability and Understorey Bird Community Structure in a Malaysian Rain Forest*. Unpubl. doctoral dissertation, University of Michigan.
- WONG, M. 1986. Trophic organisation of understorey birds in a Malaysian dipterocarp forest. *The Auk* 103: 100-116.
- WYATT-SMITH, J. 1950. Virgin Jungle Reserves. *The Malayan Forester* 13: 92-94.
- WYATT-SMITH, J. 1963. Manual of Malayan silviculture for inland forests. *Malayan Forest Records No. 23*.



Plate 1. The common tree shrew, *Tupaia glis*, which was encountered in every study site, regardless of the type of forest disturbance.
Photo: Norazman Hussain

Appendix 1

<i>Arctitis binturong</i>	Binturong/bearcat
<i>Bos gaurus</i>	Gaur
<i>Callosciurus caniceps</i>	Grey-bellied/golden backed squirrel
<i>Callosciurus nigrovittatus</i>	Black-banded squirrel
<i>Callosciurus notatus</i>	Plantain squirrel
<i>Callosciurus prevostii</i>	Prevost's squirrel
<i>Cervus unicolor</i>	Sambhur
Civet spp.	Civet species
<i>Cynocephalus variegatus</i>	Flying lemur
<i>Elephas maximus</i>	Indian elephant
<i>Felis marmorata</i>	Marbled cat
<i>Felis</i> spp.	Cat species
<i>Helarctos malayanus</i>	Malayan sun bear
<i>Herpestes</i> sp.	Mongoose species
<i>Hylobates lar</i>	White-handed gibbon
<i>Hylobates syndactylus</i>	Siamang
<i>Hylopetes spadiceus</i>	Red-cheeked flying squirrel
<i>Hyrrix brachyura</i>	Malayan porcupine
<i>Lariscus insignis</i>	Three-striped ground squirrel
<i>Macaca fascicularis</i>	Long-tailed macaque
<i>Macaca nemestrina</i>	Pig-tailed macaque
<i>Manis javanica</i>	Malayan pangolin
<i>Martes flavigula</i>	Yellow-throated marten
<i>Muntiacus muntjak</i>	Barking-deer/Indian muntjac
<i>Neofelis nebulosa</i>	Clouded leopard
Otter spp.	Otter species
<i>Paguma larvata</i>	Masked palm civet
<i>Panthera tigris</i>	Tiger
<i>Petaurista petaurista</i>	Red giant flying squirrel
<i>Presbytis melalophos</i>	Banded langur
<i>Prilocercus lowii</i>	Pentail treeshrew
<i>Ratufa affinis</i>	Cream-coloured/common giant squirrel
<i>Ratufa bicolor</i>	Black giant squirrel
<i>Rhinosciurus laticaudatus</i>	Shrew-faced ground squirrel
Small flying squirrel spp.	Small flying squirrel species
<i>Sundasciurus hippurus</i>	Horse-tailed squirrel
<i>Sundasciurus lowii</i>	Low's squirrel
<i>Sundasciurus tenuis</i>	Slender squirrel
<i>Sus scrofa</i>	Wild pig
<i>Tapirus indicus</i>	Malayan tapir
<i>Trachypithecus obscurus</i>	Dusky leaf monkey
<i>Tragulus</i> spp.	Mouse-deer species
<i>Tupaia glis</i>	Common treeshrew
<i>Tupaia minor</i>	Lesser treeshrew

GENETICS AND REPRODUCTIVE BIOLOGY OF TWO DIPTEROCARP TREE SPECIES

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The genetic diversity and breeding systems of *Shorea leprosula* and *Hopea odorata* from Peninsular Malaysia were investigated using isozyme, random amplified polymorphic DNAs and cytogenetic analyses. The genetic diversity of *S. leprosula* is higher than that of *H. odorata*. *S. leprosula* is predominantly outcrossing whereas *H. odorata* is a facultative apomict. The implications of the level of genetic variation within and between populations and the breeding system parameters in these two species for conservation and management are discussed.

Keywords: Genetic diversity - breeding systems - *Shorea leprosula* - *Hopea odorata*

Introduction

Although the tropical rainforests of South East Asia are recognised as being extremely rich in flora and fauna, information on the genetics and reproductive biology of the ecologically and economically important tree species is fragmentary. Limited

information on the reproductive biology of species in the Dipterocarpaceae, the dominant rainforest family, is available from the early studies of Rao (1953, 1956, 1962), Maury (1968, 1970), Chan and Appanah (1980), Appanah (1987) and Kaur *et al.* (1986). Data on the genetics of rain forest species is even more scanty although some work on the cytogenetics of the Dipterocarpaceae has been carried out by Jong and Lethbridge (1967), Jong (1976, 1982), Somego (1978) and Kaur *et al.* (1986).

The pioneering work of Gan *et al.* (1981) on isozymes of lowland rainforest species including the Dipterocarpaceae is presently being pursued at the Forest Research Institute Malaysia (FRIM) (Wickneswari 1990, 1993, Wickneswari *et al.* 1996). Collaborative studies between FRIM and the Forestry and Forest Products Research Institute of Japan (FFPRI) are being carried out on molecular genetics of the Dipterocarpaceae (Tsumura & Wickneswari 1991, 1992, Tsumura *et al.* 1993, Tsumura *et al.* 1995). Recently, reports on genetic relatedness between species of *Shorea* (Harada *et al.* 1994) and the breeding systems in *Dryobalanops aromatica* (Kitamura *et al.* 1994) and *Shorea megistophylla* (Murawski *et al.* 1994) have been published. With renewed interest in gaining a better understanding of the genetics and reproductive biology of the Dipterocarpaceae, sustainable management and enhanced utilisation of members in this family appear more optimistic.

An understanding of reproductive biology, especially the origin of multiple embryos in certain dipterocarps, would aid in the development of suitable propagation methods for *ex-situ* conservation of the species. Knowledge of the pattern of genetic variation within and among populations and the type of breeding system would assist in the development of procedures for proper sampling of genetic variation for *ex-situ* conservation. The results of genetic studies together with those from taxonomic surveys and ecological studies would greatly aid proper identification and demarcation of populations for *in-situ* conservation.

This paper reports some of the results from Project A11 on evaluation of the genetic diversity and characterisation of breeding systems of some important rain forest plant species carried out under the collaborative programme between Malaysia and the United Kingdom. The project was conceived with the intention of generating comprehensive information on the genetics and reproductive biology of some *Shorea* and *Hopea* species in Peninsular Malaysia for their improved management and utilisation. Towards this end, three approaches, namely, molecular marker analysis, chromosome analysis and reproductive biology studies were carried out.

Two species, namely, *Shorea leprosula* Miq. and *Hopea odorata* Roxb. were selected. *S. leprosula* known locally as Meranti tembaga, is widely distributed and one of the most important commercial timber species in Malaysia. It is common and even abundant on deep clay soil in lowland and hill dipterocarp forests below 700 m (Symington 1943) and has been reported to occur gregariously in clumps (Ashton 1982). The natural distribution of *H. odorata* ranges from Indo-China, Myanmar, Thailand and Malaysia to the Andaman Islands. In Malaysia, it has been reported to occur in the states of Perlis, Kedah, Perak, Kelantan and Terengganu, near rivers or streams (Symington 1943). However, Wickneswari and Norwati (1994) reported that *H. odorata* is presently found in reduced numbers in disturbed habitats only in south Perak, south Terengganu and north Kelantan.

The studies reported here were conducted as part of post-graduate projects by Lee Soon Leong (Genetic diversity of *Shorea leprosula* using isozyme and RAPDs markers) and Fatimah Mohammed (Studies on reproductive biology including cytoembryology of several *Hopea* Roxb. (Dipterocarpaceae) species in Peninsular Malaysia), and as part of on-going research projects by Wickneswari Ratnam (Genetic diversity and breeding systems in *Hopea odorata*) and Mahani Mansur Clyde (Cytogenetics of *Hopea odorata*).

Materials and methods

Sampling sites

S. leprosula

Leaf and twig samples of *S. leprosula* saplings from eight natural populations in Peninsular Malaysia were collected. Details are given in Table 1. To investigate the pattern of genotypic distribution within and between clumps, the inner bark tissues of 28 mature trees from Pasoh Forest Reserve representing four clumps, were sampled. The inner bark tissues of saplings and mature trees were used for enzyme extraction following the procedures of Wickneswari *et al.* (1995a). The leaves of saplings and inner bark tissues of mature trees were used for DNA extraction using a modified CTAB method (Murray & Thompson 1980). To determine the breeding system parameters of *S. leprosula*, 50 to 100 seeds were collected from each of ten trees in Sungei Menyala Forest Reserve.

H. odorata

Four remnant populations of *H. odorata* from Simpang Sayung, Bukit Ajil, Kampung Chap and Tumpat, and two populations planted in the grounds of FRIM and in Kuala Terengganu respectively, were sampled. Details of the number of samples per population and tissues used for extraction of enzymes are given in Wickneswari *et al.* (1995a).

Isozyme analysis

S. leprosula

Tissue extracts from *S. leprosula* were screened for enzyme activity for 29 enzyme systems. Electrophoretic variation for each sample was analysed at nine loci from six enzyme systems. Details of the electrophoretic procedures and staining methods are given in Lee (1997).

H. odorata

Tissue extracts from *H. odorata* were screened for enzyme activity for 25 enzyme systems. All samples of *H. odorata* were analysed for electrophoretic variation at 16 loci from ten enzyme systems. Details of the electrophoretic procedures and staining methods are given in Wickneswari *et al.* (1995a).

Table 1. Sites and number of *Shorea leprosula* saplings sampled at each site for isozyme analysis

Forest Reserve	No. of saplings/mature trees	Habitat
Bukit Perak, Kedah	53 saplings	Inland
Sungkup, Kedah	36 saplings	Inland
Panti, Johor	42 saplings	Inland
Pasoh, Negeri Sembilan	53 saplings, 38 mature trees	Inland
Bangi, Selangor	44 saplings, 37 mature trees	Inland
Beserah, Pahang	68 saplings	Coastal
Segari Melintang, Perak	55 saplings	Coastal
Sungai Menyala, Negri Sembilan	50 saplings	Inland

*Random Amplified Polymorphic DNAs (RAPDs) analysis**S. leprosula*

Good quality DNA obtained from leaves of 35-40 saplings from each population of *S. leprosula* were used for RAPDs analysis. Table 2 summarizes the populations used for RAPDs analysis. Purified DNAs were used for optimisation of Polymerase Chain Reaction (PCR) protocols for RAPDs analysis. Five *S. leprosula* individuals were used for screening 120 arbitrary primers (OPERON Technologies Inc. and GENOSYS Biotechnology Inc., USA) for specificity and polymorphisms. Forty-nine primers yielded three to seven fragments per primer with polymorphisms between the individuals. The best ten out of the 49 or sufficient numbers of primers that could yield a total of 50-60 fragments were used for determining the genetic variation within and between all populations. Details of the RAPDs analysis are given in Lee *et al.* (1997).

H. odorata

Leaves of 23 to 26 mature trees of *H. odorata* from the remnant populations at Bukit Ajil and Tumpat and the planted populations from FRIM and Kuala Terengganu were used for RAPDs analysis. A total of 76 arbitrary primers (OPERON Technologies Inc. and GENOSYS Biotechnology Inc., USA) were screened for specificity and polymorphism. Nineteen primers which generated good amplification products were used for the RAPDs analysis. Details of the RAPDs analysis are given in Wickneswari *et al.* (1996).

Table 2. *Shorea leprosula* populations used for RAPD analysis

Population	No. of samples
Sungai Menyala, N. Sembilan	40
Panti, Johor	40
Bukit Perak, Kedah	40
Bezerah, Pahang	40
Bangi, Selangor	40
Pasoh, N. Sembilan	35
Segari Melintang, Perak	40

Results and Discussion

Estimation of genetic diversity using isozyme and RAPD markers

S. leprosula

Nine loci from 6 enzyme systems could be consistently scored for all samples. Analysis of the isozyme data for the eight populations revealed high levels of expected heterozygosities with values ranging from 0.326 to 0.400 indicating sufficient genetic diversity to support an intensive breeding programme for the species. A high proportion of the total genetic diversity was partitioned within populations with genetic differentiation among populations being only 10.7 per cent (Lee 1997). The number of migrants per generation was estimated to be 5.2 indicating high levels of gene flow among populations in Peninsular Malaysia. However, Lee (1997) reported a high correlation of genetic identity between populations and latitudinal differences irrespective of habitat differences.

RAPDs analysis of seven *S. leprosula* populations using seven random primers generating 66 fragments showed that on average, 85.6 per cent of the genetic variability (measured by Shannon's Diversity Index) in the species was distributed within populations and 14.4 per cent between populations, indicating low population differentiation (Lee *et al.* 1996). All the seven populations showed very high levels of genetic diversities (1.799 to 2.329). The Shannon's diversity indices, H_{sp} (diversity within the species) and H_{pop} (diversity within the different populations) for *S. leprosula* were 2.668 and 2.224 respectively, indicating high diversities (Lee *et al.* in press). Inland populations showed higher genetic variabilities compared to coastal populations. Disturbed (fragmented) populations also showed higher genetic variabilities compared to undisturbed populations.

The mean genetic similarity between the seven populations was 0.61 with values ranging from 0.48-0.73 suggesting moderate genetic differentiation among populations. The UPGMA (Unweighted Pair Group Method of Averaging) analysis showed weak correspondence between genetic similarity and geographical distance. However, Principle Component Analysis of genetic similarities derived from the RAPDs data also revealed good correspondence with latitudinal differences.

As mentioned earlier, *S. leprosula* trees occur in clumps. Isozyme analysis of four clumps of *S. leprosula* in Pasoh Forest Reserve did not show any distinct genotype differentiation between clumps indicating the possibility of random distribution of genotypes in a particular site. More clumps need to be analysed before concluding the absence of genotype preferences to clumping and geographical conditions.

These findings on genetic diversity of *S. leprosula* in Peninsular Malaysia using isozyme and RAPDs markers imply that *S. leprosula* is a robust species with high genetic diversity in Peninsular Malaysia. The low inter-population heterogeneity detected in *S. leprosula* most probably suggests that the populations used in this study could have been part of a larger continuous forest habitat with genetic sub-structuring occurring as a process of fragmentation due to human intervention. Hence, it is tempting to speculate that the current rate of forest fragmentation would probably result in more effective isolation of the species (i.e. less gene flow among populations) and loss of genetic variation through random genetic drift.

Information emerging from this study combined with results from progeny trials of superior wild phenotypes of *S. leprosula* would be useful for selection of plus trees for cloning and further genetic improvement.

H. odorata

From an analysis of 16 isozyme loci from ten enzyme systems, the mean expected heterozygosity for the six *H. odorata* populations ranged from 0.137 to 0.236 with an average of 0.190 (Wickneswari et al. 1995a). Mean fixation indices ranged from -0.299 to -0.190 with a mean of -0.560 indicating a general excess of heterozygotes probably due to selection because of disturbance and prevalence of asexual reproduction. Populations of *H. odorata* have been subjected to severe disturbances in Malaysia where their natural habitats have been drastically reduced or converted to other land uses. However, the existing populations/seed sources in the country appear to have sufficient genetic diversity (H_e [expected heterozygosity] = 0.190, $H_{app} = 0.455$) to support a selective breeding programme. All populations should be evaluated for growth performances in different sites with emphasis given to populations with high genetic diversity. As the *H. odorata* populations sampled in this study appear to be the only available seed sources for the species in Malaysia, conservation measures need to be taken immediately before any further genetic erosion takes place.

RAPDs analysis of the two remnant populations (Bukit Ajil and Tumpat) and the two planted populations using 19 random primers generating 44 fragments revealed a similar trend in the level of diversity for the different populations as compared to the isozyme analysis (H_e (diversity for each population) = 0.177 to 0.640 with $H_{app} = 0.455$ and $H_{pop} = 0.333$) (Wickneswari et al. 1996).

Breeding systems

S. leprosula

Estimation of multilocus outcrossing rates using six polymorphic isozyme loci in the ten families of *S. leprosula* from Sungai Menyala revealed *S. leprosula* to be predominantly outcrossing. Outcrossing rates ranged from 0.67-1.25 with a mean of 0.887 (Lee 1997). Using controlled pollination experiments, Chan and Appanah (1981) found *S. leprosula* to be self-incompatible in an arboretum. However, in this study we found that selfing can occur in the range of 0-0.33 in *S. leprosula*. Generally *S. leprosula* ($2n = 14$, Kaur *et al.* 1986) produces single embryos but seeds with two embryos were very occasionally detected in this study. Chi-square tests for the occurrence of apomixis in families with less than 0.70 multilocus outcrossing rate or families that produced multiple embryos were not significant indicating absence of apomixis in *S. leprosula* (Lee 1997). Inbreeding coefficient as measured by Wright's fixation index was low in *S. leprosula*.

In order to maintain the high outcrossing rates in *S. leprosula*, it is desirable to conserve this species in a few large populations rather than many small populations. High outcrossing rates will result in high heterozygosity of individuals and high heterogeneity of populations thus enhancing adaptability and survival of the species.

H. odorata

As is common among lowland dipterocarps, mass flowering and fruiting of *H. odorata* is irregular and may occur once in two to three years. The flowers produced are tiny and pale yellow. *H. odorata* fruits are commonly polycarpic and one fruit may produce up to seven seedlings (Maury 1970). Wickneswari and Norwati (1994) reported that 43 per cent of germinated seeds from five trees produced three viable seedlings per seed reconfirming occurrence of polyembryony.

H. odorata has been reported to be a diploid with $2n = 2x = 14$ (Roy & Jha 1965) and also a near triploid with $2n = 3x = 20, 21$ or 22 (Tixier 1953, Kaur *et al.* 1978; Somego 1978). Somego (1978) suggested the possibility of occurrence of two series of basic chromosome numbers *i.e.* $x = 7$ and $x = 11$ (or ten) in *Hopea* where *H. beccariana*, *H. subulata* and *H. odorata* belong to the group with $x = 11$, $2n = 22$. Recently, Mahani and Fatimah (unpublished) reported unambiguous counts of $2n = 21$ in seedlings from two *H. odorata* trees (one from FRIM and another from Kuala Terengganu). *H. odorata* is thus a triploid, but there is yet no confirmation of the presence of two divergent basic numbers in *Hopea*.

Apomixis has been inferred in *H. odorata* from its triploid nature (Malayan material), multiple seedlings and embryological studies (Kaur *et al.* 1986). However, Ihara *et al.* (1986) estimated 63 per cent outcrossing in seedlings from plantation grown *H. odorata* trees using an isozyme marker *Adh-1*. Recently, isozyme and DNA profiles of *H. odorata* seedlings revealed genetic variation between multiple seedlings from single seeds indicating the presence of both sexual and asexual reproduction in this species (Wickneswari & Norwati 1994, Wickneswari *et al.* 1995b).

The production of multiple seedlings should not be treated as strictly clonal material. Breeders/conservationists need to take into consideration the genetic status of multiple seedlings in *H. odorata*. The capacity to produce large quantities of seedlings through polyembryony (Maury 1970, Wickneswari & Norwati 1994) leading to higher genetic variability without manipulation in an otherwise uniform set of multiple seedlings, further enhances its potential as a plantation species. As this species is amenable to vegetative propagation by stem cuttings (Aminah 1991), some of the novel genotypes detected in multiple seedlings could be multiplied and field tested for their growth performance and other useful parameters e.g. resistance to diseases and drought.

This paper has attempted to highlight the value of genetic studies of lowland tropical trees, and also the endangered status of certain species, such as *H. odorata*, where clear evidence of genetic erosion in that species is found in Malaysia.

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References

- APPANAH, S. 1987. Insect pollination and the diversity of dipterocarps. Pp. 277-291 in Kostermans, A.J.G.H. (Ed.) *Proceedings of the Third Round Table Conference on Dipterocarps*. UNESCO, Jakarta, Indonesia.
- AMINAH, H. 1991. Rooting ability of Dipterocarp species. *Journal of Malaysian Applied Biology* 20: 155-159.
- ASHTON, P.S. 1982. Dipterocarpaceae. *Flora Malesiana* Ser. I. Vol. 9: 237-552.
- CHAN, H.T. & APPANAH, S. 1980. Reproductive biology of some Malaysian dipterocarps. I. Flowering biology. *Malaysian Forester* 43: 132-148.
- GAN, Y.Y., ROBERTSON F.W. & SOEPADMO E. 1981. Isozyme variation in some rainforest trees. *Biotropica* 13: 20-28.
- HARADA, K., KINOSHITA, A., SHUKOR, N.A.A., TACHIDA, H. & YAMAZAKI, T. 1994. Genetic variation estimate in three *Shorea* species by the RAPD analysis. *Japanese Journal of Genetics* 69: 713-718.
- IHARA, M., GARRINAB, L.U., SIREGAR, U.J. & IYAMA, S. 1986. Genetic control of alcohol dehydrogenase and estimation of some population parameters in *Hopea odorata* Roxb. (Dipterocarpaceae). *Japanese Journal of Genetics* 61: 127-136.
- JONG, K. & LETTBRIDGE, A. 1967. Cytological studies in the Dipterocarpaceae, I. Chromosome number of certain Malaysian genera. *Notes of the Royal Botanical Garden Edinburgh* 27: 175-184.
- JONG, K. 1976. Cytology of the Dipterocarpaceae. Pp. 79-84 in Burley, J. & Styles, B.T. (Eds.) *Tropical Trees: Variation, Breeding and Conservation*. Linnean Society, London.
- JONG, K. 1982. Cytology. Pp. 267-273 in P.S. Ashton (Ed.) *Dipterocarpaceae. Flora Malesiana* Ser. 1 Vol. 9.
- KACR, A., HA, C.O., JONG, K., SANDS, V.E., CHAN, H.T., SOEPADMO, E. & ASHTON, P.S. 1978. Apomixis may be widespread among trees of the climax rain forest. *Nature* 271: 440-442.
- KACR, A., JONG, K., SANDS, V. E. & SOEPADMO, E. 1986. Cytoembryology of some Malaysian dipterocarps, with some evidence of apomixis. *Botanical Journal of the Linnean Society* 92: 75-88.
- KITAMURA, K., MOHAMAD YUSOF, A.R., OCHIAI, Y. & YOSHIMARU, H. 1994. Estimation of the outcrossing rate on *Dryobalanops aromatica* Gaertn. f. in primary and secondary forest in Brunei, Southeast Asia. *Plant Species Biology* 9: 37-41.

- LEE, S.L. 1997. Genetic diversity and mating system of *Shorea leprosula* Miq. (Dipterocarpaceae). Ph.D. thesis, Universiti Kebangsaan Malaysia.
- LEE, S.L., WICKNESWARI, R., MAHANI, M.C. & ZAKRI, A.H. *Shorea leprosula* Miq. (Dipterocarpaceae): A species with high genetic diversity but low population differentiation revealed by RAPD analysis in Peninsular Malaysia. *Malaysian Forester* (in press).
- MAURY, G. 1968. Germination anormale chez les Dipterocarpacees de Malaisie. *Bulletin du la Societe d'Histoire Naturelle de Toulouse* 104: 187-202.
- MAURY, G. 1970. Différents types de polyembryonie chez quelques Dipterocarpacees Asiatiques. *Bulletin du la Societe d'Histoire Naturelle de Toulouse* 106: 282-288.
- MURAWSKI, D. A., DAYANANDAN, B. & BAWA, K.S. 1994. Outcrossing rates of two endemic *Shorea* species from Sri Lankan tropical rain forests. *Biotropica* 26: 23-29.
- MURAWSKI D.A., GUNATILLEKE I.A.U.N. & BAWA K.S. 1994. The effects of selective logging on inbreeding in *Shorea megistophylla* (Dipterocarpaceae) from Sri Lanka. *Conservation Biology* 8(4): 997-1002.
- RAO, A.N. 1953. Embryology of *Shorea tatora*. *Phytomorphology* 3: 476-484.
- RAO, A.N. 1956. Life history of *Shorea robusta* Gaertn. *Current Science* 25: 128-129.
- RAO, A.N. 1962. Floral anatomy and gametogenesis in *Hopea racophloea*. *Journal of the Indian Botanical Society* 41: 557-562.
- ROY, R.P. & JHA, R.P. 1965. Cytological studies in the Dipterocarpaceae. *Journal of the Indian Botanical Society* 44: 387-397.
- SOMEGO, M. 1978. Cytogenetical study of Dipterocarpaceae. *Malaysian Forester* 41: 358-365.
- SYMINGTON, C.F. 1943. Forester's manual of Dipterocarps. *Malayan Forest Records No. 16*. Forest Research Institute Kepong, Selangor.
- TEXIER, P. 1953. Données cytologiques sur quelques Guttiferales du Vietnam. *Revue de Cytologie et de Biologie vegetales* 14: 1-12.
- TSUMURA, Y. & WICKNESWARI R. 1991. Phylogenetic relationships of Dipterocarpaceae. Paper presented at the 104th Japanese Forestry Society Meeting, Tokyo.
- TSUMURA, Y. & WICKNESWARI R. 1992. Chloroplast DNA variation in Dipterocarpaceae. Preliminary results. Paper presented at 5th National Molecular Biology Seminar, Kuala Lumpur, 2-3 October 1992.
- TSUMURA, Y., WICKNESWARI R., KAWAHARA, T. & YOSHIMURA K. 1993. Phylogeny of Dipterocarpaceae using RFLP of chloroplast DNA. Paper presented at XV International Botanical Congress, Yokohama, Japan, 28 August - 3 September 1993.
- TSUMURA, Y., KAWAHARA, T., WICKNESWARI, R. & YOSHIMURA, K. 1995. Molecular phylogeny of Dipterocarpaceae in Malesia using RFLP of PCR-amplified specific genes in chloroplast DNA. *Theoretical and Applied Genetics* 93: 22-29.
- WICKNESWARI R. 1990. Isozyme analysis of tropical rainforest tree species. Paper presented at XIX IUFRO World Congress, August 5-11, 1990, Montreal, Canada.
- WICKNESWARI R. 1993. Genetic considerations of biodiversity in tropical rain forests. *Malaysian Forester* 56(3): 109-115.
- WICKNESWARI, R. & NORWATI, M. 1994. Genetic variation in polycembryos of *Hopea odorata* Roxb. Pp. 76-78. in Koh, C.L. (Ed.) *Proceedings of the First National Congress on Genetics*. Genetics Society of Malaysia Publication.
- WICKNESWARI, R., ZAWAWI, I., LEE, S.L. & NORWATI, M. 1995a. Genetic diversity of remnant and planted populations of *Hopea odorata* Roxb. Pp. 72-76 in Wickneswari, R., Ahmad Zuhaidi Yahya, Amir Husni Mohd. Shariff, Darus Hj. Ahmad, Khoo, K.C., Suzuki, K., Sakurai, S. & Ishii, K. (Eds.) *Proceedings of the International Workshop of BIO-REFOR*, Kangar, 28 November - 1 December, 1994. BIO-REFOR, IUFRO/SPDC.
- WICKNESWARI R., LEE S.L. & MARIAM D. 1995b. Utility of RAPD markers in detecting genetic variation in multiple seedlings of *Hopea odorata* Roxb. (Dipterocarpaceae). *Malaysian Forester* 58(2): 42-50.
- WICKNESWARI R., NORWATI M., LEE S.L. & LEE C.T. 1996. Effective usage of molecular markers in tropical tree improvement and conservation. Pp. 135-141 in Mahani M.C., Mohamad O. & Zulkiflic Z. (Eds.) *Proceedings of the Second National Genetics Congress*. Genetics Society of Malaysia Publication.

MULTIPLE-USE FOREST MANAGEMENT SYSTEMS

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There has been much public interest and concern about multiple-use forest management systems. However, the general applicability of such management systems is often difficult due to a range of reasons which are highlighted in the paper. The need to incorporate values of soil and water conservation, landscape, biodiversity and wildlife conservation, as well as sustainable local employment into multiple-use forest management is discussed. Some of the systems and tools for multiple-use management are also discussed and research needs identified.

Keywords: Multiple-use management - values - tools

Introduction

The forestry professionals – the managers of forests – have consistently, over the last two hundred years, seen themselves as balancing and maximising the often conflicting demands on forest land within the overriding constraint that they will hand on to the next generation an intact, functioning forest. It is no accident that they have consistently used the term 'Conservator of Forests' for their most senior officers.

The forestry literature of the last ten years contains at least a thousand articles dealing directly with some aspect of multiple-use management of forests – reflecting not only the key nature of this subject for foresters but the accelerating public concern in it.

Certain trends are apparent in the recent literature. Earlier publications tend to concentrate on just two factors – for example, managing wildlife and logging together or incorporating soil conservation and forest management. Later publications are concerned with a much wider range of potential values. There is also discussion of a wide range of potential solutions varying greatly in complexity which tend to be rather site-specific in their application.

The general applicability of multiple-use management

In an important statement to the Commonwealth Forestry Conference in New Zealand, Kirkland (1988) discussed the rise and fall of multiple-use forest management in New Zealand. He described how in 1976 an amendment to the Forest Act gave equal weighting to commercial and non-commercial uses of state forest, which comprised nearly 500,000 hectares of pine plantation and native beech and podocarp forest and forest scrub covering nearly 26 per cent of the country (Blaschke *et al.* 1981).

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Application of the multiple-use approach to both pine and native forests caused disagreements with the Treasury and with the environmental movement who were both dissatisfied that the outcomes were not in their favour and that decision-making lacked transparency. The solution was to divide the then Forest Service into a number of independent single purpose organisations. A para-statal organisation took over the pine forests to run for commercial objectives. A Conservation Department took over nearly all the indigenous forest which was then managed for non-cash benefits.

The difficulties with achieving clarity and harmony in multiple-use management are admitted and will be dealt with later, but is the New Zealand approach a viable solution globally to the conflicts inherent in multiple-use management, or is it the supreme example of a solution that has only local relevance?

Deforestation represents a clear case of the breakdown of multiple-use management - not that this necessarily implies a value judgement on the process itself. It is now generally agreed that there is a close but complex relationship between tropical deforestation and population density such that the denser the population the greater the deforestation (Brown & Pearce 1994). There also appears to be a trend with per capita income, such that deforestation tends to increase with rising per capita income up to a turning point, which one can infer occurs at around US\$1000-2000 per capita per year. Very few authors have tried to integrate theories about tropical deforestation with processes in more highly developed countries. Palo (1994) is one of the exceptions. This author surmises that the situation can be summarised as shown in Table 1. While the summary attempts to reflect the situation prevailing in the world today, it will be apparent to many readers that it also reflects the history of forest management in more developed countries (*e.g.* Stridsberg 1984).

It is very clear therefore that the New Zealand solution is one which is appropriate to a high income country with a very low population density but not one which can apply to the majority of countries, particularly those in the tropics with low incomes and high population densities. Most countries are forced to implement multiple-use management.

Conflicts in forest management can be predicted to occur between countries at different stages of development where the perspective of the relative populations can be expected to be very different. Conflicts can be expected to occur at the break-points in the continuum where perspective shifts. An established institution can be expected to lag popular opinion in its responses.

Values to be incorporated in multiple-use management

There are now a very great number of issues that the public somewhere expect to be protected in forest ecosystems.

Soil and water conservation

It is generally accepted that while a forested landscape will not reduce the overall flow of water from a storm event, it can reduce the speed with which flood waters descend to the often populated flood plain, limit the maximum height of flood water and

reduce damage to crops and property. It is now generally known that selection logging of a catchment can occur in such a way that these values are not lost. However, steep slopes must be avoided and are generally zoned out of forest operations. Logging tracks are responsible for much of the erosion that does occur and they need to be well planned and controlled (O'Loughlin 1982).

Table 1. Interaction of income level and forest activity

Income level per capita US\$	Activities	Role of multiple-use management
< 300	Most of population are rural, hunter-gatherers, migrant graziers, extensive cropping. Forest production, mainly NTFPs, very important in overall economy.	Essential. Forests are key to food-security and livelihoods.
> 300 & < 2000	Cropping intensifies, forest is cleared but key sections of the population still depend on the forest. Forest production seen as less important than new agricultural land.	Essential and very difficult. Most developing countries where deforestation is still high are in this zone.
> 2000 & < 10,000	Role of industry increases. Population more urbanised but relatively immobile. Forest production decreases in relative importance; forest industry increases.	Historically a time of single-issues management with a reversal of deforestation trends.
> 10,000	Economies become more dependent on service industries. Population educated, urbanised and mobile. Forest productivity contributes very little to national GDP. Industry still important but decoupled in public's mind from production.	Public demands multiple-use management of forest lands but are likely to stress non-cash values (recreation, biodiversity conservation) over production and may oppose production if it cannot deliver these.

Landscape values

An urbanised population increasingly expects that the forest will form a static part of the scenery and in developed countries is increasingly hostile to the abrupt change in landscape appearance which occurs when areas are clear felled. At its most extreme, these expectations and the transfer payments that tend to be paid by Central Governments to support the status quo, can totally disrupt orthodox forest management. Price and Vining (1990) document the cases from the Swiss Alps and the Rocky Mountains where the opportunities that tourism presents to earn higher income has caused financial and personnel resources (the latter often being the prime restraint) to be diverted away from forest management. The author is also aware of the situation in the Black Forest where transfer payments from the EU and tourism income make up the bulk of some farmers' incomes. They effectively become paid guardians of the landscape.

Biodiversity conservation

There is a very stark contrast between public expectations for agriculture and industry and those for forestry. It is commonplace to eradicate all pests and competing vegetation in agricultural crops and normal to expect that insect and plant biodiversity will be maximised in forests. Foresters accept the need but find it difficult to incorporate biodiversity conservation as an object of management in a meaningful and effective way. Data are generally lacking on the impacts of management on biodiversity in general and on subsets of biodiversity in particular. It is very easy to overlook those components that are small to invisible. Trivially, logging can be expected to increase biodiversity at any one point, by providing sites that are normally occupied by edge-dwelling species, but may not increase and may decrease aggregate biodiversity in the landscape. However, in those countries where forests are under pressure, destroying the cash values of a forest by making it a strict reserve may cause the destruction of the forest itself. This author has attempted to present the kind of decision chart a forester might need in Figure 1, without wishing to suggest that this figure represents a suggested solution.

In countries where forest is becoming fragmented, there is an urgent need for scientists to advise foresters on the desirable size and inter-connectedness of remnants such that genetic islands are not created.

Wildlife conservation

Wildlife conservation is a subset of the wider issue of biodiversity conservation but is somewhat easier to grapple with. Forested areas naturally contain a range of wildlife which forest management aims to preserve. The problems of establishing an adequate area sufficient for outbreeding and the problems of maintaining adequate corridors between these areas are brought more sharply into focus with larger animals. Foresters' attempts at accommodation may not be adequate (Edge *et al.* 1990).

Sustainable local employment

There is widespread public expectation both in Europe and in the developing world that forest dwelling people will benefit from any development that takes place in the forest near where or in which they live. That can often mean entering into some form of joint management with local people as well as ensuring that the supply of non-timber forest products on which they depend is at worst not disadvantaged by any other form of forest management.

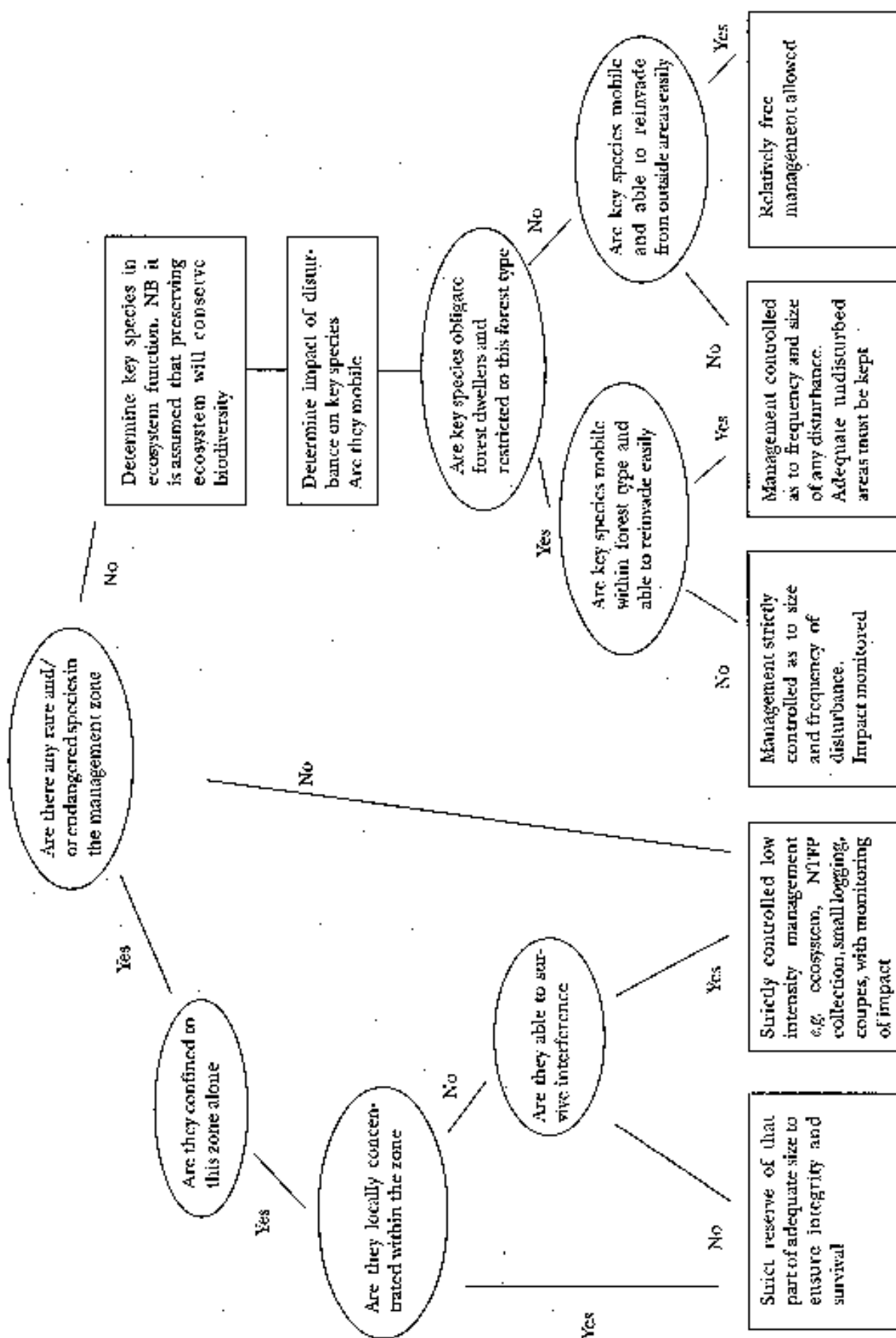


Figure 1. Foresters' decision chart for biodiversity conservation

Systems of multiple-use management

Identifying conflicting aims

There is now a wide range of techniques available for discerning the needs of various stakeholders and attempting to fit them into multiple-use management plans. All suffer from the danger that they can produce an 'activist's compromise' if not carefully used. In the tropics, a technique which is often called 'Participatory Rural Appraisal' (PRA) has been developed to attempt to rank the needs that local people satisfy from the forest so that these needs can be protected or enhanced in management planning. Local people are asked to identify the products they use, when they use them, and how crucial they are. The approach throws up a very large number of subsequent problems that foresters are only beginning to grapple with. For example, what is the distance travelled for certain key resources like medicinal plants? How do neighbouring villages resolve conflicts if their 'ranges' overlap? Should foresters enrichment plant part of the forest to improve the availability of key resources such as rattan and bamboo? How can foresters be sure that all affected parties have been included? How do foresters reconcile the demands of local villagers with those of environmental private volunteer organisations (EPVO) which are probably town-based and not involved in the PRA?

In developed countries various forms of conflict resolution techniques have been used, including face-to-face externally mediated meetings (Marcouiller & Ellefson 1987) and sophisticated psychologically-based survey techniques to find out people's wishes. All approaches do suffer from the danger that they tend to define multiple-use in terms of the groups currently active in the area at the time and are not immune to later discontent from groups that have been inadvertently excluded.

It is probably superficial to believe that people's wishes are well informed. While this is no excuse for an old-fashioned paternalistic 'techno-fix', it is a good reason to see public education as part of any solution. Hamish Kimmins of the University of British Columbia has produced a truly excellent computer game called FORTOON which is suitable for all ages from young to old, which forces the player to make choices about multiple-use management. Thor and Creighton (1978) report a similar approach and Burrus-Bammel *et al.* (1979) describe success in improving the attitudes and factual knowledge of late teenage children through direct field exposure to issues. One should not forget too that some members of the forest administration may benefit from re-orientation and without this may not assist the process (Goufal & Ostby 1989).

Tools for multiple-use management

At an early stage a manager has to decide whether or not he will attempt to manage for all uses on one area or whether he will opt for a mosaic of different uses (zoning). The zoning solution is the one most commonly adopted but arguably is not multiple-use management at all but a means of separating the contestants. We have already seen

how foresters have for two decades at least, tended to leave unlogged slopes greater than 25 degrees for soil and water conservation. It is not as profitable to log steep slopes, hence there is often no great resistance from industrialists to such a zoning. Villagers tend to live on the lowlands. Thus a tendency has arisen to zone out hilly country as a reserve (and hope that will nicely conserve wildlife and other biodiversity), while allowing a zone around the village, which is probably already heavily exploited, to be further exploited for NTFPs. This is clearly neither a stable nor adequate solution. It invites further degradation by villagers because such behaviour is "rewarded" with a larger area for use. It is unlikely to satisfy EPVOs who will argue that it does not adequately preserve all types of biodiversity – flat lowlands are not preserved. Yet, the bounds within which truly multiple-use management can be practised are imperfectly defined.

We must not forget that the power to implement is effectively constrained by land-tenure and by wider Government policies (Kumari 1995). It is no accident that most of the pressure for multiple-use management is applied to securely-managed national lands. Most Governments lack the writ to ensure it occurs on private land [although small private owners may be more sympathetic than large companies (Hyberg & Holthausen 1989)] or on land they own but over which they have no effective control. One has always to remember that a private forestry company cannot repay loans with intangible non-cash benefits and could easily go bankrupt while heavily endowed with non-cash values.

There are several formal tools for arriving at optimal solutions to conflicting demands. Many of these have their base in tools such as linear programming (Parades & Brodie 1988) which is a statistical tool that attempts to find the solution to conflicting aims that yields the maximum utility. It is immediately apparent that the limit to the utilisation of such tools is that the varying costs and benefits can be described in a way that is consistent between the varying aims – and that is seldom easy. How does one rate the value of clean water against more slash and burn farming?

Nevertheless there has been significant progress in formalising multiple-use management systems. FORPLAN which was developed in the United States in response to the legal requirement to develop multiple-use management, is an early and highly developed example (Iverson & Alston 1986). It is held not to provide suitable solutions in some situations (Edge *et al.* 1990). TEAMS is another example (Covington *et al.* 1988). Davis and Liu (1991) discuss another weakness of linear programming based models – that they must be formulated from the view point of one decision maker and suggest a multiple ownership, integrated multiple-use model. The Otway forest plan in Australia (Brinkman 1990) attempts to integrate water, flora, and fauna conservation and soil and landscape protection with recreation, timber production, gravel and rock extraction based on the principles of sustainability, environmental sensitivity, economic viability and public participation. The process is linked to a GIS to facilitate communication. One of the advantages of the raw linear programming tools was that if a solution could not be found they would tell you. Game theory also provides a mechanism for finding solutions to conflicting interests (Rideout & Hof 1987). Pukkala (1988) describes a planning system in which the landscape results of a planning scenario can be projected onto a computer screen as

a member of the public might see them. Other such systems exist. However, there appears to be no general consensus as to which of these many tools yields the better answer.

Conclusions: Research Needs

Foresters believe they have been in the business of multiple-use management for at least two centuries. Foresters are not generally independently wealthy but have to draw their salary from an employer who values their professional input. In recent history many of those employers tended to be industrial companies and government agencies that gave the greatest stress to timber production. The fact that the world has changed and that people are now genuinely interested in multiple-use management is a matter of great pleasure to most foresters. However, the tools to enable competent multiple-use management are still imperfectly developed and here the scientific community can be of great assistance. Specifically we need to know:-

- how can we be sure that we have captured all relevant stakeholders' views and avoided an 'activist's compromise'?
- how can we rank and value the relevant demands such that a generally acceptable solution can be arrived at?
- how can we acceptably factor in to management new information about biodiversity?
- whether it is considered preferable to separate the contestants (by zoning) or to attempt to manage most functions together?
- what methodologies are most acceptable to resolve conflict?

References

- BLASCHKE, P.M., HUNTER, G.G., EYLES, G.O. & VAN BERKEL, P.R. 1981. Analysis of New Zealand's vegetation cover using Land Resource Inventory data. *New Zealand Journal of Ecology* 4: 1-19.
- BRINKMAN, P.R. 1990. Advanced forest planning in the Olways. *Australian Forestry* 53: 290-294.
- BROWN, K. & PEARCE D.W. (eds) 1994. *The Cause of Tropical Deforestation*. 338pp. University College of London Press, London.
- BURRUS-BAMMEL, L.L., BAMMEL, G.C., KIDD, W.E., BAMMEL, L.L. & BAMMEL, G. 1979. Can foresters affect attitudinal change? *West Virginia Forestry Notes* 7: 13-16.
- COUFAT, J.E. & OSTBY, D. 1989. Forestry: in evolution or revolution? *Journal of Forestry* 87: 27-32.
- COVINGTON, W.W., WOOD, D.B., YOUNG, D.L., DYKSTRA, D.P. & GARRETT, L.D. 1988. TEAMS: a decision support system for multiresource management. *Journal of Forestry* 86: 25-33.
- DAVIS, S.L. & LIU, G. 1991. Integrated forest planning across multiple ownerships and decision makers. *Forest Science* 37: 200-226.
- EDGE, W.D., OLSON-EDGE, S.L. & IRWIN, L.L. 1990. Planning for wildlife in national forest: elk and mule deer habitats as an example. *Wildlife Society Bulletin* 18: 87-98.
- HYBERG, B.T. & HOLTHAUSEN, D.M. 1989. The behaviour of non-industrial private forest landowners. *Canadian Journal of Forest Research* 19: 1014-1023.
- IVERSON, D.C. & ALSTON, R.M. 1986. The genesis of FORPLAN: a historical and analytical review of Forest Service planning models. 31pp. USDA Forest Service IRS GTR INT-214.
- KIRLAND, A. 1988. The rise and fall of multiple-use forestry in New Zealand. *New Zealand Forestry* 33: 9-12.
- KUMARI, K. 1995. Is Malaysian forest policy and legislation conducive to multiple-use forest management? *Unasylva* 46: 51-56.

- MARCOUILLER, D.W. & ELLEFSON, P.V. 1987. *Forest land-use and management conflicts: a review and evaluation of approaches for management*. 86pp. University of Minnesota, Forestry Department Staff Paper 65.
- O'LOUGHLIN, C. 1982. Forest land use and its contribution to and control of soil erosion - examples from New Zealand and Malaysia. *Water and Soil Miscellaneous Publication* 46: 327-340.
- PALO, M. 1994. Population and deforestation. Pp. 42-56 in Brown, K. & Pearce, D.W. (Eds.) *The Cause of Tropical Deforestation*. University College of London Press, London.
- PARADES, G.L. & BRODIE, J.D. 1988. Activity analysis in forest planning. *Forest Science* 34: 3-18.
- PRICE, M.F. & VINING, J. 1990. Are mountain tourism and forestry inextricably linked? Pp. 201-218 in Vining, J. (Ed.) *Social Science and Natural Resource Management*. Westview Press, Boulder, Colorado, USA.
- PUTKALA, T. 1988. Methods to incorporate the amenity of landscape into forest management. *Silva Fennica* 22: 135-146.
- RIDEOUT, D. & HOF, J. 1987. Cost sharing in multiple-use forestry: a game theoretic approach. *Forest Science* 33: 81-88.
- THOR, E.C. & CREIGHTON, J.L. 1978. *Mystic Mountain: an educational alternative futures wildland planning game*. 14pp. USDA Forest Service PSWRES, GTR PSW 30.

MULTIPLE-USE FOREST MANAGEMENT AND NON-TIMBER FOREST PRODUCE

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The management of non-timber forest produce is discussed in the context of multiple-use forest management planning. Four management options for non-timber forest produce are presented of which the cultivation of rattans and bamboos and the conservation of biological diversity including plant species yielding non-timber forest produce through best management practices are given highest priority.

Key words: Multiple-use forest management - forest management planning - non-timber forest resources - non-timber forest produce

Introduction

This workshop deals with the management and development of forest resources. In the past forest resources were defined mainly as timber resources and non-wood forest produce *sensu* minor forest products. Today, we would define forest resources with regard to all that is provided by the forests in their various functional aspects. Thus, we would include in Non-Timber Forest Resources the forest's potential for recreation, its potential for providing important scientific information, drinking water and other services. Forest Resources defined in this manner are shown in Figure 1.

Attention must be drawn to the fact that ecological/environmental functions shall as far as possible also be fulfilled within production forests. To be able to do so, so-called Best Management Practices have to be applied, *i.e.* on the forest management planning side, the zoning according to forest functions, and on the forest operations side, the application of on-site operations with low negative impact on the forest environment in general and the forest stand especially. Barden *et al.* (1993) distinguish the following categories of forest functions: (i) regulatory functions (*e.g.* climate regulation, water flow regulation, watershed protection), (ii) carrier functions (*e.g.* recreation sites, carbon storage, nature conservation areas, wildlife habitats), (iii) information functions (*e.g.* educational, historic, scientific information),

and (iv) production function (timber production, other wood products, non-wood forest produce) (Table 1).

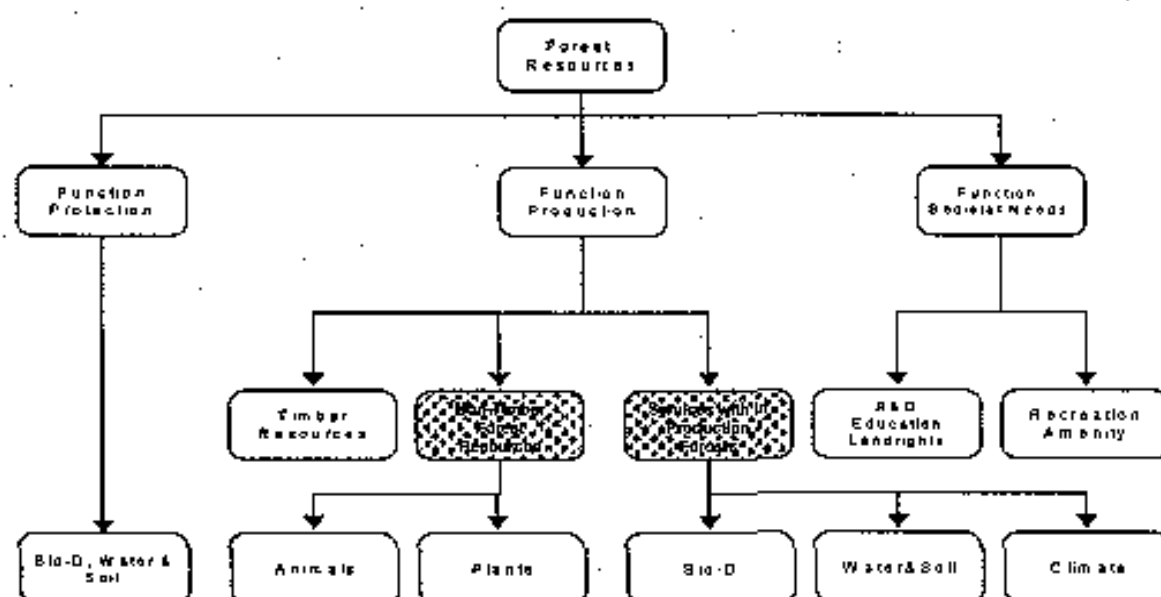


Figure 1. Definition of Forest Resources (Source: Gan & Weinland 1996)

Table 1. Forest functions

Category	Function
Regulatory functions	Climate regulation, water flow regulation, watershed protection, erosion protection, maintenance of biodiversity, provision of migration habitats
Carrier functions	Recreation sites, cultivation areas, carbon storage, tribal land, nature conservation areas and wildlife habitats
Information functions	Spiritual and religious information, cultural and artistic inspiration, educational, historic and scientific information
Production functions	Timber, other wood products, non-wood forest products, genetic resources

We see that the production function is only one among many other functions. Today, forest management planning has to integrate all these functions. Certain restrictions are imposed on the production functions and the restrictions which are applicable to the management of non-timber forest produce forms the theme of this paper.

Non-timber forest produce in forest management planning

Integrated forest management planning proceeds in very distinct steps (see Figure 2). The first step is the zoning of the forest according to functions (production, protection and societal needs). Where forests are managed for protection and meeting societal needs, forest operations are not permitted. Most of the non-production functions can, however, be accommodated within the production function through Best Management Practices.

In the management of a Forest Management Unit at district level of, say, 100,000 ha, a problem arises as to how the management of non-timber forest produce (NTFP) can be considered in the Forest Management Plan.

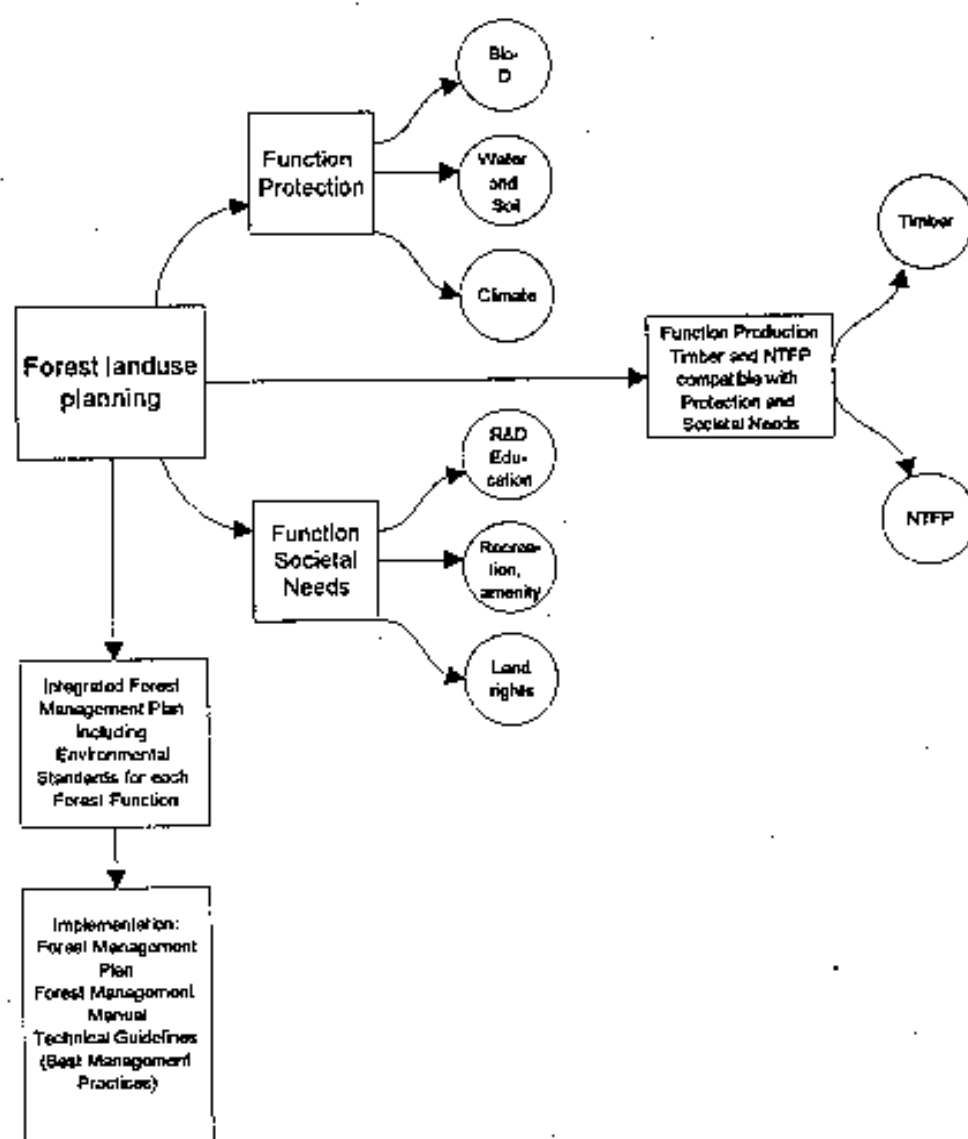


Figure 2. Forest management

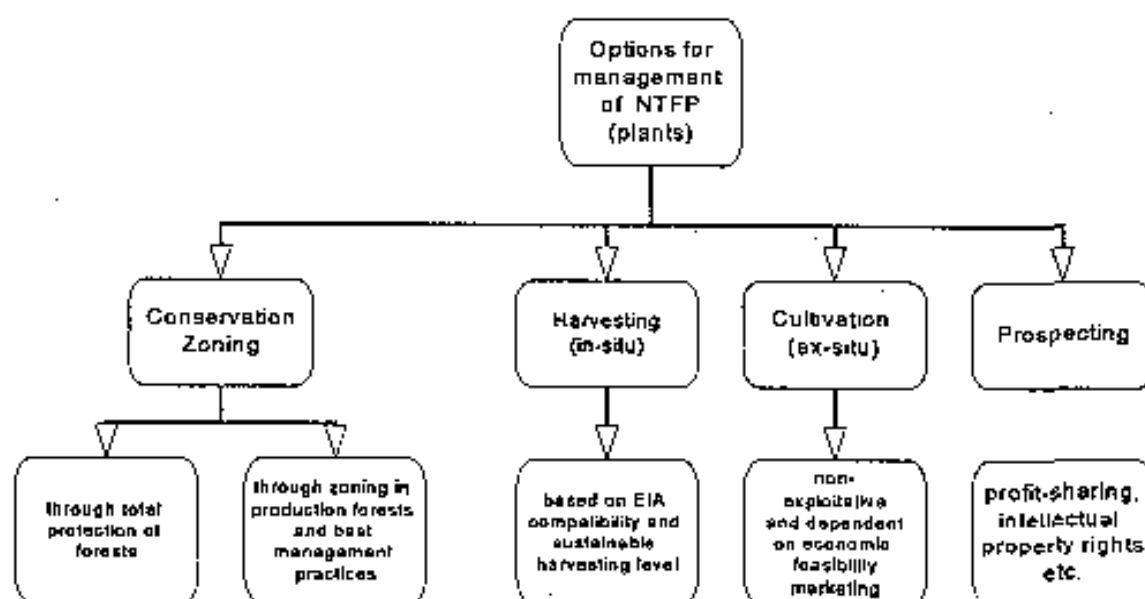


Figure 3. Management options for non-timber forest produce (plants)

There are four basic options of managing non-timber forest produce, namely:

- Harvesting, which in this context means the extraction of a whole plant or parts of a plant from the forests with or without a harvesting plan; such a scheme may include some kind of processing of the harvested material
- Domestication and cultivation, which means the genetic improvement of the NTFP species to the required yield and grade and the subsequent cultivation usually outside the forested area; this scheme may include some kind of processing of the raw material
- Bio-Prospecting, which in this context means the screening of the forest area for plants containing phytochemicals of industrial potential
- Conservation, a passive management scheme, whereby the potential of NTFP plant diversity is maintained through total protection and/or low-impact management and field practices.

When integrating NTFP management into a forest management plan not all the options mentioned would be equally feasible. There are considerable constraints for the implementation of NTFP management schemes. Difficulties may arise from different sources, such as risks of over-exploitation, lack of schemes for immediate implementation, high resource inputs, environmentally unsound practices and lack of know-how concerning the life-cycle of the plant species.

Harvesting (collection from the forests)

In harvesting of plants or plant parts we have to distinguish between the following types:

Harvest of vegetative structures

- Type 1: the removal (destruction) of the whole plant (e.g., single-culm rattan species, *Aquilaria malaccensis*); either completely unsustainable or highly prone to over-exploitation.
- Type 2: the removal of the above surface part of the plant allowing for regrowth by, for example, coppice or root suckers (e.g., bamboos); this would include also the harvesting of the fruit bodies of mushrooms; infrequent, if regrowth is uncertain or, if certain, strictly according to a management plan.
- Type 3: the removal of certain sections of the plant without inflicting injuries on the live tissues of the plant (e.g., harvesting of outer bark in *Melaleuca leucadendron*); strictly according to management plan; this would include the removal of leaves from plants too.

Harvest of plant exudates (latex, gums and resins)

- Type 4: the removal of certain sections of the plant, inflicting injuries on the plant in the process of harvesting (e.g., resin tapping in *Dipterocarpus* spp., *Shorea javanica*; however, certain techniques create destructive wounds, for example, tapping of *Shorea javanica*).

Harvesting of fruits, seeds, honey

- Type 5: the harvesting of fruits (e.g., *Durio* spp., *Parkia speciosa*) without removing the whole plant or branches, which in general is non-destructive; however, the harvesting of commercial quantities of fruits and seeds can affect not only species regeneration, but genetic composition and quality of the resource if only genetically inferior seeds and fruits are left to regenerate; the effect on wildlife depending on those seeds and fruits collected has also to be considered.
- Type 6: the collecting of NTFP which is not produced by the plant it is growing on or attached to (e.g., honey collection from *Koompassia excelsa*); in general of low impact.

Harvesting of NTFP is a critical issue for the following reasons:

- the extraction of resources from the forests may endanger a species owing to over-exploitation (e.g., *Calamus manan*, *Eurycoma longifolia* and *Aquilaria* spp.)
- removal of plant species may disrupt important ecological processes (e.g., removal of source plants for pollinators)
- sustainable use levels are not easily obtained, because the biological cycle normally is not known for these NTFP species.

The importance of conservation of, for example, medicinal plants amongst others, has received attention because plant species were brought to near extinction by large-scale wild collection e.g. *Rauvolfia serpentina* in India (Akerele 1991) and *Parkia roxburghii*, *Curcuma zedoaria*, *Kaempferia galanga*, *Arcangelisia flava* in Indonesia (Rifai & Kartawinata 1991). In the Indian context, Alok (1991) states that much of the collection of medicinal plants from the forests is done by people from the lower segment of society, who have not been trained for the purpose. As a result the collection is wasteful and destructive.

Reinhard (1993) suggests that the integration of the local population into the management of natural tropical forests may facilitate the conservation of forests, since the local people might have an interest in harvesting NTFP in a continuous supply from the forests. However, the notion of the local population as custodians of sustainable use of plants from the forests is doubtful considering the experience mentioned above.

When managing the harvesting of NTFP from the forests the following should be observed:

- Type 1 harvesting should only be allowed, if it does not lead to over-exploitation. Since sustainability is difficult to ascertain, it is recommended - wherever possible - to move into cultivation (e.g., rattan).
- The monitoring of sustainability in Type 2 and Type 4 harvesting will only be possible if the plants are concentrated in specific areas (e.g., bamboos). Otherwise, monitoring would be difficult owing to scattered distribution of plants. On top of that, a continuous quantification of the resources would be required over wide areas which is costly.
- Harvesting in some cases is distinctly seasonal and in, for example, durian and *Parkia* spp. over-exploitation is not an issue. However, care should be taken to monitor the stock and its continuous recruitment.
- The collecting of NTFP from the forests requires considerable effort and time if the resource is scattered over the area. Table 3 gives an impression of how rare the average occurrence of important NTFP tree species is in 1-ha of forest. In the long run, for better monitoring of the resource and for easier collection, it is suggested that the buffer zones of the Forest Estates be enriched with these species (buffer zone management). The forest zones along the main forest roads could be included in such schemes. Kumpulan Perkayuan Kayu-Kayan Trengganu (KPKKT) is carrying out a scheme of planting rattans along the main roads of the logged-over forests.

The harvesting decision process is illustrated in Figure 4.

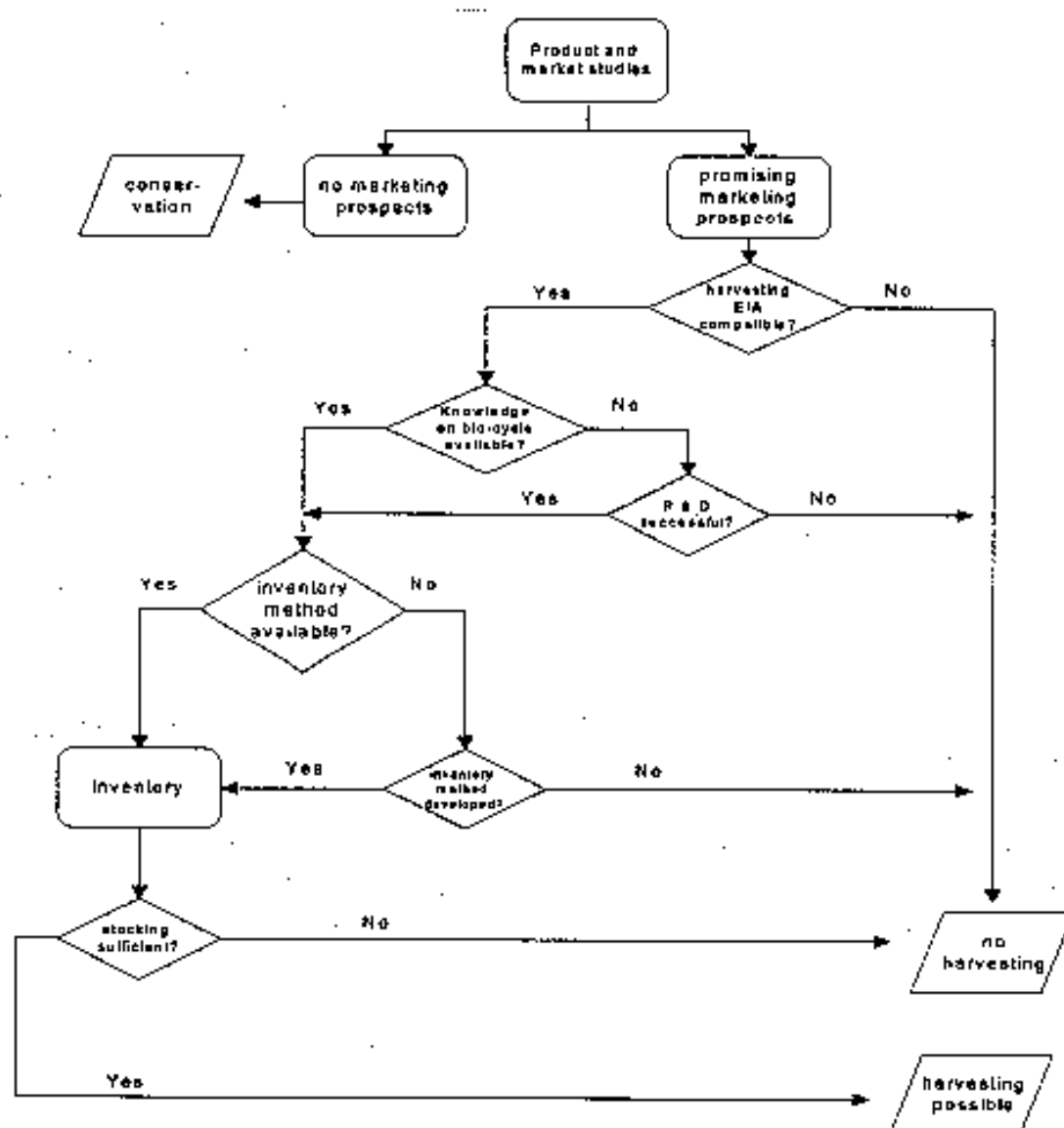


Figure 4. Flow chart on harvesting decision (collection from the forest)

Sustainable harvest levels are not easily obtained, because close to nothing is known about the life-cycle of most of the potential NTFP species. Yield and regeneration studies and harvest assessment can be used to overcome these bottlenecks. Yield studies would concentrate on the relationship between productivity, site and plant size. Together with information from forest inventories the manager can determine (i) total production of the area, (ii) the production according to size classes, and (iii) the production according to forest types. Based on this information different management units may be delineated and harvesting schemes formulated. The regeneration studies serve to assess the impact of harvesting on the regeneration of the plant species. The assessment of adult plants ready for harvesting will reveal the variability in vigour and yield and the extent of damage from pests and diseases. Together with regeneration studies sustainable-use levels can be estimated, for example, in the following ways: (i) the harvest level is reduced if it is found that

regeneration is brought below replacement levels; and (ii) the harvest level is determined using computer models and simulations.

The risk of over-exploitation, the difficulty of introducing a NTFP management system based on harvesting and the disadvantages listed in Table 2 are the reasons why harvesting should be discouraged and cultivation recommended (e.g., Bonati 1991). Chemical and pharmaceutical companies which process high-grade extractions usually demand *ex-situ* cultivation under conditions that can be better controlled because of homogeneous soil and climatic conditions, exact information on age and active constituents, controlled harvesting time and drying conditions, better management, etc.

Table 2. Disadvantages of collecting medicinal plants from the wild compared to cultivation*

	Collecting	Cultivation
Availability	decreasing	increasing
Fluctuation in supply	relatively unstable	stable
Quality control	poor	high
Botanical identification	sometimes questionable	not questionable
Genetic improvement	no	yes
Agronomic manipulation	no	yes
Post-harvest handling	poor	usually good
Adulteration	likely	relatively safe

*(Adopted with modifications from Palevitch 1991)

It may be concluded that mere collecting from the forests is less viable for most of the NTFP species (low abundance, long walking distances). Thus schemes to spatially concentrate utilization of NTFP species in easily accessible areas should be developed. This means that such areas would be enriched with NTFP species and/or the growth and recruitment of existing NTFP species would be enhanced through silvicultural measures. The following scenarios should be tested for feasibility:

- planting of NTFP species that allows for quick return on the investment (e.g., rattans, bamboos)
- planting of NTFP species in mixture with timber producing trees to provide intermediate yield
- planting of NTFP species in degraded stands or on degraded sites beyond rehabilitation for timber
- buffer-zone management that includes planting of NTFP species and tending of existing ones
- planting NTFP species in accessible areas, e.g., along forest roads

Within the present forest management activities the most likely candidates for NTFP management are rattan species. Refinement of the current management practices should be the goal. Simultaneously, other species could be identified and management systems developed for them.

Domestication and cultivation

In Peninsular Malaysia, the domestication and cultivation of NTFP species is at present negligible, except for some fruit tree species (e.g., *Durio zibethinus*), rattans and some ornamental plants. Close to nothing is known about the life-cycle and cultivation techniques of most of the potential NTFP species. The cultivation of aromatic and medicinal plants for high-grade extractives requires skilled farming to ensure qualitative homogeneity of the chemical extracts (Azizol & Ng 1995). Pharmaceutical and chemical companies generally prefer to contract the cultivation to highly specialised and appropriately equipped farms. Smallholders are often not capable of coping with the quality requirements.

NTFP-species to be selected for domestication and cultivation must have the following main characteristics:

- potential for genetic improvement of product characteristics
- potential for cultivation outside its natural habitat
- market potential.

The stages involved in the domestication of, for example, tropical trees is given by Leakey and Newton (1994) as follows:

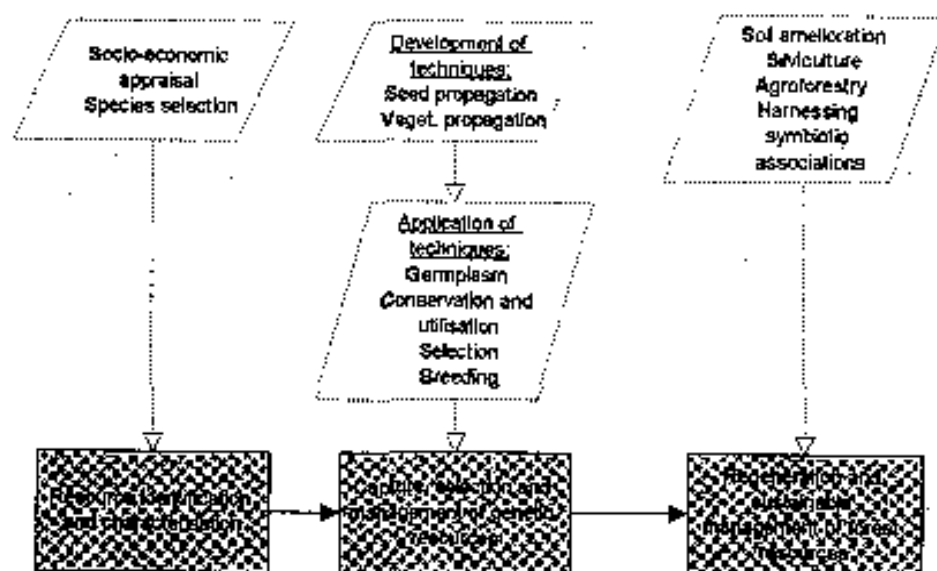


Figure 5. Stages involved in the domestication of tropical trees (with changes from Leakey & Newton 1994)

Domestication is a two-stage process in plants (Janick *et al.* 1982, cited in Leakey & Newton 1994):

- to bring wild plants into cultivation or exposing them to some form of management, and
- subjecting these to differential production or selection.

Domestication is a human-induced change in the genetics of a plant population to conform to human desires and agro-ecosystems, culminating in the plant's loss of its ability to survive in natural ecosystems (Harlan 1975 cited in Clement & Villachica 1994). The domestication can end at three distinct stages:

- a managed species which is a species that receives some degree of care but is not cultivated, i.e. no agro-ecosystem is prepared for it (e.g., durian groves in the forests managed by orang asli);
- a semi-domesticated species is significantly modified from the wild state, but can survive if abandoned (some fruit tree species in farm orchards);
- a domesticated species that requires human intervention to survive (e.g., clonally selected *Hevea brasiliensis* plantations).

The domestication process is pursued until the required yield level and grade of the product is achieved. Domestication of NTFP species is a long-lasting process and requires - at least initially - the involvement of crop improvement experts to speed up the process and to achieve the desired results.

The procedure is especially complicated in medicinal plants. The following description of the procedure is based on Palevitch (1991).

The domestication process requires activities at the natural habitat and at the cultivation site. Investigations and observations at the natural habitat would amongst others include: systematic botany, climatic conditions, soil properties, plant development, plant physiology, reproduction, natural propagation, susceptibility to pests and diseases. At the cultivation site the following have to be investigated: propagation methods, genetic improvement, advanced cultural practices, protection needs and methods, harvesting timing and methods, mechanization needs and methods, post-harvest treatments, handling of the raw material, quality control and phytochemical analysis. Contributions from agronomy and genetics are needed.

The implementation of domestication and cultivation schemes for NTFP species would require the following:

- Identification of NTFP species with market prospects and potential for domestication;
- Design of the domestication process and the stage to which domestication should be advanced (production goals);
- Implementation of the domestication process;
- Design of cultivation schemes (technique and management);

- Testing and implementation of the optimal cultivation scheme;
- Design of the processing (production goals, processing technique, organization and management);
- Market development (promotion, marketing, market outlets).

We may conclude that the domestication and cultivation of NTFP species is a long-term process requiring considerable inputs in research and funds. It further requires that forest management move from administering forest resources to managing production of goods and services from the forests. At present, cultivation schemes are available for rattans, but the management of rattan growing should be further improved.

Bio-prospecting

In this context prospecting is defined as the process of screening the forest for NTFP species containing phytochemicals of industrial potential. It can either be done internally by the forest owner himself or externally by the buyer (company or intermediary). In the first case the extract of a taxonomically nondescript sample would be given to a chemical or pharmaceutical company for further chemical evaluation. In the second case the extract would be produced externally. The plant would be taxonomically known to the chemical or pharmaceutical company. Up to now certain substances found in nature cannot be synthesized or at very high cost only. Thus, chemical and pharmaceutical companies still need plant extracts for some of their products.

Two main scenarios for a cooperation with chemical or pharmaceutical companies are given:

- The company (usually operating internationally) signs a contract with the forest owner which allows the company to do prospecting work in the forest for phytochemicals. It carries out the processing and marketing. The forest owner may be given an up-front payment for allowing the company in and may share the profits from the end-product. The company will most probably move into the domestication and cultivation of the plants.
- The forest owner carries out the prospecting work and the first phytochemical extraction through a scientific institution. These taxonomically nondescript extracts are given to the company for further chemical evaluation, processing and marketing. The forest owner may share the profits from the end-product. The forest owner will most probably move into the domestication and cultivation of the plants.

Chemical prospecting in Malaysian forests began some time back. Scientists are working on the resources, general screening, isolation and chemical characterisation of compounds and their biological activity (Ghazally *et al.* 1995). The derivation of new drugs from natural substances faces considerable problems. Firstly, there are

the high costs involved (Farnsworth & Soejarto 1991). Secondly, patenting is a problem. Patent protection is granted and becomes effective from the beginning of the drug development, and not when the drug begins to be marketed. Thus, patent life is considerably reduced as returns are diminished. When the drug is derived from a plant long used in folk medicine or other substances long used by local populations, patent protection might pose a problem. An example is the recent attempt to patent an insecticide derived from *Azadirachta indica* in India which in some crude form has long been used by the local population. Thirdly, there are government regulations that require proof that the developed drugs/substances are safe and effective.

In 1991, 121 biologically active compounds derived from 95 plant species were in use world wide. Of these 95 plant species, 39 originate from and around the tropical rain forests and 18 from the Asian rain forests (Farnsworth & Soejarto 1991). These are not convincing figures to demonstrate that the tropical rain forests are an important source of therapeutic chemical compounds.

On the other hand, the tropical forests are an important source of traditional medicinal substances. These plant species are used mainly in non-extractive forms. South East Asia, the Medicinal Plants Network established by the Canadian International Development Research Centre (IDRC) supports research and small-scale activities related to medicinal plants.

The tropical forests of South East Asia are also an important source of substances for dyeing and tanning, of essential and aromatic oils, of spices, etc. Lim (1991) lists 47 plant species found in Malaysia that provide raw materials for traditional medicine. A list of 384 dye and tannin producing plants, of which 47 species are native to South East Asia, is contained in Lemmens and Wulijarni-Soetjipto (1992). Azizol (pers. comm.) mentions 588 essential oil and resin producing tree species, shrubs and palms which have been or are currently under investigation in Malaysia. Lim and Jamaluddin (1994) identified NTFP-producing timber trees in the 50-ha demographic plot in the Pasoh Forest Reserve (Table 3).

Table 3. Number of species with NTFP value found in the 50-ha plot in Pasoh Forest Reserve, Negri Sembilan, Malaysia

Use	No. of Species	% of total no. of species
Timber trees of NTFP value	83	30
Food	118	43
Building material/handicraft	23	8
Fuelwood	26	9
Traditional medicine	129	46
Resin, fibre, latex, essential oils	93	33
Poison	28	10
Ornamental/shade plants	19	7
Fodder	6	2

(Compiled from information contained in Lim & Jamaluddin 1994)

Of the 820 tree, shrub and palm species found in the 50-ha demographic plot in the Pasoh Forest Reserve, 279 species have NTFP value. Almost half of the species are important for traditional medicine and about the same proportion produces food. About a third of the species can be used for timber production.

An important aspect of prospecting is the intellectual property rights, *i.e.* patents, trade secrets, trademarks, etc., and procedures for enforcing such rights are a specific task of the World Trade Organization (WTO). The Agreement on Trade-Related Intellectual Property Rights (TRIPS) cares for protection and encourages developing countries to conduct research and innovation. Under the agreement countries can prevent patent protection to an invention, if the commercialization endangers the environment (Anonymous 1995).

We may conclude that for bio-prospecting, forest management should concentrate firstly on strict control of prospecting activities by third parties (research institutions, companies, etc.) in forest areas. Overall, forest management should not assign high priority to bio-prospecting schemes.

Conservation of non-timber forest produce

The Convention on International Trade in Endangered Species of Wild Flora and Fauna (CITES) imposes restrictions on the trade of endangered species. CITES was ratified by 111 nations and its secretariat is hosted by the United Nations Environmental Programme (UNEP). The monitoring body of the International Union for the Conservation of Nature (IUCN) and the World Wide Fund for Nature (WWF), that tracks wildlife trade and compliance with CITES is TRAFFIC International. It appears that until 1991 CITES had not included many plants of medicinal value in its list but to have instead concentrated on the trade of endangered timber tree species and ornamental plants and cacti (de Klemm 1991). The IUCN-WWF Plants Conservation Programme has six major objectives of which the following are especially important:

- the *in-situ* conservation of plant genetic resources as a complement to *ex-situ* conservation; and
- the conservation of wild plants of economic value, especially medicinal plants used in primary health care (Hamann 1991).

At the end of the WHO/IUCN/WWF International Consultation on the Conservation of Medicinal Plants 1988, a declaration, the so-called Chiang Mai Declaration was issued, which stated that the increasing and unacceptable loss of medicinal plants is caused by habitat destruction and unsustainable harvesting practices (Akerele 1991). As a follow-up, the 'Guidelines on the Conservation of Medicinal Plants' were issued in which is stated that *in-situ* conservation should not only be pursued by totally protecting habitats containing important medicinal plant species, but also by applying less destructive practices in forests managed for timber (Anonymous 1993). This is exactly the strategy which is being pursued by the Malaysian-German Forest Management and Conservation Project. Under the

heading Planning, Choice of Silvicultural Concept, the ITTO Guidelines on the Conservation of Biological Diversity in Tropical Production Forests (ITTO 1993) state: 'Silvicultural systems that aim to change species composition of selectively managed forests and remove certain structural or floristic components of the forest can have a negative effect on biodiversity conservation....' The recommended action is: 'Particular care should be taken in applying silvicultural treatments to ensure that adequate populations of species which are important in food chains or in providing ecological functions (keystone species) are retained.' (Recommended Action 8). We should add here that not only considerate silvicultural treatments but also harvesting operations with minimum destruction of site and forest stands have to be applied. In Principle 11, sites of particular importance for biodiversity are mentioned, amongst others: (i) areas with populations of rare or endangered species or with high concentrations of endemic species, or with exceptional species richness, (ii) areas that contain biological diversity of social or cultural value, or of medicinal, agricultural or other economic value, (iii) areas that contain habitats frequented by migrating birds. The Convention on the Conservation of Migratory Species of Wild Animals obligates countries to protect endangered migratory species and precludes commercial trading of some 51 listed species, including antelopes, 24 bird species, and six marine turtle species.

An important option of NTFP management is the conservation of the genetic resources through multiple-use forest management including zoning and low impact field operations complying with EIA-compatible standards. By generally prescribing such EIA-compatible management and field practices, vegetation, including NTFP species, will be prevented from being indiscriminately removed and destroyed. Table 12 contains a selected list of so-called best practices meant to keep the impacts of management decisions and field operations on biological diversity low. It is also important to prove that application of best practices makes economic sense. Habitats containing important NTFP species could be delineated and put under conservation through total protection or application of specifically designed low-impact measures. To be able to do so, measurements and monitoring of NTFP species is needed. The methods would be equivalent to those for measuring and monitoring biodiversity in tropical forests. Principles and methodology are explained in Boyle and Boontawee (1995) to which the reader may refer.

We may conclude that in general habitat conservation is preferable to single-species conservation wherever possible. It is easier to achieve. It is worthwhile to investigate the issue of whether NTFP species (plants) have a spatially concentrated occurrence. If so, the conservation of NTFP species would be considerably facilitated. Surveys would have to be carried out with the aim of identifying such areas of concentration. Such surveys would concentrate on lower storey trees and plants and of the ground vegetation layer.

Conservation of biological diversity including important NTFP plant species within forest management is best obtained by:

- forest zoning according to forest functions (the basic stratification of the forests according to the functions protection, production and societal needs),

- multiple-use forest management planning, and
- application and enforcement of management and field operations with low impact on the forest site and the forest stand.

Table 4. Examples of best management practices to mitigate negative impacts of field operations on NTFP species diversity

Activity	Potential adverse impact	Best practice
Forest engineering	• large scale habitat destruction or changes • sedimentation of aquatic habitats • fragmentation of terrestrial habitats • destruction of key functional elements of the forest ecosystem	• forest engineering strictly according to low impact standards based on EIA, requiring least amount of infrastructure
Forest conversion, e.g., substitution of natural forests for plantations	• destruction of terrestrial habitats and sedimentation of aquatic habitats • drastic reduction in biodiversity	• no blanket removal of vegetation • corridor planting into existing vegetation • clear-felling and planting system EIA compatible
Plantation silviculture	• setting back of succession through tending • prevention of biodiversity build-up • prevention of build-up of multi-layered structure	• retention of ground and understorey vegetation • selective tending procedures • natural regeneration after first generation
Natural forest silviculture	• interruption of regeneration cycle through harvesting • removal of key-functional elements through timber stand improvement • gap sizes too large (secondary succession instead of direct build-up of resources) • reduction in biodiversity on timber stand improvement	• simulation of natural gap dynamics • harvesting only, if young regeneration is on the ground • selection of crop trees according to tree-marking rules • timber stand improvement according to list of protected species and of species of key ecological functions • selective timber stand improvement operations

Conclusion

The production function is only one among many other functions. Multiple-use forest management planning has to integrate all these functions into the Forest Management Plan. Within the production function the Forest Management Plan should include statements and directives for the management of non-timber forest produce. The basic options for the management of non-timber forest produce are: (i) harvesting (collection from the forest), (ii) domestication and cultivation, (iii) bio-prospecting, and (iv) conservation.

Of these options cultivation of NTFP species and conservation have the best chance for immediate implementation. Wild collection from the forests is to be discouraged owing to the risk of over-exploitation. It also appears to become more

and more uneconomic because of low abundance and long walking distances. Rattan cultivation in forest areas should be further improved.

Domestication of NTFP species is a long-term process requiring considerable inputs in research and funds. It further requires that forest management move from administration of forest resources to managing the production of goods and services from the forests.

Bio-prospecting should receive low priority only. Management activities here should primarily concentrate on strict control of bio-prospecting activities carried out by third parties (research institutions, companies, etc.).

Habitat conservation should be preferred to conservation of individual plant species. Conservation of biological diversity including important NTFP plant species within forest management is best obtained by:

- forest zoning according to forest functions,
- multiple-use forest management planning,
- application and enforcement of Best Management Practices.

References

- AKERELE, O. 1991. Medicinal plants: policies and priorities. Pp. 9-12 in Akerele, O., Heywood, V. & Synge, H. (Eds.) *The Conservation of Medicinal Plants*. Cambridge University Press.
- ALOR, S.K. 1991. Medicinal Plants in India: Approaches to exploitation and conservation. Pp. 295-303 in Akerele, O., Heywood, V. & Synge, H. (Eds.) *The Conservation of Medicinal Plants*. Cambridge University Press.
- ANONYMOUS. 1993. Guidelines on the conservation of medicinal plants. WHO, IUCN, WWF.
- ANONYMOUS. 1995. Malaysia-United Kingdom: Conservation, management and development of forest resources. Sixth report of the Programme Manager, July 1995. Natural Resource Institute. Overseas Development Administration.
- AZIZOL, A.K. & NG, L.T. 1995. Industry of medicinal and aromatic plants from Malaysian rain forests: potential and problems. Paper presented at the 12th Malaysian Forestry Conference in Miri, Sarawak, 26-29 November 1995.
- BARDEN, C.D., JEANRENAUD, S. & SECKER-WALKER, J. 1993. *Roles. Multi-purpose Roles of Tree Planting: Description, Analysis and Recommendations*. 40 pp. Study no. 2. Shell/WWF Tree Plantation Review.
- BONATI, A. 1991. Industry and the conservation of medicinal plants. Pp. 141-146 in Akerele, O., Heywood, V. & Synge, H. (Eds.) *The Conservation of Medicinal Plants*. Cambridge University Press.
- CLEMENT, C.R. & VILLAGHICA, H. 1994. Amazonian fruits and nuts: potential for domestication in various agroecosystems. Pp. 280-288 in Leakey, R.R.B. & Newton, A.C. (Eds.) *Tropical Trees: The Potential for Domestication and the Rebuilding of Forest Resources*. ITE Symposium No. 29.
- FARNSWORTH, N. & SOEJARTO, D.D. 1991. Global importance of medicinal plants. Pp. 25-52 in Akerele, O., Heywood, V. & Synge, H. (Eds.) *The Conservation of Medicinal Plants*. Cambridge University Press.
- GAN, B.K. & WEINLAND, G. 1996. *Management of Non-Timber Forest Resources. A Management Review*. Malaysian-German Sustainable Forest Management and Conservation Project. 83 pp. Project Document No. 11.
- GHAZALLE, I., MURIEDZA, M. & LAILY B. DIN (Eds.) 1995. *Chemical Prospecting in the Malaysian Forest*. 228 pp. Pelanduk Publications.
- HAMANN, O. 1991. The joint IUCN-WWF plants conservation programme and its interest in medicinal plants. Pp. 13-22 in Akerele, O., Heywood, V. & Synge, H. (Eds.) *The Conservation of Medicinal Plants*. Cambridge University Press.

- HARLAN, J.R. 1975. *Crops and Man*. 295 pp. American Society of Agronomy/Crop Science Society of America, Wisconsin, Madison.
- ITTO. 1993. *ITTO Guidelines on the Conservation of Biological Diversity in Tropical Production Forests*. 18 pp. ITTO Policy Development Series No. 1.
- JANICE, J., SCHERY, R.W., WOODS, F.W. & RUTTAN, V.W. 1982. *Plant Science*. 629 pp. Freeman, San Francisco, California.
- DE KLEMM, C. 1991. Medicinal plants and the law. Pp. 259-271 in Akerele, O., Heywood, V. & Synge, H. (Eds.) *The Conservation of Medicinal Plants*. Cambridge University Press.
- Leakey R.R.B. & Newton A.C. 1991. Domestication of "Cinderella" species as the start of a woody plant revolution. Pp. 3-6 in Leakey, R.R.B. & Newton, A.C. (Eds.) *Tropical Trees: The Potential for Domestication and the Rebuilding of Forest Resources*. London: HMSO.
- LEMMENS, R.H.M.J. & WUJAJARNI-SOETJITTO, N. (Eds.) 1992. *Plant Resources of South-East Asia No. 3: Dye and Tannin Producing Plants*. 169 pp. Prosea, Bogor, Indonesia.
- LIM, H.F. 1991. Knowledge and use of forest produce as traditional medicine: The case of the forest-dwelling communities. Pp. 385 - 400 in Khozirah, S., Azizol, A.K. & Razak, A. (Eds.) *Proceedings of the Conference 'Medicinal Products from Tropical Forests'*, held at the Forest Research Institute Malaysia, 13-15 May 1991. Kuala Lumpur.
- LIM, H.F. & Jamaluddin J. 1994. The Uses of Non-Timber Forest Products in Pasoh Forest Reserve, Malaysia. *Research Pamphlet No. 113*. 132 pp. Forest Research Institute Malaysia.
- PALEVITCH, D. 1991. Agronomy applied to medicinal plant conservation. Pp. 167-178 in Akerele, O., Heywood, V. & Synge, H. (Eds.) *The Conservation of Medicinal Plants*. Cambridge University Press.
- REINHARD, E. 1993. Nutzung von Nichtholzprodukten - Ein Beitrag zur Tropenwalderhaltung? Deutsche Gesellschaft für Technische Zusammenarbeit. *Waldinfo* 11: 26-28.
- RIFAI, M.A. & KARTAWINATA, K. 1991. Germplasm, genetic erosion and the conservation of Indonesian medicinal plants. Pp. 281-292 in Akerele, O., Heywood, V. & Synge, H. (Eds.) *The Conservation of Medicinal Plants*. Cambridge University Press.

Sub-programme B

**Valuation of the Costs and Benefits
*of Non-timber Forest Products and Services***

THE ECONOMICS OF NON-TIMBER FOREST BENEFITS

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Economic development is often associated with rising demand for environmental amenities. Forests are a particular focus of environmental concern; in many countries the value of non-timber forest benefits - many of them non-marketed - may be increasing faster than the prices of wood products. One result is that certain forest areas are increasingly valued more for the environmental benefits they provide than for their timber. Hence the 'set-aside' of timber-rich areas for wildlife conservation, and the increasing attention of public agencies to managing forests for recreational or aesthetic values. Problems arise when policy-makers try to balance the twin objectives of timber production and environmental protection. When values conflict, what is the appropriate trade-off? What opportunities exist for 'win-win' solution, where timber and non-timber benefits are complementary? This paper focuses on recent advances in the economic evaluation of forestry activities and, in particular, on how techniques for valuing non-timber forest benefits in monetary terms can assist the development of forest policy and management systems. The paper considers the nature of non-market values and the need for valuation, as well as the different techniques used. It briefly considers the long-term dynamics of forest value and outlines the use of valuation results in forest policy and management.

Key words: Non-timber forest benefits - market failure - forest valuation - forest policy

Introduction

Forests have been central to human survival for as long as we have inhabited the earth. How people use and value forests at a particular place and time, however, depends in large part on their scarcity or abundance relative to changing human needs. In recent years, human population growth, migration and industrialization, and other socio-economic changes have had a dramatic impact on the world's forest resources. Deforestation in tropical regions is widely acknowledged as a global problem, as is the decline in so-called 'old-growth' forests in all countries (Barbier *et al.* 1994, Brown & Pearce 1994, Sharma 1992). The recent increase in secondary forests in temperate regions, while less well-known, will also have a profound effect on the future supply of forest goods and services (Arnold 1991, Sedjo & Lyon 1990). Meanwhile, human demands on forests are changing rapidly, as we become more aware of the important environmental benefits they provide.

Economic development is often associated with rising demand for environmental amenities. Forests are a particular focus of public environmental concern; in many countries the demand for non-timber forest benefits - many of them non-marketed - may be increasing faster than demand for wood products. One result is that certain forest areas are increasingly valued, by the public as well as their political representa-

ives, more for the environmental benefits they provide than for their timber. Hence the 'set-aside' of extensive areas of timber-rich forest for wildlife conservation. Hence also the increasing attention of public agencies to managing forests for recreational or aesthetic values. Problems can arise, however, when policy-makers try to balance the twin objectives of timber production and environmental protection. When market and non-market values conflict, what is the appropriate trade-off? What opportunities exist for 'win-win' solutions, where timber and non-timber benefits are complementary?

Understanding the changing pattern of land-use and environmental preferences is essential for a better understanding of the current debate on forest policy, which is raging at global, national and local levels. Calls for increased forest conservation, timber certification and trade policy reforms, more 'sustainable' forest management and other initiatives are driven by growing concern that the world's forest will require more protection and better management if they are to meet future human needs, including demand for both timber and non-timber forest goods and services.

This paper focuses on recent advances in the economic evaluation of forestry activities and, in particular, on how techniques for valuing non-timber forest benefits in monetary terms can assist the development of forest policy and management systems. We first consider the non-market nature of many non-timber forest benefits, and the reasons why markets often fail to account for them. The paper then reviews the different techniques used to evaluate non-market benefits in monetary terms, and explores the long-term dynamics of forest value. We conclude with a brief discussion of how the results of valuation studies can contribute to improved forest policy and management.

Market and non-market values in forestry

Economists use the term 'total economic value' to refer to the various benefits which may be obtained from a natural resource. The benefits include the *direct use value* of a resource as an input to production or as consumption goods, its *indirect use value* through protecting or sustaining economic activity, and its non-use value to people who derive satisfaction from the mere existence of a resource, even though they may never see it or consume any product obtained from it (Pearce *et al.* 1989).

Examples of direct use values in forestry include timber and non-timber products, but also non-commodity benefits such as forest recreation (Table 1). Indirect use values include the role of forests in protecting watersheds and fisheries; and the storage of carbon in trees (to offset the atmospheric accumulation of 'greenhouse' gases implicated in global warming). Non-use values in forestry comprise such intangible benefits as the continued existence of certain species of wildlife, which the general public wishes to protect for posterity.

In general, direct use values are most likely to be reflected in market prices. Indirect use values may be reflected in the prices of certain goods and services which depend heavily on the underlying environmental benefit, while non-use values are rarely reflected in market prices or decision-making. Clearly, however, the absence

of a market price does not mean that a thing has no economic values.¹

Most forest land owners are aware of the many environmental benefits they provide, in addition to supplying timber or other commodities to the market. Public agencies in many countries, some of them responsible for managing millions of hectares of forest land, often make special efforts to provide non-timber benefits. This includes restricting logging in areas of exceptional natural beauty, for the sake of recreational uses, or on steep slopes, so as to protect water quality and reduce the risk of flooding downstream. Similarly, some companies provide access to their land to hikers, hunters and fishermen on a voluntary basis.

Table 1. Forest values and valuation techniques

		Use values		Non-use values	
		1. Direct	2. Indirect	3. Option	4. Existence
VALUATION	Wood products (timber, fuel)		Watershed protection	Future uses as per 1 & 2)	Biodiversity
			Nutrient cycling		Culture, heritage
	Non-wood products (food, medicine, genetic material)		Air pollution reduction		Intrinsic worth
	Educational, recreational & cultural use		Microclimatic regulation		
	Human habitat		Carbon store		
	Amenities				
		↓	↓	↓	↓
TECHNIQUES	Market prices and analysis		Production function	Contingent valuation	Contingent valuation
	Related goods & approaches		Preventive expenditures		
	Contingent valuation		Replacement costs		
	Hedonic price				

Note: Not all valuation techniques can be applied to all of the uses under which they are listed. Equally, some uses may be amenable to more than one valuation technique, depending on the context.

Source: Derived from Barbier (1991)

¹Economists distinguish financial from economic values. The former refer to market prices, while economic values (or 'efficiency prices') are estimates of the prices which would prevail in a competitive market, free of market imperfections (e.g. monopolies) or policy interventions (e.g. taxes or barriers to trade). Efficiency prices are usually considered a more accurate reflection of the contribution of economic activity to human welfare.

While such efforts are welcome they are usually limited in scope and often inadequate relative to public demand. The reason is that forest land owners and managers in most countries get little or no material advantage from providing environmental benefits. Both in the private and public sectors, land owners and managers tend to focus on the direct costs and tangible benefits of their activities. Thus foresters produce timber because they can sell it, while farmers convert forest land because they can cultivate it for profit or subsistence.

Many non-timber forest benefits, on the other hand, cannot easily be bought and sold (*e.g.* biodiversity, watershed protection, carbon storage). Others generate little or no revenue for the land owner, although they may have significant value to the general public (*e.g.* aesthetic values). Where non-timber forest benefits are also non-marketed, private land owners will have little motivation to produce them unless compelled to do so. Similarly, public forest agencies may underestimate the importance of such benefits, which are often less visible than the revenue, taxes and jobs generated by the timber and agriculture industries.

Even where forest benefits are partly or informally traded, they often escape notice. In many developing countries, for example, rural populations exploit non-timber forest products such as vines and edible fruit for both subsistence and sale, but this activity is rarely recorded and is thus easily ignored by forest authorities. Similarly, in the developed world, entry fees to forest recreational areas often grossly undervalue the true willingness-to-pay of visitors and thus the full value of recreational benefits.

The fact that many non-timber forest benefits are not traded or do not have a directly observable market price is not a problem in itself. However, the use of forests to produce tradeable commodities such as timber or agricultural crops often reduces the availability of non-timber goods and services, with the result that non-market (environmental) values are lost. If the latter are significant forest resources will be used inefficiently, both in terms of the area devoted to timber (or converted to agriculture), and in terms of the technology of production (*i.e.* management). We now turn to why the market often fails to account for non-timber benefits, even when they are important in economic (as opposed to financial) terms.

Non-timber benefits and market failure

In principle, market will allocate resources efficiently if price reflect both the full marginal costs of production and the full marginal benefits of consumption, including all components of total economic value². Where prices do not reflect all costs and benefits, however, the so-called 'invisible hand' of the market does not work and resources may be used inefficiently, resulting in a loss of human welfare (Baumol & Oates 1988).

²The marginal benefit (or cost) of goods refers to the incremental change in consumer welfare (or producer cost) resulting from an incremental change in the quantity of the goods consumed (or supplied). In a competitive market the level of output is determined by prices, which will tend to equilibrate at the point where marginal benefit equals marginal cost and social welfare is maximized. This is the "efficient" level of output, for a given distribution of income (Henderson & Quandt 1958)

Economists have identified various reasons why and how market prices may fail to reflect environmental costs and benefits. Two of the most important reasons for market failure in forestry are what economists call 'public goods' and 'externalities'.

Public goods are characterised by the fact that: (i) no one can be effectively excluded from consuming them and (ii) increased consumption of the goods by one individual does not reduce availability to others. For example, no one travelling on a public thoroughfare can be charged for enjoying a pretty view, even if the land in question is privately owned. Nor does one person's enjoyment of the view detract from that of another (provided there is no crowding!). Such aesthetic value is among many public goods provided by forests, along with carbon storage and biodiversity conservation. Economic theory states that the market will systematically underprovide such goods, and that collective action (e.g. by government) is required to ensure their adequate provision.

Externalities are uncompensated costs or benefits arising from economic activity. A classic example in forestry is the decline in availability of game or other non-timber forest products due to logging. Unless the logging company (or land owner) pays compensation to hunters and gatherers for their loss of livelihood, the full economic cost of extracting timber will not have been paid. If similar conditions prevail elsewhere, market prices of timber products will tend to understate true economic costs and consumers will use timber relatively inefficiently.

In addition to public goods and externalities, the market may fail to reflect non-timber forest benefits due to lack of information about their contribution to economic welfare, distortions in prices arising from public policy and regulations, lack of clear or secure property rights over forest lands, and other factors. In such cases, the question arises as to how decision-makers can compensate for market failure, and ensure that non-timber forest benefits are given sufficient weight in land-use planning and management.

There are many ways to internalize non-market values in the behaviour of producers and consumers, ranging from the introduction of strict environmental standards to ecological tax reform, and from facilitating environmental damage claims in the courts to the promotion of trade in environmental services or 'pollution permits'. An extensive literature describes the economics of different approaches to environmental protection (Baumol & Oates 1988, Cropper & Oates 1992, OECD 1989, Portney 1990).

A full review of environmental policy is beyond the scope of this paper. Nevertheless, it is clear that information on the significance of non-market environmental impacts, and the trade-offs between market and non-market values, is an essential input to rational environmental policy-making. Without such information, it is difficult to see how one can determine the urgency, stringency and scope of intervention required. One promising approach is to express non-market environmental costs and benefits in monetary terms, so they can be compared directly with the value of marketed commodities. We now turn to the various methods available for this purpose.

Economic valuation methods

To help private firms and government policy-makers make more informed decisions about activities with significant environmental impacts, economists have devoted considerable effort in recent years to developing and applying methods for valuing non-marketed benefits in monetary terms (Freeman 1993). All of the methods attempt to express consumer demand, *i.e.* the willingness-to-pay (WTP) of consumers for a particular non-marketed benefit in monetary terms, or their willingness-to-accept (WTA) monetary compensation for the loss of same. In short, these valuation methods attempt to express the utility derived from non-market goods and services in the metric of the market, which is considered to provide an accurate reflection of the relative preferences of producers and consumers for different goods and services. (Just how 'accurate' is discussed in the following section). The resulting values may be used in cost-benefit analysis or as input to more elaborate economic models.

Methods of estimating non-market or non-timber forest values vary in their theoretical validity and acceptance among economists, their data requirements and ease of use, and the extent to which they have been applied in (and perhaps their relevance to) different countries (Munasinghe & Lutz 1993). Broadly speaking, the various methods can be divided into three groups:

- i) market price or cost-based methods;
- ii) surrogate market methods; and
- iii) constructed market or contingent methods (see Table 2).

The simplest valuation methods are those which rely on market prices, with or without adjustment for market imperfections or policy distortions. These methods include the use of market surveys to collect the prices of many so-called minor non-timber forest products, which may be traded on a small-scale or occasionally, and which are often neglected by official economic statistics. Note that even when market prices for non-timber forest products exist, they may still understate the full economic value of the resource⁸.

Where the forest benefit in question is not traded, but a close substitute is widely marketed, researchers may use the price of the latter (adjusted for any quality differences) to approximate the value of the non-marketed goods. Alternatively, one may consider the cost of measures taken to prevent or compensate for the loss of a non-market benefit (*i.e.* the replacement or relocation cost or the amount of defensive expenditure) to be a proxy for the value of the benefit itself. For example, where logging or road construction in upland forest areas had led to increased run-off and sedimentation, some studies use information on the costs of dredging or flood control as a rough estimate of the non-market benefit of watershed protection. Such cost-based approaches must be used with extreme caution, however, particularly where potential rather than actual expenditures are concerned, as it is not always clear that the environmental benefit in question justifies the costs of replacement, relocation, etc.

⁸For example, if there are no clear property rights over the resource or other restrictions on harvest levels, market prices may fail to reflect user costs (*e.g.* the stumpage value of standing timber).

Table 2. Methods for valuing forests

Valuation method	Relevant forest benefits	Strengths and weaknesses
Marker price or cost-based:		
- Market prices - from surveys of producers and/or official statistics. - Substitute goods - uses market prices of substitute for non-marketed forest benefits. - Cost-based valuation - uses data on the costs of measures taken to preserve and/or replace forest goods and service.	Price-based valuation is generally applied to non-timber forest products which are partly or informally traded, in order to estimate subsistence and/or unrecorded consumption. Substitute goods approaches may be used wherever close market substitutes for non-timber benefit exist. Cost-based approaches include defensive or preventive expenditure, replacement or relocation cost; may be used (with caution) to value any type of non-timber forest benefit.	Market prices clearly reflect consumer preferences, but may need adjustment for policy distortions or over-exploitation. Aggregation or extrapolation of values based on potential production is not valid unless account is taken of likely price effects (elasticity of demand). Cost-based approaches are usually considered less reliable than other methods. One test of validity is evidence that people are prepared to incur costs to secure relevant benefits.
The simplest and most direct methods.		
Surrogate markets:		
- Travel cost - uses survey data on direct costs (e.g. fares, accommodation) and, in some cases, opportunity costs of time spent travelling to and from a site, evaluated at some fraction of the average wage rate. - Hedonic pricing - uses statistical methods to correlate variation in the price of marketed goods to changes in the level of a related, non-marketed environmental amenity. - Changes in production - uses data on the physical relation between level (or quality) of a non-market benefit and level (or quality) of output of marketed goods/services.	Travel cost is often used to estimate demand for forest recreation at specific locations. Related methods used mainly in developing countries estimate the value of non-marketed, non-timber forest products in terms of the opportunity cost of time spent collecting and/or processing them. Hedonic pricing used to estimate the impact of proximity to forested land and/or logging on the price of residential and commercial property. Change-in-production or (dose-response) methods are used to estimate both on and off-site impacts of land use change, e.g. the effect of logging on hunting, downstream water users, fisheries, climate.	Provided the relation between the NMB being valued and the surrogate market is correctly specified, such methods are considered reliable. Travel cost estimates may need to account for various objectives (benefits) in a single trip. Hedonic pricing requires large data sets, in order to isolate the influence of the NMB on price relative to other factors. Changes in production methods require good data on bio-physical relationships (dose-response).
Constructed or contingent markets		
Contingent valuation method - uses consumer surveys to elicit hypothetical ('contingent') willingness-to-pay for a benefit, or willingness-to-accept compensation for the loss of that benefit. Experimental markets - controlled experiments in laboratory setting, involving direct questioning or other methods to elicit information on consumer preferences and trade-offs.	Recreational values are often estimated using contingent valuation. Constructed market or contingent methods are the only known way to estimate non-use values, e.g. landscape or biodiversity values, for which price data do not exist and/or links to marketed goods cannot easily be established.	Contingent valuation estimates are considered reliable if strict procedural rules are followed. Experimental methods (used in social science laboratories) are more easily controlled but are not widely used in forestry.

A second group of methods rely on the fact that certain non-market values may be reflected in consumer expenditure, in the prices of marketed goods and services, or in level of productivity of certain market activities. The travel cost method, for example, is based on the assumption that consumers value the experience of a particular site at no less than the cost of getting there, including all direct transport costs as well as the opportunity cost of time spent travelling to the site (i.e. foregone earnings). This survey-based method is widely used to estimate the value of forest recreational benefits (see Willis *et al.* in this volume)⁴.

Another method in this second group is hedonic pricing, which attempts to isolate the specific influence of an environmental amenity or risk on the market price of particular goods or services. This approach has been used to estimate the negative impact of noise pollution or the presence of waste disposal facilities on the market prices of residential property or, conversely, the positive impact of proximity to water or public green space (Garrod & Willis 1992)⁵. The hedonic pricing method requires relatively large data sets, in order to account for and eliminate the influence of all other variables which affect market prices. The approach also assumes that markets for land are competitive, and that both buyers and sellers are fully informed of the environmental amenity or hazard.

The third method in this group is variously called the change-in-production approach, the input-output or dose-response approach, or the production function approach. Whatever the name used, all involve an attempt to relate the incremental output of a marketed good or service to a measureable change in the quality or quantity of a natural resource (Maler 1992). One example is the relationship between forest disturbance along streams and rivers, or near coastlines, and the productivity of freshwater or marine fisheries, which has been observed in several locations (Gammage 1997). This approach is very demanding of reliable data on the bio-physical links between the non-market benefit and the marketed goods or service.

A third category of non-market valuation methods includes several so-called 'constructed' techniques, among which the most widely used is the contingent valuation (CV) method. In the latter case, researchers obtain information on the value of an environmental benefit by posing direct questions to consumers about their willingness to pay for it (or their willingness to accept compensation for losing it). Several variants are used, but in most cases the aim of CV is to elicit individual expressions of value (or 'bids') from survey respondents for specified increase or decreases in the quantity of non-market goods. The CV method is widely used to estimate recreational benefits (see Willis *et al.* in this volume). Moreover, CV is the only method currently available to estimate non-use benefits such as existence value. On the other hand, because in most cases no actual payment is made, many observers question the validity of constructed market techniques. While the CV

⁴A similar approach is sometimes used to value 'travel time' for gathering fuelwood or for water collection (Munasinghe & Lutz 1993).

⁵A similar approach may be used to evaluate the impact of occupational hazards or other environmental factors on wages, based on the assumption that the supply of labour varies with local living and working conditions.

method has been accepted by the United States' legal system as a basis for assessing environmental damage, the procedural requirements for using CV estimates in court cases are very strict (Arrow *et al.* 1993).

In addition to the above valuation methods, some other techniques are used by economists to shed light on the trade-offs between market and non-market benefits. Among the most useful are *opportunity cost* and *cost-effectiveness* approaches. In these cases, no attempt is made to estimate non-market benefits in monetary terms; the focus instead is on the market costs or the opportunities foregone in order to secure or protect the benefits in question. The idea is that certain means of providing an environmental benefit will be more efficient than others, either in terms of the inputs required or the loss of market values.

Criticism of valuation

Critics of valuation raise various objections to attempts of estimating non-market values in monetary terms, ranging from minor methodological quibbles to sweeping rejection of any attempt to estimate non-market values. One of the most common complaints is that valuation is too costly, or that the methods are imperfectly developed, although this could also be said of many other decision-making processes!

Others highlight the potential bias in how people respond to surveys, including the frequency of 'protest bids' in CV studies and indications that many people prefer to rely on moral judgement or a rights-based approach, when asked to consider certain environmental benefits (Hanley & Milne 1996). Extreme versions of the latter view consider any economic approach to environmental decision-making to be tainted by association with market forces, which are identified as the root cause of all environmental problems. From this perspective, any attempt to express non-market benefits in monetary terms implies a 'slide down the slippery slope' of reducing all concepts of value to an economic bottom-line.

Another frequently noted problem is that monetary estimates fail to account for distributional considerations, *i.e.* the relative importance of non-market values to different groups of people (this problem of course is not confined to non-market valuation studies but affects much economic analysis). In some cases this leads to arguments for social weights to favour the poor, or altogether different criteria for land-use decisions, *e.g.* historical precedence.

Others refer to the poor record of valuation studies in influencing public policy (again a problem which afflicts several branches of applied economics). And some make the further point that valuation by itself may be meaningless, if there is no mechanism to capture and convey consumers' willingness-to-pay for non-market values to the people who, by their actions, can either fulfil or frustrate that demand.

While many of the criticisms of valuation are valid, the problem remains that environmental protection is often incompatible with other social and economic objectives. In forestry, for example, people must often choose between alternative, incompatible uses of land resources, *e.g.* preservation, timber production or conversion to agriculture. Moreover, the view taken here is that many if not most land-use

decisions will inevitably have a strong economic basis, and that factors which are not quantified risk being ignored. We must acknowledge, however, that economic valuation of forest benefits can provide only part of the total picture, and that economic efficiency must be considered alongside other criteria such as social and cultural value, historical claims, distributional impacts and other political factors. Equally, we must be aware of how market and non-market values shift over time, particularly in periods of rapid socio-economic change. Hence we now examine the dynamics of forest values.

Income growth and non-timber forest values

Non-timber forest benefits have always been an important part of forest value. Their relative importance varies, however, in different places and stages of economic development. For example, in traditional, hunter-gathering societies, forest lands have long been valued for low-intensity harvest of game and edible wild plants, as well as the occasional felling of vines and timber for fuel and other subsistence uses. This may be considered the 'original' use of forests, which can still be found in remote areas of Latin America, Africa and Southeast Asia.

As populations grow and economies develop, forest values change dramatically. Initially, forests are often valued mainly for the agricultural potential of the land they cover, or for timber for construction and industry. As economies mature, however, agricultural land-use tends to intensify and stabilize. At the same time, there is often a shift away from solid wood to paper and other materials, resulting in stagnant demand for many timber products. Forests themselves are increasingly specialized, with some areas under intensive management for the production of timber, while others are devoted to recreational uses or simply preserved for their amenity and landscape values. Finally, as we have seen recently in many of the richest economies, there is increasing public demand for the protection and set-aside of mature forest, not just locally, for recreational or amenity purposes, but even in remote areas that most people will never see. This reflects the emerging importance of 'non-use' or preservation values, sometimes associated with the role of forest in conserving biological diversity and maintaining climate functions.

This trend can be seen in many countries in South East Asia (Malaysia among them) which have recorded exceptionally high rates of economic growth in recent years. Economic development has led to the emergence of an educated and urbanised middle-class. Rising average incomes are in turn associated with increasing demand for environmental protection and amenities, as well as increased means with which to pay for them. One example of such changing preferences is increased demand for outdoor recreation, reflected in the rapid rise in domestic tourism and visits to parks, reserves and forest recreational areas. Experience in the more developed countries suggests that this and other expressions of public demand for, and concern about, the environment will further intensify as incomes continue to rise.

Meanwhile, the demand for traditional forest products - timber and pulp - is also expected to increase with economic growth. Recent forecasts suggest that consumption of industrial roundwood in Asia will grow at just over one per cent per year over

the next 15 years (FAO 1997)⁶. Domestic timber prices are also expected to rise in many countries, due to the increasing scarcity of easily accessible, mature stands of timber in the region, although price increases will be moderated by plentiful supplies from other parts of the world (Perez-Garcia & Lippke 1993).

How are trends related? Recent experience in the more developed countries suggests that forests are increasingly valued, by the public as well as their political representatives, as much (or even more) for the environmental benefits they provide than for their timber. Hence the 'set-aside' of large timber-rich areas for wildlife conservation. Hence also the increasing attention of public agencies to managing forests for recreational or landscape values. The key factor is the relative rates of growth in timber and non-timber values, which in turn reflects the income-elasticity of demand for different forest benefits⁷. Even if the value of forest land for timber production is initially much higher than for production of non-timber benefits in certain areas, this may change with time. Over a sufficiently long period, non-timber values may well overtake and surpass timber values, reflecting the relatively high income elasticity of demand for environmental amenities, compared to demand for wood products.

Of course, demand for different non-timber forest benefits will not grow at the same rate, and may even shrink in some cases. Demand for forest recreation and landscape amenity values can be expected to grow rapidly with urbanisation and rising incomes, whereas the demand for certain non-timber forest products may fall. For example, higher rural incomes can lead to decline in both the range and volume of forest products used for subsistence, but this may be offset for certain products by increased commercial exploitation and sales in urban markets. Recent work on the consumption of an edible forest fruit in Malaysia has found that urban consumption has increased at almost the same rate as income (Woon *et al.* in this volume).

Change in the relative importance of different forest values can have important distributional consequences, particularly where these values are conflicting. For example, the designation of forests as protected areas can be seen as a means by which certain interest groups (typically not the poor) secure recreational, amenity or non-use values. This may result in significant loss to another group, *e.g.* subsistence farmers who rely on forest land for extraction of non-timber forest products, or for shifting agriculture. Where the values of domestic and foreign consumers differ widely the resulting conflict may be international in scale, as shown by recent heated debates about tropical forestry and timber trade policy in global fora.

Similarly, efficiency and equity objectives in forest land-use often conflict. Cost benefit analysis may lend weight to certain values and associated land-use options which are unavailable to poorer groups, due to their limited access to capital land information. These groups must therefore confine themselves to 'inferior' uses. For example, a study of a new national park in Madagascar estimated the value of

⁶This may be compared to average annual growth of about 2.2% over the period 1970-90 (FAO 1997).

⁷The income-elasticity of demand refers to the percentage change in demand for a given product resulting from a one per cent increase in income, usually calculated as an average value for a population based on time-series data. Income elasticity may be negative or positive, depending on whether the goods are 'inferior' or 'normal'.

additional benefits to international tourists at two to three times the loss, in terms of lost agricultural land incurred by local villagers, despite measures allowing them access to buffer zones (Kramer *et al.* 1995). While such a change in land-use may be economically efficient, since the potential for compensation exists, it will aggravate poverty where compensation is absent or inadequate.

Valuation for forest policy and management

In contrast to the considerable advance made in valuing non-timber forest benefits, there has been relatively little progress in applying the results of valuation studies to forest policy and management. However, this is probably due to political and institutional barriers rather than a reflection of the quality or relevance of valuation studies. Despite the discouraging record to date, a number of potential applications can be identified.

The integration of forest values in policy is a crucial step. Forest land users and managers are often reluctant to modify their management practices, even where they acknowledge the importance of environmental benefits, due to the constant pressure to increase revenue and reduce costs. Careful design of forestry regulations, concessions and tax policy can encourage forest managers and land users to account for non-market benefits in their own interests. This in turn can reduce the need for and costs of supervision by regulatory agencies, while achieving a more efficient mix of market and non-market benefits.

Information on the economic value of non-timber forest benefits can be applied at different geographic scales: in determining the appropriate extent and type of forest cover (*i.e.* for land use planning); and in deciding how individual forest stands should be managed. In both cases the scope for improving policies runs the gamut from zoning and property rights to regulation and pricing schemes.

How much forest is needed, of what type and where?

Virtually all forests have some positive non-market value. This implies that the value of keeping land under forest is almost always greater than the amount which can be realised by private firms producing for the market. This means in turn that private land owners will systematically under-provide forested land.

Similarly, valuation studies suggest that the general public prefers forested landscapes composed of mixed species and varying ages. For recreational purposes (*e.g.* trekking, camping) the public generally prefers mature forests with little undergrowth, high canopies and relatively few stems, over younger, denser stands. Both of these preferences run counter to the usual aims of industrial forestry, which in turn implies that private firms will tend to under-supply older and more diverse forest landscapes.

The traditional solution to this problem is for the state to provide recreational and amenity forests on publicly owned land, in which industrial uses are strictly limited or forbidden. An alternative to public provision is to introduce land-use zoning or other

restrictions on the use of private land, to ensure greater forest cover and/or more diverse forests in areas of relatively high demand.

One interesting implication of travel cost and other valuation studies is that many forests may be misplaced. In effect, there should be more (and more diverse) forests near population centres. On the other hand, existing land-use restrictions in some areas may already provide an appropriate level of forest cover with respect to recreational, landscape and other non-market values. This applies particularly to blanket restrictions on farming or logging of slopes above a certain steepness, irrespective of opportunity costs or actual downstream water uses and flood risk.

Non-timber values and private property rights

Economists often argue that a fundamental cause of the under-supply of non-market benefits (and the over-supply of non-market costs or 'externalities') is the lack of exclusive property rights. The notion is that private property, where it is enforceable, creates an opportunity for profitable exchange and thus an incentive for careful management. As a rule, therefore, economists tend to favour the creation of property rights over regulation or price policy. One advantage of such an approach is that government need not concern itself with the difficult task of setting prices but can devote its efforts to enforcing property rights and contracts.

Promising areas for property rights-based solutions to the under-supply of non-timber forestry benefits include concessions for non-timber forest products and for recreational uses⁸. These may overlap with timber concessions, requiring logging companies (or land owners) to make proper compensation for loss to non-timber benefits. Constraints on the viability of private concession include the difficulty of excluding poachers and/or free-loaders, and competition from publicly-owned land, where access to comparable benefits may be free or below cost.

Non-timber values and forestry regulations

Where private property rights are not feasible⁹, it may be possible to account directly for the value of non-timber benefits in forestry regulations. In fact, many public agencies already account for environmental values either explicitly or implicitly. Timber cutting limits and rotation length, careful road layout, mandatory low-impact logging methods, stream-site buffer strips and wildlife corridors, etc. are all increasingly standard practice and can help to mitigate damage or loss of non-timber benefits due to logging.

The weakness of such regulatory approaches is their insensitivity to differences in the costs and benefits of compliance at different forest sites. Many forestry regulations

⁸The results of valuation studies may be used to provide a bench-mark or reserve price for auctioning concessions.

⁹For example, an exclusive right to the carbon storage benefits of a particular forested area is a ridiculous notion for two reasons: firstly, because one person's enjoyment of the climate benefits secured thereby does not detract from another's and secondly, because it is impossible for the 'owner' of the right to prevent others from enjoying the same benefit.

are applied uniformly to all areas in the same way, regardless of the type of forest involved or its location. And yet evidence from valuation studies suggests that demand for many non-timber benefits varies widely from place to place, mainly as a function of the proximity and density of human populations but also as a function of forest characteristics (e.g. age and species composition, topography and accessibility, presence or absence of streams and waterfalls, etc.) This in turn implies a need for greater flexibility and sensitivity of forestry regulations to the effective demand for non-timber benefits at particular sites. Valuation studies can help by demonstrating the relationship between key characteristics and WTP for non-timber benefits.

Non-timber benefit and forest pricing policy

Land owners are clearly sensitive to taxes in their choice of land-use. Similarly, timber concession holders and logging firms are sensitive to royalties, taxes and other fees. The results of valuation studies may be incorporated in such policies and can be expected to induce changes in land-use and logging practices¹⁰.

For example, the sale price of timber concessions on public forest land can be adjusted to account for the relative importance of non-timber benefits in different areas and the impact of timber harvesting on them (positive or negative). This can apply whether the price of timber concessions is fixed administratively or by auction. At the margin, higher (or lower) prices will lead firms to lose (increase) interest in harvesting timber from certain areas altogether (i.e. forests which are less accessible or less densely stocked with mature commercial timber species). Similarly, on private land, rates of tax may be adjusted up or down according to the level of provision and the importance of non-timber forest benefits in that area. Of course, both measures require detailed knowledge of local conditions and thus may be best administered by local government.

Finally, the results of recreational demand studies (using travel cost and/or contingent valuation) can and often are used to set entry and license fees for forest recreational areas, including day trippers, campers and hunters.

Conclusion

Economic valuation of forests is an important tool for making more informed decisions about the use of forest lands. A number of reliable methods have been developed to assign monetary values to non-marketed or non-timber forest benefits. There are important differences in the significance of different non-timber forest benefits in developing countries, with implication for the choice of valuation methods.

¹⁰Industry usually argues that such measures will erode their competitive position. However, there is considerable evidence which suggests the reverse, namely, that adoption of more environmentally sensitive production methods, if combined with appropriate marketing effort, can confer a 'green' market advantage and improve profits.

Information on the economic significance of non-timber forest benefits can and should be incorporated in private property rights, forestry regulations and pricing policy. This potential has not yet been realised, largely due to political and institutional barriers but also because of the lack of regular, reliable information on the use of (and changes in) non-timber benefits. An important priority is to develop routine systems for monitoring and evaluating non-timber forest benefits on a national and local scale.

In summary, the challenge faced by forest managers and policy-makers is:

- i) to assess the current and expected future economic importance of non-timber benefits at the level of the forest site, region and nation, and under different land-use and management regimes;
- ii) to make informed trade-offs between the marketed and non-market benefits of forestry activities, both at the level of national or regional land-use planning and in the management of particular forest sites; and
- iii) to devise regulations and incentives which lead forest managers and land users to account more fully for non-timber benefits in their decision-making. Where non-timber values are held mainly by foreigners, this may imply the need for innovative mechanisms for international financial transfers for environmental benefits.

References

- ARNOLD, M. 1991. Forestry expansion: a study of technical, economic and ecological factors. *Oxford Forestry Institute Paper No. 3*, Oxford.
- ARROW, K., SOLOW, R., PORTNEY, P.R., LEAMER, E.E., RADNER, R. & SCHUMAN, H. 1993. Report of the National Oceanic and Atmospheric Administration Panel on Contingent Valuation. *Federal Register* 58: 4601 - 4614.
- BARBER, E.B. 1991. The economic value of ecosystems : 2 - Tropical Forests. London Environmental Economics Centre Gatekeeper Series No 91 - 01, IIED, London, 10 pp.
- BARBER, E.B., BURGESS, J.C., BISHOP, J. & AYIWARD, B. 1994. *The Economics of the Tropical Timber Trade*. 179 pp. Earthscan, London.
- BAUMOL, W.J. & OATES, W.E. 1988. *The Theory of Environmental Policy*, Second edition. 2999 pp. Cambridge University Press, Cambridge.
- BROWN, K. & PEARCE, D.W. 1991. *The Causes of Tropical Deforestation*. 338 pp. University College London Press, London.
- CROPPER, M.L. & OATES, W.E. 1992. Environmental economics: a survey. *Journal of Economic Literature* 30: 675 - 740.
- FAO, 1997. *State of the World's Forests*. 200 pp. Food and Agriculture Organization of the United Nations, Rome.
- FREEMAN, A.M. 1993. *The Measurement of Environmental and Resource Values*. 516 pp. Resources for the Future. Washington, D.C.
- GAMMAGE, S. 1997. Estimating the returns to mangrove conversion: sustainable management or short term gain? *Environmental Economics Discussion Paper No. 97-02*. 74 pp. International Institute for Environment and Development, London.

- GARROD, G. & WILLIS, K. 1992. The environmental economic impact of woodland: a two-stage hedonic price model of the amenity value of forestry in Britain. *Applied Economics* 24: 715 - 728.
- HANLEY, N. & MILNE, J. 1996. Ethical beliefs and behaviour in contingent valuation surveys. *Journal of Environmental Planning and Management* 39(2): 255-272.
- HENDERSON, J. & QUANDT, R. 1958. *Microeconomic Theory: A Mathematical Approach*. 85 pp. McGraw-Hill Book Company.
- KRAMER, R.A., SHARMA, N. & MUNASINGHE, M. 1995. Valuing tropical forests: methodology and case study of Madagascar. *Environment Paper No.13*. The World Bank, Washington, D.C.
- MAKER, K.G. 1992. Production function approach in developing countries. In: J.R., Crawford, E.W. & Hoehn, J.P. (Eds.) *Valuing Environmental Benefits in Developing Countries*. Special Report 29. Michigan State University, East Lansing, MI.
- MUNASINGHE, M. & LUTZ, E. 1993. Environmental economic and valuation in development decision making. In: Munasinghe, M. (Ed.) *Environmental Economics and Natural Resource Management in Developing Countries*. Committee of International Development Institutions on the Environment. The World Bank, Washington, D.C.
- OECD. 1989. *Economic Instruments for Environmental Protection*. OECD, Paris.
- PEARCE, D.W., MARKANDYA, A. & BARBIER, E.B. 1989. *Blueprint for a Green Economy*. 192 pp. Earthscan, London.
- PEREZ-GARCIA, J.M. & LIPPKE, B.R. 1993. The Timber Trade and Tropical Forests: Modeling the Impacts of Supply Constraints, Trade Constraints and Trade Liberalization. *London Environmental Economics Centre Discussion Paper No. 93-03*. 34 pp. International Institute for Environment and Development, London.
- PORTNEY, P.R. 1990. *Public Policies for Environmental Protection*. Resources for the Future, Washington, D.C.
- SEIJO, R.A. & LYON, K.S. 1990. *The Long-Term Adequacy of World Timber Supply*. 230 pp. Resources for the Future, Washington, D.C.
- SHARMA, N.P. (ed.) 1992. *Managing the World's Forests: Looking For Balance Between Conservation and Development*. 605 pp. Kendall/Hunt Publishing Company, Dubuque.

Suggested further reading

- ADGER, W.N., BROWN, D., CERVIGNI, R. & MORAN, D. 1995. 'Total economic value of forests in Mexico'. *Ambio* 24: 286 - 296.
- BALICK, M. & MENDELSON, R.O. 1992. 'Assessing the economic value of traditional medicines from tropical forests'. *Conservation Biology* 6: 128 - 130.
- BARBIER, E.B. & AYLWARD, B.A. 1996. Capturing the pharmaceutical value of biodiversity in a developing country. *Environmental and Resource Economics* 8: 157 - 181.
- CHOPRA, K. 1993. The value of non-timber forest products: an estimation for tropical deciduous forests in India. *Economic Botany* 47: 251 - 257.
- DIXON, J.A. & SHERMAN, P.B. 1990. *Economics of protected areas: a new look at benefits and costs*. 234 pp. Earthscan, London.
- DUDLEY, N., JEANRENAUD, J.P. & SULLIVAN, F. 1995. *Bad harvest? The timber trade and the degradation of the world's forests*. 204 pp. Earthscan, London.
- ECHVERRIA, J., HANRAHAN, M. & SOLORZANO, R. 1995. Valuation of non-priced amenities provided by the biological resources within the Monteverde Cloud Forest Preserve. *Ecological Economics* 13: 43 - 52.
- FANKHAUSER, S. 1994. *Valuing climate change: the economics of the greenhouse effect*. 176 pp. Earthscan, London.
- GODOY, R., LUBOWSKI, R. & MARKANDYA, A. 1993. A method for the economic valuation of non-timber tropical forest products. *Economic Botany* 47: 220 - 233.
- GREGENSEN, H., ARNOLD, J., LUNDGREN, A. & CONTRERAS-HERMOSILLA, A. 1995. Valuing forests: context, issues and guidelines. *Forestry Paper No. 127*. Food and Agriculture Organization of the United Nations, Rome.

- INTERNATIONAL INSTITUTE FOR ENVIRONMENT AND DEVELOPMENT. 1994. *Economic analysis of tropical forest land-use options: A review of methodology and applications*. 238 pp. IIED, London.
- KUMARI, K. 1995. An environmental and economic assessment of forest management options: a case study in Malaysia. *Environment Economics Paper* No. 026. Environment Dept., The World Bank, Washington, D.C.
- LAMPIETTI, J.A. & DIXON, J.A. 1995. To see the forest for the trees: a guide to non-timber forest benefits. *Environmental Economics Paper* No. 013. Environment Dept., The World Bank, Washington, D.C.
- PETERS, C.M., GENTRY, A.H. & MENDELSON, R.O. 1989. Valuation of an Amazonian rainforest. *Nature* 339: 655 - 656.
- PINHO-VAZQUES, M., ZARIN, D. & JIPP, P. 1992. Economic returns from forest conversion in the Peruvian Amazon. *Ecological Economics* 6: 163 - 173.
- TOBIAS, D. & MENDELSON, R. 1991. Valuing ecotourism in a tropical rain-forest preserve. *Ambio* 20: 91 - 9.

ESTIMATION OF PETAI CONSUMPTION IN THE KLANG VALLEY IN PENINSULAR MALAYSIA

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Based on a survey of consumers in the greater Kuala Lumpur area of Malaysia (Klang Valley), this paper estimates a model of petai consumption. The model allows the decision to purchase petai to be separate from the consideration of how much to purchase. Factors significantly affecting the decision to purchase petai include household size. This participation model also confirms the view that Malays are more likely to purchase petai than people from either Chinese or Indian households. The study examined the effects of the same explanatory variables on how much petai is purchased once the decision to buy petai has been made. The only significant variables in this case were household income and the number of children (under 15 years of age) in the household. Both higher household income and more children lead to greater expenditure on petai. The results indicate that petai does not lose favour as incomes grow. While richer households will purchase more petai, they do not seem to purchase it more frequently. On the other hand, the household's ethnic group significantly affects the frequency of purchase, but not the amount purchased at a given time. Taken together, this suggests that Malays do indeed consume more petai than Chinese or Indian households.

Keywords: Non-timber forest produce - petai - consumption

Introduction

An important non-timber forest product (NTFP) in Peninsular Malaysia is the seed and/or pods of the native forest tree, *Parkia speciosa* (local name being 'petai'). The seeds and pods of this species are widely consumed by both rural and urban populations. Petai is collected primarily from forested areas, and is traded throughout Peninsular Malaysia. Despite its popularity and apparent economic importance, however, little information is available regarding the magnitude of the trade.



Plate 1. The magnificent crown of a petai tree, *Parkia speciosa*, with many fruit bunches
Photo: W.C. Woon

Parallel research has discovered that petai production increases in logged-over or cleared forest (Woon 1995, Woon *et al.* 1995). The petai trees are left in place by timber harvesters as the tree is of lower commercial value. The associated opening in the forest canopy leads to increased productivity and reproduction of the species. Similarly, where logged over or secondary forest is encroached by agriculturists, the petai trees are often maintained in an agroforestry production system. Petai provides valuable shade and consumer products (*i.e.* the pods). A thorough study of the sources of traded petai has not yet been undertaken but preliminary research indicates that many of the pods which are harvested and marketed to urban centres originate from secondary or encroached forest areas.

Analysis conducted by Woon *et al.* (1995) suggests that combining petai harvesting with forest management for sustained timber production may be a competitive land-use option, with an estimated financial net present value per hectare of approximately RM 22,000 (over a 60-year rotation).¹ Natural forest management (*i.e.* harvesting petai without timber) is not financially attractive as there is no timber revenue and the net income from petai harvesting is also lower.² On the other hand, the net present value from petai trees intercropped with banana in encroached forest seems to be about half as much, at RM 11,000 per hectare. With additional labour and material inputs, cultivated petai intercropped with durian fruit may yield a net present value per hectare of approximately RM38,000.

¹ The analysis of land-use options should be viewed as tentative given the limited number of sites studied. Moreover, the analysis presented in Woon *et al.* (1995) is from a strictly financial perspective; in particular, environmental costs and benefits (*e.g.* soil erosion or biodiversity impacts) are not included.

² In a natural forest setting, both pod production per tree and the number of trees per hectare are lower and labour requirements for harvesting are higher.

One implication of this research is that if petai continues to maintain or even increase its popularity in the face of rapid economic development, cultivation may become even more widespread. Hence the importance of developing a better understanding of consumer demand for petai. Such information can also inform policy-makers on non-timber forest products generally.

This study concentrates on the consumption within the Klang Valley area, the most populated area in Peninsular Malaysia. The Klang Valley encompasses the Federal Territory of Kuala Lumpur and part of the state of Selangor. The study focuses on the purchase by consumers of raw petai.⁶ The specific objectives of the study were to derive estimates of petai consumption by the urban population of the Kuala Lumpur (KL) area (Klang Valley) and to test whether consumption is related to socio-economic characteristics, such as income and ethnic groups.

Methodology

While the Tobit model is often employed for estimating consumer demand models, the variables and parameters that determine the level of consumption in the Tobit model also affect the decision to consume (Cragg 1971). Greene (1991) proposes a more general model that allows the probability of consumption to be estimated independently of the regression for the amount consumed:

Decision equation:

$$\begin{aligned} \text{Prob}[y_i > 0] &= \Phi(\gamma'x_i) & z_i &= 1 \text{ if } y_i > 0 \\ \text{Prob}[y_i \leq 0] &= 1 - \Phi(\gamma'x_i) & z_i &= 0 \text{ if } y_i \leq 0 \end{aligned}$$

Regression equation for non-limit observations:

$$E[y_i | z_i = 1] = \beta'x_i + \sigma\lambda_i$$

y_i is observed consumption. The probability of consumption for household i is the standard normal distribution $\Phi(\gamma'x_i)$, where x_i is a vector of exogenous variables and γ is vector of unknown parameters. In the truncated regression equation, positive values of consumption are determined by the same vector of exogenous variables, x_i , and a vector of unknown parameters, β .

This type of model has been proposed for both durable consumer goods and for consumption data based on short sampling periods (Yen 1994). In the latter case, many respondents are likely to have reported zero purchases during the relatively short sampling period, although they have actually consumed the commodity. They may simply purchase the commodity less frequently. But the factors affecting that

⁶Cooked petai is bought in restaurants and food stalls. This may also form a significant part of the total petai consumed. A survey of restaurant operators would be necessary to estimate the quantities involved. In this survey, a question was included on the consumption of cooked versus raw petai. Far more respondents reported purchasing raw compared to cooked petai, suggesting that the consumption at home is more than consumption in restaurants.

frequency may be different from those influencing how much is purchased, once that decision is made. Greene (1991) also provides a simple likelihood ratio statistic that can be used to test the restriction on this model, which results in the Tobit formulation.

Data

Data used in this study were collected by means of a consumer questionnaire administered through an interview in December 1994.⁴ The questionnaire focused on various socio-economic characteristics of the individual and asked the interviewee to recall how much raw petai had been purchased during the last week, as well as the price paid.

The most appropriate unit of analysis for analysing the consumption of petai would be the household given that purchases of foodstuffs are often made by a limited number of household members on behalf of the entire household. Due to the difficulties of approaching households in the KL area, the questionnaire was administered to individuals in selected public areas (see discussion below) and concentrated on their purchase of petai (as distinct from their consumption at home).

The population studied consisted of all individuals over the age of 14 in the greater Kuala Lumpur/Klang Valley metropolis. As there is no official administrative or geographical boundary for the Klang Valley, the following five districts were assumed to make up the study area: Federal Territory of Kuala Lumpur, Gombak, Ulu Langat, Petaling and Kelang (Figure 1).

Five locations were selected from different parts of the city to sample individuals (Figure 2): Chow Kit day market, Sentul day market, Kepong night market, Sungai Wang Shopping Mall and a government building, Bukit Damansara (Immigration Department). The choice reflects an attempt to balance the need for different types of locations with that of having an environment where people could be comfortably approached by interviewers. In the end, four of the five locations were markets or commercial environments. In addition, it is likely that some of the poorest sections of the population being studied were not sampled adequately given the final mix of sample locations chosen. The possible effects this may have on the results are discussed below.

The Chow Kit day market is situated in the city centre and people from the middle to lower income groups usually frequent this area for their daily marketing needs. Mid-way through the survey, it was found that the Indians were poorly represented in this market. Interviewers were therefore asked to shift to the day market located in Sentul (where a large portion of the Indian population reside).

⁴ A copy of the questionnaire is included in Appendix 1.

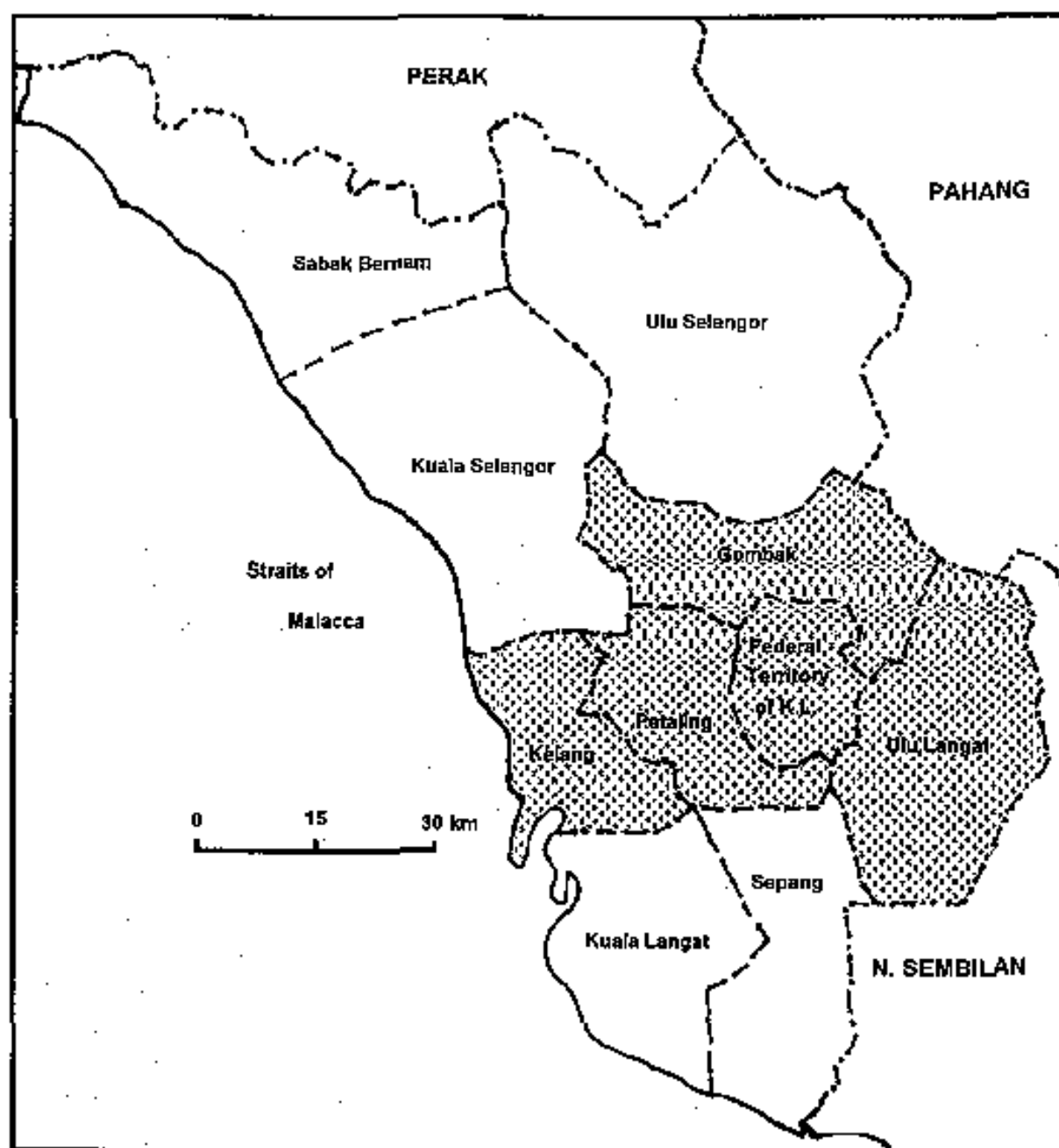


Figure 1. Location of the Klang Valley

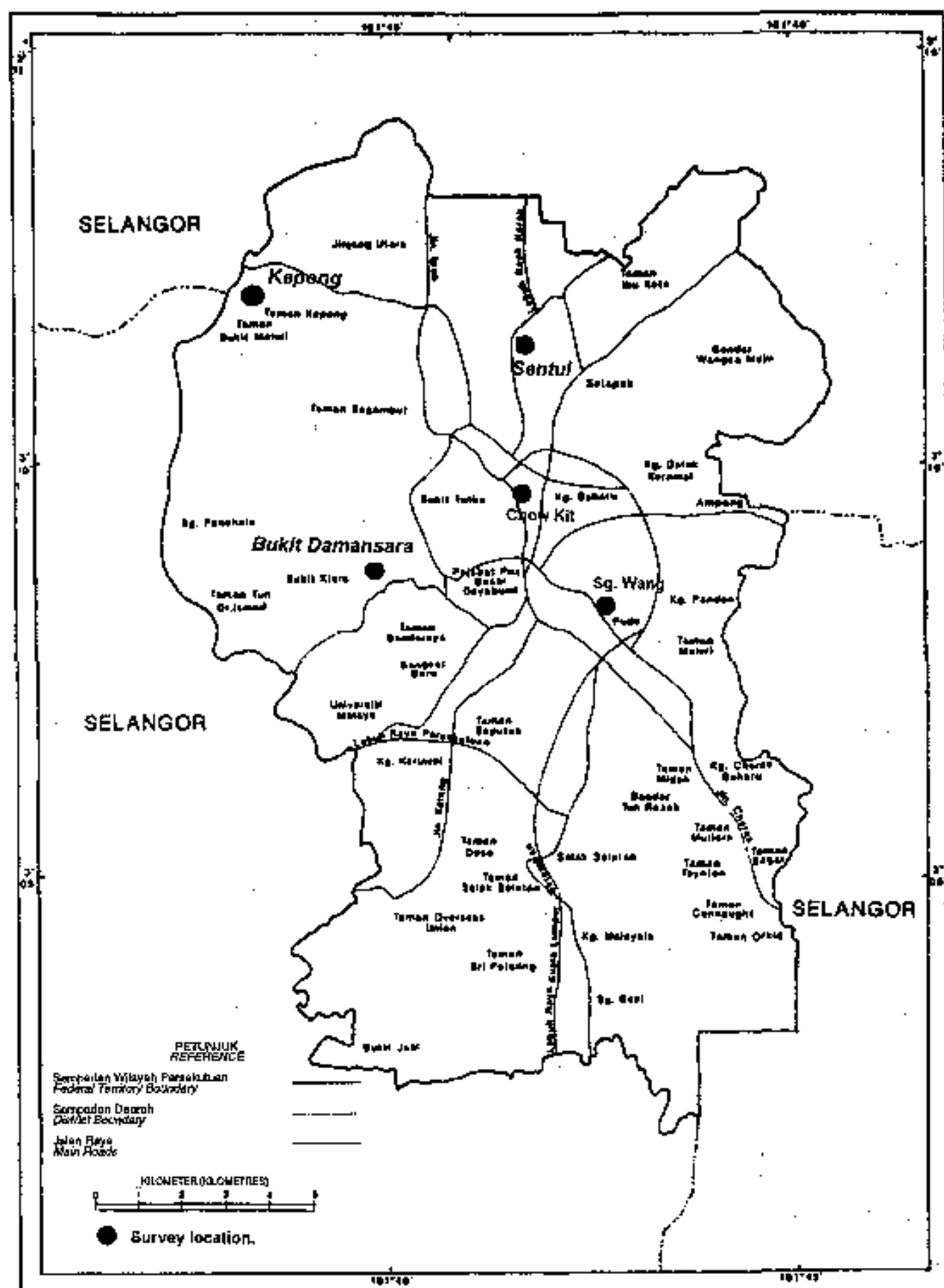


Figure 2. Location of survey in Kuala Lumpur

The Kepong area situated in the north-west part of Kuala Lumpur was the second location selected but only the night markets around the area were sampled. The night markets are very popular and many households within the area frequent these markets to meet their daily needs. As the markets are open only one night of the week in a particular location, the survey was carried out in four night markets in different parts of Kepong. The survey was spread over two weeks as it was not possible to carry out the survey on some nights due to rain. The area has a high percentage of Chinese and a fair number of Malays. In general, the area is made up of lower to middle income households.

The Sungai Wang Shopping Mall was selected on the basis that all the three different ethnic groups are likely to be found there. It is centrally located in the city and provides a focal point for many people to either meet or shop. The survey was carried out over four days between 11 a.m. and 4 p.m.

The Immigration Department Complex in Bukit Damansara was selected as a place to sample respondents from the middle to upper income classes. A number of other government departments (Road Transport Department and Labour Department) are also situated there. A large number of people turn up daily at this complex to apply for or renew their international passports, pay their road tax and to settle other matters with the Labour Department. The survey was carried out over four working days between 10 a.m. and 4 p.m.

The lack of existing surveys of this nature in the greater KL area made it difficult to assess the necessary sample size. To ensure adequate representation by ethnic group, a stratified random sampling methodology was employed. Using published population statistics and the results of a testing of the questionnaire among FRIM households, a Neymann allocation formula helped to determine the approximate numbers required for each population's sample. This resulted in a target sample of 225 Malays, 225 Chinese and 50 Indians.

Interviewing was undertaken by three teams of researchers. For each day of interviewing, teams were given quotas of numbers of each ethnic group to interview. The teams followed a procedure of positioning themselves at an area of high traffic, or people flow, at the sampling location. After finishing with a respondent, the interviewer then approached the second individual from the ethnic group being sampled who walked by. This helped to ensure a more random selection of respondents and consequently, a large number of non-respondents were recorded. In such cases, the ethnic group and sex of the non-respondents was recorded.

The total number of potential respondents approached by the interviewers during the survey period was 1,025. Of these, only 509 (49.7%) were willing to be interviewed. A higher percentage of Malays approached (58%) agreed to participate in the survey than for either Chinese (45%) or Indians (41%).⁵

⁵ A chi-squared value of 19.69 (degrees of freedom = 2) rejected the null hypothesis of independence between the ethnic group and willingness to participate in the survey.

Expenditure on petai during the last week is used as the dependent variable. The explanatory variables include the following:

1. Household income (monthly household income in RM)
2. Household composition: number of adults (15 years of age or older) and number of children (under 15); and
3. Dummy variables for ethnic groups.

The preferred dependent variable would normally be the quantity consumed. However, it is difficult to compare the quantity of petai consumed by one household with that of another since petai comes in various grades for which there is no standardised classification in the market. The study was limited therefore to measuring the expenditure on petai. Relating this to income results in a traditional Engels curve.

After cleaning the data for extreme or missing responses, the final sample size was 454. The sample is heavily censored with only 111 (24.4%) respondents reporting expenditure on petai during the previous week. The mean expenditure on raw petai over the week was RM 3.99 (standard deviation of 3.45) for consuming households and RM 1.04 (standard deviation of 2.48) for the full sample. Sample statistics for the full and truncated samples are provided in Table 1.

Table 1. Sample statistics

	Full sample (n = 454)		Consuming households (n = 111)	
	Mean	Standard deviation	Mean	Standard deviation
Weekly petai expenditure (RM)	1.04	2.48	3.99	3.45
Monthly income (RM '000)	2.53	2.30	2.21	1.99
Household composition				
Under 15	1.41	1.28	1.61	1.31
15 and over	3.08	1.72	3.35	1.81
Dummy variables				
Chinese	.37		.20	
Indian	.13		.10	

Results

Estimation of the Probit and truncated regression models was undertaken using the LIMDEP (Version 7) econometric software package. The same variables were used in explaining both the participation and consumption decisions. The estimation results are presented in Table 2.

Factors that significantly affect the decision to purchase raw petai include the size of the household and the ethnic group. The number of both children and adults can increase the likelihood of purchasing petai (although the results for adults are more statistically significant). The decision to purchase petai is also significantly less for Chinese and Indian households. The results are generally as expected although the

positive influence of children on the decision to purchase petai is somewhat surprising; it is often thought that children do not enjoy the taste as much as adults. It is also interesting to note that the effects of the dummy variables for Chinese or Indian households are almost identical.



Plate 2. A harvester bundling petai fruit bunches for collection by the middleman.
Photo: Forestry Department Peninsular Malaysia



Plate 3. Bunches of the best grade petai pods.
Photo: Forestry Department Peninsular Malaysia

Table 2. Estimates for the purchase and consumption models

Variable	Participation (probit model) ^a	Consumption (truncated regression) ^a
Constant	-0.742*** (0.163)	0.830 (0.943)
Household income	-0.056 (0.043)	0.658** (0.295)
Household composition		
Under 15	0.104** (0.051)	0.629*** (0.214)
15 and over	0.120*** (0.042)	-0.187 (0.191)
Dummy variables		
Chinese	-0.671*** (0.159)	-0.292 (0.797)
Indian	-0.663*** (0.214)	0.803 (1.04)

^a Standard errors are in parenthesis. Asterisks denote significance levels: ***=0.01; **=0.05; *=0.10.

On the other hand, the model of the amount of petai consumed (using a truncated regression model) is far less satisfactory. Only two of the included variables are statistically significant: household income and the number of children (under 15 years of age). Higher income increases the amount consumed in a week, as does the number of children in the household. Furthermore, the number of adults (15 years of age and older) in the household has negative influence (though not significant) on the amount consumed.

The marginal effects of the variables on the amount consumed are presented in Table 3. Recalling that household income is a scaled variable (RM '000 per month) and that the mean of petai expenditure is almost RM 4 among those who purchased in the past week, the effect of income on the amount of petai consumed is quite substantial. Although derived from cross-sectional data, this suggests that petai is not likely to lose its appeal as incomes continue to grow. Further analysis is clearly necessary given the imperfections in the second model.

The data also indicates (though without much statistical significance) that ethnic group is not an important factor in influencing the amount of petai purchased, once this decision is made. This is in contrast to the results of the first model but may have a plausible explanation. Overall petai consumption may be significantly influenced by ethnicity of the household. Perhaps Malays purchase petai far more frequently than the Chinese or Indians. However, once households in the latter groups make a decision to purchase petai, they are just as likely to purchase as much as the Malays.

Despite the uninspiring results of the second model, a Lagrange Multiplier Test suggested by Greene (1991) strongly rejects the hypothesis that the two decisions should be combined into one consumption model ($X^2 = 123.024$; 6 degrees of freedom). This further indicates that the decision to purchase and the amount purchased are influenced by different factors, some of which may not have been captured in the survey.

Table 3. Marginal effects of variables in consumption model

Variable	Partial derivative of expected value of consumption (computed at means of variables using whole sample)*
Household income	0.438** (0.196)
Household composition	
Under 15	0.418*** (0.142)
15 and over	-0.124 (0.127)
Dummy variables	
Chinese	-0.195 (0.531)
Indian	0.535 (0.692)

*Standard errors are in parenthesis. Asterisks denote significance levels: ***=0.01; **=0.05; *=0.10.

Estimation of petai consumption

Using the results of the survey, it is also possible to make a preliminary estimate of aggregate expenditure on petai by households in the greater KL area. This can be done by multiplying the mean expenditure per week on petai by the number of households in the targeted population (611,509; from the 1991 population census). This results in an estimate of RM 0.634 million per week with a 95 per cent confidence interval of between 0.495 million and 0.780 million.

Obtaining an annual estimate from this weekly figure is difficult as the consumption of petai is seasonal. The survey was conducted during neither the highest nor the lowest part of petai season, which lasts about four months a year. Thus for present purposes, we assume that this weekly estimate represents the average level of expenditure throughout the petai season. This leads to an estimated annual expenditure of RM 10.8 million and the 95% confidence interval would be between RM8.4 million and RM13.3 million.⁶

In comparison, Woon (1995) estimated the potential value (ex-forest gate prices) of the petai trade in Peninsular Malaysia to be RM47 million annually. This reflects the popularity of petai in the urban areas.

6 Multiplying the weekly estimate by 17 weeks (per 4 month season).

Discussion

Based on a survey of consumers in the greater KL area of Malaysia (Klang Valley), this paper estimates a model of petai consumption. The model allows the decision to purchase petai to be separate from the consideration of how much to purchase. Factors significantly affecting the decision to purchase petai include household size and ethnic background. This participation model confirms the view that Malays are more likely to purchase petai than people from either Chinese or Indian households.

The study examined the effects of the same explanatory variables on how much petai is purchased once the decision to buy petai has been made. The only significant variables in this case were household income and the number of children (under 15 years of age) in the household. Both higher household income and more children lead to greater expenditure on petai. The results indicate that petai does not lose favour as incomes grow. Although richer households will purchase somewhat more petai, they do not seem to purchase it more frequently.

On the other hand, the household's ethnic group significantly affects the frequency of purchase, but not the amount purchased at a given time. Taken together, this suggests that Malays do indeed consume more petai than Chinese or Indian households.

Nonetheless, a number of issues deserve further investigation. Most importantly, it appears that the conditional consumption model for the amount purchased is misspecified. Alternative plausible specifications have been tried using the existing data but none of these are any more satisfactory. One option would be to collect further data, although theory and experience provides little guidance as to what more appropriate explanatory variables might be.

Although the Lagrange Multiplier Test favours the separation of the participation and consumption decisions, this formulation still leaves the problem of predicting the weekly expenditure of households as there is no satisfactory way to combine the results of the two equations. The alternative is to return to the simpler Tobit specification. Aside from being able to evaluate the effects of various characteristics on total weekly expenditure on petai, this option would also have the advantage of being much more statistically robust. Indeed, the initial Tobit estimates obtained were very similar in direction and significance to those of the participation model. This suggests that the participation decision has a much stronger influence on the final outcome (*i.e.* total weekly expenditure) than the subsequent consumption decision, probably because of the infrequency of purchases of petai. Further work will therefore concentrate on the Tobit specification in more detail, refining the model with tests for heteroscedasticity and missing variables, among other issues.

These issues suggest that these preliminary results should, as usual, be interpreted with caution. As this paper represents one of the first efforts to investigate consumption of a widely-traded NTFP in South East Asia, additional studies are definitely needed.

Acknowledgement

We would like to thank Dr. Lim Hin Fui, Jamaludin Ismail, Lau Lim Chau, Wong Swee Ming, supporting staff of the Techno-Economic Division of FRIM and Economics Unit of the Forest Department of Peninsular Malaysia for their assistance in carrying out the petai consumption survey.

References

- Cragg, J. 1971. Some statistical models for limited dependent variables with application to the demand for durable goods. *Econometrica* **39**: 829-844.
- Greene, W.H. 1991. *Econometric Analysis*. New York: Macmillan.
- Woon W.C. 1995. *The Economic Valuation of Parkia speciosa (Petai) in Peninsular Malaysia*. 229 pp. Unpublished Ph.D. thesis, University of Wales, Bangor, U.K.
- Woon, W.C., Lim, H.F., Dan, Y.M. & Poh, L.Y. 1995. Final Report for EEPSEA/IDRC Small Research Grant Award (92-0419-09): The Economic Value of *Parkia speciosa* (Petai). Kuala Lumpur: Forest Research Institute Malaysia (FRIM) and Forestry Department of Peninsular Malaysia.
- Yen, S.T. 1994. Cross-section estimation of US demand for alcoholic beverage. *Applied Economics* **26**: 381-392.

Appendix 1. Petai consumption survey questionnaire

Ref. No.

Date: _____ Time: _____ Interviewer's Name: _____

Location: _____

A. PETAI EXPENDITURE

Coding

1. Do you eat petai?	1. Often (every week) 2. Sometimes 3. Not at all		1
2. Is there anyone in your family who eats petai?	1. Yes 2. No 3. Not sure		2
3. In the last 7 days how many time(s) have you bought cooked petai?	No. of times: _____		3
4. In the last 7 days how many time(s) did you buy raw petai?	No. of times: _____		4
5. 5.1. When was the last time you bought raw petai? (If none or cannot remember put a 0 and go on to Question 6).	Days/weeks/months		5.1
5.2.a. How many pods did you buy?	No. of pods: _____		5.2.a
5.2.b. Or how many packet(s) did you buy (if in peeled form)?	No. of packets: _____		5.2.b
5.3.a. How much did you pay for it?	RM _____ per _____ pods		5.3.a
5.3.b. Or how much per packet(s)?	RM _____ per _____ packet(s)		5.3.b
5.4. Where did you buy the petai (location)?			5.4
1. in the Klang Valley (KL, PJ, Subang Jaya, Klang, Cheras, Gombak etc.)			
2. Other places			
3. Not applicable			

B. SOCIO-ECONOMIC BACKGROUND OF RESPONDENT

6. Sex:	1. Male		6
	2. Female		
7. Ethnic group	1. Malay		7
	2. Chinese		
	3. Indian		
8. Where do you live (residence)?	1. Klang Valley		8
	2. Outside Klang Valley		
9. How old are you?	1. 15-24		9
	2. 25-34		
	3. 35-44		
	4. 45-54		
	5. 55 & above		
10. Educational level	1. No formal education		10
	2. Primary school		
	3. Lower Secondary		
	4. Upper Secondary		
	5. Diploma/University		
	6. No Response		
11. What is your monthly gross income? (if answer is 0, ask how much allowance received from parents or spouse)	RM _____		11
12. Are you married? (if married go to Q.14)	1. Married		12
	2. Single		
	3. Widower		
	4. Separated		
13. If not married, are you staying with your family or relatives? If not terminate interview	1. Yes		13
	2. No		
	3. Not applicable		
14. How many people are there in your household?	No. of people: _____		14
15. How many of them are under 15 years?	No. of people: _____		15
16. How many of them are above 15 years?	No. of people: _____		16
17. How many of them are wage-earners?	No. of people: _____		17
18. What is the gross monthly household income? (inclusive of part-time income)	RM _____		18

This is an English translation of the original questionnaire which was prepared in Bahasa Malaysia.

ECONOMIC SIGNIFICANCE OF MEDICINAL PLANTS IN PENINSULAR MALAYSIA

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The over-riding aim of this study is to determine the economic significance of local medicinal plants of Peninsular Malaysia. Preliminary results from this study indicated that both the consumer demand (urban) and scale of economic activity within the local medicinal plant industry is growing. The trends for both of these are positive but the precise magnitude of these would need more detailed analysis. As the industry and demand grows, the source of raw materials for these medicinal plants becomes an issue of major concern. The Forestry Department as custodian of the source of much of the raw materials would need to formulate a consolidated plan for the integration of these concerns into their existing forest management system.

Key words: Economic significance - medicinal plants - non-timber forest products - traditional medicine

Introduction

Medicinal plants constitute an important group among all of mankind's natural resources. Healing herbs have been traded and used since ancient times, but for all that they are neglected by mainstream development (Lambert *et al.* 1996). Nonetheless, the conservation, cultivation, collecting and processing of medicinal plant raw materials constitute a large formal market. Millions of people in developing countries use herbal medicines. In view of the growing momentum in traditional medicine worldwide, the current study is very timely.

The international interest in medicinal plants is also reflected in the Malaysian scene where there has been a mushrooming of activity in the arena (Kumari 1996). The Forestry Department as the custodian of the forest resources in the country needs to be better informed on the role of medicinal plants. Speculative ad-hoc information on the growing importance of traditional medicine is not sufficient for the Forestry Department to 'act upon'. There is a need for clear, consistent and empirical information on the growing importance of medicinal plant use and the associated industry. This, if it should be significant, would then form the basis for the formulation of a strategic action plan for the consolidation of medicinal plants into the current forest management system. So the key question at hand is: 'What is the economic significance of medicinal plants in Malaysia?' The current study seeks to fill this information gap by providing quantitative indicators on the growing significance of medicinal plants in Peninsular Malaysia.

Brief overview of the state of medicinal plants

International initiatives

A resurgence of interest in the study of medicinal plants has been taking place during the past two decades. Today, according to the World Health Organization (WHO), as many as 80 per cent of the world's people depend on traditional medicine for their primary health care needs. The greater part of traditional therapy involves the use of plant extracts or their active principles (IUCN *et al.* 1993). This is partly due to poverty, but also because traditional systems are more culturally acceptable, and are able to meet psychological needs in a way western medicine does not (Prescott-Allen & Prescott-Allen 1982). The preliminary results of a study on behalf of WHO have shown that the number of individuals using medicinal plants is large, and on the increase, even among young people. China and India are two countries where there are long traditions of medicinal plant use (Lambert *et al.* 1996). It is not just in the developing countries that medicinal plants are important. Even in the United States where synthetics dominate the drug market scene, plant products still represent an important source of prescriptions dispensed from community pharmacies, and was valued at US\$8 billion in 1980 (Farnsworth & Morris 1976).

Popular, official, and commercial interest in the use of natural products has also grown considerably. For example, as consumers become more and more health conscious, it is expected that the demand for health food products will increase enormously in the coming decade. In 1981, about 400 species of plants were reported in products marketed by the herbal industry in 'health-food' stores throughout US, and valued at US\$ 360 million (Tyler 1986). This number increased to US\$ 36 billion in 1994 (Hasler 1995). In China and Japan, the market value was US\$ 2.5 billion (Weng & Chen 1995) and US\$ 5 billion (Kojima 1995), respectively. In Malaysia, the health food market is growing steadily at about 15 per cent per year. The market was valued at RM 38 million in 1994 and is estimated to be RM 45 million by the end of 1995 (Anonymous 1994).

Over the last decade, the World Health Assembly has passed a number of resolutions in response to the resurgence of interest in the study and use of traditional medicine in health care, and in recognition of the importance of medicinal plants to the health system of many developing countries. The Traditional Medicine Program of WHO is based on the reality that:

- (i) the majority of the world's population depends on traditional medicine for primary health care,
- (ii) the manpower represented by practitioners of traditional medicine is a potentially important resource for the delivery of health care, and
- (iii) medicinal plants are of great importance to the health of individuals and communities.

In March 1988 an International Consultation on the Conservation of Medicinal Plants was convened in Chiang Mai, Thailand by WHO, in association with IUCN (International Union for the Conservation of Nature and Natural Resources) and WWF (World Wide Fund for Nature). There were two important outcomes of this Consultation: the first was the Chiang Mai Declaration entitled 'Saving Lives by Saving Plants', and second the generation of a set of guidelines which describe the various tasks that should be carried out to ensure that medicinal plants are conserved effectively for the future and that where medicinal plants are taken from the wild, they are taken on a basis that is sustainable (IUCN *et al.* 1993). Even in China and India which have fairly well established industries - inadequate attention is currently paid to conservation and cultivation programmes that would protect and enhance genetic diversity (Lambert *et al.* 1996). The main features of the Chiang Mai Declaration are presented in Box 1.

Box 1: Guidelines for the conservation and sustainable use of medicinal plants

1. To study traditional knowledge on the use of plants in health care.
2. To identify the medicinal plants, outline their distributions and assess their abundance.
3. Wherever possible, to cultivate the medicinal plants as the source of supply.
4. To ensure that any collecting from the wild is sustainable.
5. To improve techniques for harvesting, storage and production.
6. To conserve populations of medicinal plant species in natural habitats.
7. To conserve populations of medicinal plant species *ex-situ*.
8. To build public support for the conservation of medicinal plants through communication and cooperation.

Source: IUCN *et al.* (1993)

It was equally emphasized in the guidelines that no single sector, private or public can undertake the conservation of medicinal plants alone. The job requires a team effort, involving a wide range of disciplines (including taxonomists, ethnobotanists, traditional healers and practitioners, park managers, etc.) and institutions (medical centers, village cooperatives, medical authorities, universities and research institutions, etc.). For any successful conservation and utilization of medicinal plants, a holistic approach involving all these groups, together with the cooperation and support of the people at the ground level and public needs to be harnessed (Kumari *et al.* 1997).

Economic significance of medicinal plants

In the North, up to 25 per cent of all medical drugs are based on plants or plant derivatives. In the South, the proportion is closer to 75 per cent (Principe 1991). Plant species are used for medicines in two ways:

- (i) major commercial use, whether by prescription or over the counter sales, and
- (ii) as traditional medicines which may or may not attract a market price (Pearce & Moran 1994).

In the latter case two medicinal plant markets often co-exist:

- (i) formal - regulated to a limited degree by government, market crude and processed products with varying degrees of quality control; and
- (ii) informal - unregulated without any apparent government control, provides basic healthcare, especially to rural populations.

The latter is largely dependent on raw plant material. Although, the conservation, cultivation, collecting and processing of medicinal plant raw material constitute a large informal market, the exact size has never been objectively defined nor subjected to serious economic valuation (Lambert *et al.* 1996). Clearly, both the commercial and less formal uses have an economic value, but what little work there has been on valuation of medicinal plants tends to focus on the commercial, formal markets.

Few studies of trade in medicinal plants have been carried out, often because the networks for trade in medicinal plants are informal, and characterizing such trade is often difficult. Recent attempts to value medicinal plants (Balick & Mendelsohn 1992) have examined only the current local market value of these products and have not attempted any in-depth evaluation of the benefits to rural communities of traditional health strategies (Brown 1992). In addition, no studies have attempted to place a value on the health care provided by traditional healers and traditional plant medicines in terms of the costs of the modern equivalents. The paucity of studies available, however, should not obscure the likelihood that local willingness to pay (WTP) for traditional medicines may be substantial.

The compelling argument for the identification and preservation of the world's most species rich ecosystems often comes from the potential pay-off from a 'blockbuster' drug discovery. However, in reality the probability of a 'discovery' is often low, and the subsequent appropriation by the nation equally low or undefined (Ruitenbeek 1991, Pearce & Puroshotaman 1992, Kumari 1995). The role of plants in traditional medicine on the other hand provides more certain markets, and if systematically exploited could themselves be 'blockbuster' trades at the national level.

Malaysian forests as a source of medicinal plants

The Malaysian rain forests are endowed with high biological diversity. There are over 20,000 species (accounting for over 10% of the world's total number of plant species) some of which are unique only to Malaysia (Soepadmo 1995). Malaysia is rich in natural resources basic to traditional medicine. Traditional medicine is an integral part of Malaysian culture and has been practised by various ethnic groups long before the introduction of the modern medicine system into the country. Much of the knowledge is still dominant in the culture of the various ethnic groups in an unrecorded form. They are assumed to be passed from one generation to another in the traditional, oral manner. In Malaysia, the classical works of Burkill and Hanniff (1930), Gimlett and Burkill (1930) and Burkill (1935) represent the monuments of our knowledge on traditional medicine.

Of the more than 7,000 species of angiosperms and 600 species of ferns in Malaysia, about 1,082 species (about 15%) and 76 species (about 13%) respectively, are reported to have medicinal properties (Latiff *et al.* 1984). Burkill (1935) reports that more than 1,300 plants have been used in traditional Malay medicine, although the system is not as well organized as the Indian and Chinese systems. The actual number of medicinal plants commonly used in the country was, however, indicated to lie between 12 to 18 per cent of the claims (Sabariah 1989), which approximates to 174 species. This figure is close to other estimates, which cite that the forests support more than 200 potentially important medicinal plants (Hurst 1990). While some species are more popular than others, many form the minor ingredients of a decoction, or components of a wider curative concept.

Given that thousands of plants in Malaysia have at one time or another been used for medicinal purposes, knowledge of such folk or ethnomedical uses could lead us to cut short the time required to discover modern therapeutic drugs from plants. Although many scientists still regard folk remedies somewhat skeptically, one should not ignore the fact that many important modern drugs (*e.g.* digitoxin, reserpine, ephedrine) were discovered by following leads from folk medicine. It is reported that 74 per cent of the 121 biologically active plant-derived compounds presently in use worldwide, were discovered by researchers aimed at verifying the authenticity of information derived from folk/ethnomedical uses of the plants (Farnsworth *et al.* 1985). The number of Malaysian rainforest plants that have been thoroughly evaluated for pharmacological potential remains small and the vast majority of them still have no identified market. Many of the known Malaysian plants need further clarification and verification of their reported medicinal use.

Every tribe and race has its own methods or ways of curing the affliction of diseases. It depends very much on the practice, belief and knowledge each one possesses. Malaysia as a melting pot of the key ethnic cultures of Asia - Malay, Chinese and Indian - has a wide range of medicinal plant products available in the market. In addition to these, there are the medicinal plant products used by the indigenous tribes (Orang Asli) who live close to the forests or within them. The Orang Asli are renowned for their skills in combining herbal remedies from forest products. Their close relationship with the jungle is the basis for their survival despite the modern

conveniences of Twentieth Century Malaysia. Those deep in the jungles still rely on traditional cures handed down through the generations. They use these plants in one form or another to cure or alleviate a variety of ills from bruises, bee or snake bites, tooth or stomach ache, rashes, kidney pains to healing haemorrhoids, tongue or mouth ulcers, bone fractures and malaria. There are also preparations and infusions for diabetes, diarrhoea, rheumatism, coughs, anaemia and smallpox. Sometimes the same plants are used by the rural (Malay) people, but not for the same purpose. For example, tubers of the black lily or keladi murai are used to treat rashes by Malay villages, but the Orang Asli use the leaves as a hot poultice for rheumatism and aching limbs. Malays use the roots of *Forrestia griffithii* to treat fevers but the tribes use them for snake or centipede bites (Kress 1995).

For the Orang Asli, up to very recently, medicinal plants represented the only form of treatment available to them since modern medicine was not available. Even now there is often a preference for the traditional forms of medicine, especially in the very remote areas. In the case of the Malays, traditional herbal medicinal practices have persisted despite access to modern medicine. In many ways these are socially acceptable and have a wide cultural acceptance. The local Malay traditional medicine is actually based on old Indonesian traditional medicine, which has been modified to suit the local and current needs (Muhamad & Mustafa 1994).

Recent developments in the field of traditional medicine in Malaysia

There has been a surge of public interest in traditional medicine in Malaysia. The National Committee on Medicinal Plants was set up in January 1995 as an Act of Parliament, following Cabinet approval. The Forest Research Institute Malaysia (FRIM) as the Secretariat of the Committee hosts the Traditional Medicine Section and has the task of charting out a strategic vision on the future of medicinal plants in the country in terms of the short, medium and long-term approaches.

The Minister of Health made a statement that the Medical Act will be amended to give traditional medicine a greater role in health care. Also, acknowledging that plants hold the key to many remedies yet untapped, the Cabinet made a decision recently instructing the Institute of Medical Research (IMR) and Forest Research Institute Malaysia (FRIM) to study plants and document their curative properties (Anonymous 1997 - Star 17/3/1997). In recent years several seminars, conferences and fora have been organized which address specifically the topic of medicinal plants (Soepadmo *et al.* 1989, Khozirah Shaari *et al.* 1991, UPM 1991, Chan *et al.* 1993, MNPS 1994, FRIM 1995).

In addition, the Botany Departments of University Malaya (UM), Universiti Kebangsaan Malaysia (UKM) and Universiti Putra Malaysia (UPM) have been actively involved in the botanical compilation of useful medicinal plants, whilst the ethnobotanical use of these species is of interest at FRIM, the Forestry Department, Institute of Medical Research (IMR) and the Department of Anthropology and Sociology at UKM. The Pharmacy School of Universiti Sains Malaysia (USM), and the medical faculties of UKM and UM have made considerable progress on the pharmacological and phytochemical aspects of specific medicinal plants (Kumari 1996).

This 'official' endorsement of the Government comes as a culmination of years of effort by several individuals and agencies, including private practitioners, universities, FRIM and the IMR. For example, the Rimba Ilmu at University Malaya (UM), with a collection of over 600 rare plant species, represents one of the pioneering efforts towards in-situ conservation of medicinal plants in the country (Ong 1997). A plot of land has been allocated in Selangor (near Sungai Buloh) for the purpose of ex-situ planting of traditional medicinal plants.

Consumers and manufacturers of medicinal plants

Preliminary evidence for the demand of medicinal plants in Selangor and Kuala Lumpur comes from consumer surveys undertaken by IMR. These surveys were aggregated for the different types of medicinal plants used by the main ethnic groups i.e. the Malay, Chinese and Indian (Haliza 1989). Some estimates of revenue generated through the sale of Chinese herbal products is also forthcoming. For example, in Malaysia, based only on data obtained from 4,000 Chinese herbal stores, the annual sales of herbal products is estimated at RM 500 million in 1994. This value would be higher if sales from the Malay practitioners and Indian herbal stores are included (Ng & Azizol 1995).

Local practitioners and 'medicine men' have been expanding their trade in medicinal plants to meet the growing demand, and over the years several medium to large-scale manufacturers have emerged (e.g. Nona Roguy and Jamu Arjuna). To supplement the increased need for the raw plant material, some of these local manufacturers have commenced cultivation of specific plants/herbs on a commercial basis (e.g. Nona Roguy enterprise has commercial plots in Kedah and Kelantan; others are known to have plots in Perak). Not all of these plants are amenable to cultivation, or in other cases, the agronomic practices may not have been adequately developed. As demand for these more popular species increases, their continuous harvest from the forests is likely to lead to their extinction. For example, two species *Rafflesia hasseltii* (Bunga pakma), commonly used after childbirth by the Orang Asli, and *Eurycoma longifolia* (Tongkat Ali), largely consumed for its aphrodisiac qualities have been heavily depleted in the natural forests. Although the harvest of these species is 'officially' banned, the regulation is difficult to enforce in practice.

Trade: Import and export of medicinal plants and raw materials

Preliminary trade statistics on the import and export of medicinal plants, both of the finished products and the raw materials shed further light on the changing trends in the country. The statistics show the total import value of medicinal plant products to have increased from RM 54 million in 1990 to RM 64 million in 1992. There has also been a corresponding decline in exports from RM 3.3 million to RM 1.4 million over the same two year period. The import of these medicinal plants comes largely from China while export on the other hand is largely to Singapore. The reason for this trend has been attributed to the increased demand for these medicinal plants on the domestic front.

Import of raw plant material for traditional medicine in the form of powder, pellets and plants is largely from Indonesia, China, Thailand, Taiwan and the US and is largely channeled through Singapore, Philippines, Australia and Hong Kong. The import of this raw material increased slightly from RM 9.6 to RM 9.8 million, whilst there was a corresponding decline in the export from RM 1.0 million to RM 0.80 million between the same two years. The suggestion again is that the increased domestic demand had resulted in the decline in exports, and increase in imports. These statistics, are too preliminary to draw any major conclusions but the figures do suggest that there is substantial trade in medicinal products. These trends have to be confirmed with data over a longer time series, and supported with interviews with the relevant actors.

Good manufacturing practices

The rapid expansion in the utilization of traditional medicinal plants calls for greater stringency in the prescription and administration of these drugs. Currently, this is required under the third phase of the implementation of the Control of Drugs and Cosmetic Regulation Act (1984), which came into effect in 1992. Under this requirement, all traditional medicinal plants, both local and imported, must be registered by the Drug Control Authority and the National Pharmaceutical Control Bureau (NPCB) (Ahmad 1993). By the end of 1994, a total of 14,000 traditional medicinal products had been registered (Zhari & Hawariah 1995), and NPCB is currently involved in the process of evaluating each of the registered applications for pre-defined criteria of safety, efficacy and acceptable quality and ultimately for compliance with 'Good Manufacturing Practices' (GMP). There are avenues of assistance and training available to assist, especially the smaller practitioners, towards meeting these official requirements. The date for the formal standards comes into effect in January 1998. It is suspected that any move to effect these requirements within a shorter time frame would have resulted in a shutdown of up to 80-90 per cent of the factories/practitioners, especially those operated by small or solitary practitioners. It is hoped that given a reasonable time frame, technical guidance and support, a flourishing modern pharmaceutical industry of traditional medicine will emerge in Malaysia, which can be promoted regionally and worldwide.

In response to these legal and administrative overtures, the Perak Forestry Department has set aside 40 ha in Reserved Forest Area in Kledang Saiong, Bt Tapah, Bubu, Bt Larut and Pondok Tanjung for biodiversity projects. Nona Roguy from the private sector has also established 1,170 ha of herbal plantation in Gua Musang to provide for the establishment of 'stock' for herbal plants as well as a GMP factory which would allow for drug production to comply with the official, legal requirements.

We see therefore, that there is much going on in the field of medicinal plants in Malaysia. The general complaint appears to be that the various groups (botanists, ethnobotanists, chemists, pharmacists) and agencies (public and private) tend to

work in isolation, and that much could be gained if the issues and problems facing the medicinal plant industry were tackled in a concerted and coordinated fashion.

The recent developments in the medicinal plant field in Malaysia, taken isolatedly or collectively, suggest intuitively that the 'inherent' economic value of medicinal plants must be quite significant. However, it has also been argued that the official commitment to this cause is ad-hoc, and that it needs to be consolidated on the basis of sound economics. The argument here is that, the current study, if carefully structured, could provide the necessary justification for the consolidation of the variety of activities currently underway in the medicinal plant programmes in Malaysia.

Objectives, scope and methodology of the study

Aim and objectives

The over-riding aim of this study is to determine the 'economic significance of medicinal plants in Peninsular Malaysia'.

The immediate questions which follow are: What is the demand trend for medicinal plant use, both in current and projected terms? What is the willingness to pay for these medicinal plants - is it income elastic? What is the magnitude of economic activity associated with the production of medicinal plants? Is it a growing industry? A synthesis of this information together with the larger picture on the import and export associated with medicinal plants would give an indication of the current and potential status of the medicinal plant industry. If the economic activity is significant, the corresponding questions are: Where is the raw material for these medicinal plants harvested from? Is it harvested sustainably, or is the raw material being over-harvested; can these plants which are over-harvested be cultivated? Are they already being cultivated? Is it urgent to have an inventory of these plants in the forest (as has been done for commercial timber species, rattan and bamboo) to set up a representative system of protection? The results of the study will be used to formulate recommendations for forest management options to include medicinal plants should they be found to be economically significant. Briefly, five main parts can be identified in the study (Box 2).

Box 2: Outline of the study

Aim

To determine the economic significance of local medicinal plants of Peninsular Malaysia

Objectives

- I. To establish the consumer demand for local medicinal plants
 - user surveys
 - willingness to pay for local medicinal plants
 - establish trend, current and projected
 - II. To establish economic activity associated with local medicinal plants
 - surveys of manufacturers cum practitioners
 - categorization of practitioners into small, medium and large practices for analysis
 - sale volume of these manufacturers cum practitioners
 - total value of products sold
 - trend of sale
 - estimation of net benefits of small, medium and large scale practitioners
 - III. Synthesis of information to get an indication of the demand and economic activity for medicinal plants (current and projected), also to get information on
 - raw material and finished products imported and exported
 - establish trend of medicinal/herbal plant import and export
 - IV. To establish link with resource raw material availability^{1,2}
 - forest survey, inventory or data on species distribution
 - status: common, rare, endangered, unknown
 - its biology, ecology and ability for cultivation
 - to establish link between resource use and supply from the forest/cultivated habitats
 - costs and benefits of sustainable extraction from the wild versus cultivation
 - V. Conclusions and recommendations
 - describe current state of management and policy on medicinal plants and need for review in view of 'new information' from this study
- ¹ This part of the study (IV) could not be undertaken due to time and resource constraints.

Definitions and scope of the study

Traditional medicine in its broadest sense encompasses a whole range of treatments and is embedded and intertwined with religious, philosophical and spiritual elements. Malay traditional medicine is defined as the knowledge, practices and the use of natural materials, including spiritual and bodily empirical aspects, utilized by various groups in Malaysia. It is traditionally inherited.

According to Werner (1993), traditional healers are categorized according to their hierarchy in society. He has divided them into seven hierarchical status, the top being comprised of 'Great Teacher' while the bottom is made up of the herbalists (Figure 1). This bottom-most level is also characterized by the largest number of persons who are engaged in the occupation. Herbalists fall into three main categories, namely **bomoh akar kayu**, **penjual akar kayu** and **pengusaha akar kayu** (Halizah 1995). As the name indicates, **bomoh akar kayu** is a bomoh (healer) specialising in herbs and medicinal plants. This means that he not only knows an illness, he also knows the kinds of plants to use in treatment. **Penjual akar kayu** sells various kinds of roots, barks, creeping stems, fruits and flowers. He knows something of each but cannot elaborate on its properties other than 'this is good for...'. **Pengusaha akar kayu** turns the plant materials into powdered mixtures. He also knows something about the plants used in his industry, be it small-scale or medium-sized, but he is not a dealer. These, however, are not defined professions, and there is much overlap between these skills. A small scale practitioner may undertake all of these tasks, or two of the three. Furthermore they may also be more than just herbalists, *i.e.* one or more categories of the triangle.

In view of this broad range in the understanding of what is implied in the context of traditional medicine it is important to define our scope appropriately.

Firstly, in this study we are interested in medicinal plants *i.e.* of relevance here is the bottom rung of the hierarchical pyramid (herbalists). The rationale being that it is these herbal aspects of medicinal plants that provide the link with the forest resource. The term 'medicinal plants'¹ is used in this study to include trade in herbal products, herbal foods, natural products, but does not include the traditional religious and spiritual practices which are often practiced alongside. These latter aspects are equally important but are beyond the scope of this study. In the questionnaires which are designed for the consumers we try to capture the variation in use and expenditure incurred in the usage of medicinal plants for general health (as a tonic) and that which is used for the treatment of a specific ailment.

Second, the study here is confined to the local medicinal products of the Malay and Orang Asli ethnic groups. The rationale being that the local medicine prepared by these two groups derives its raw material from the forests of Peninsular Malaysia, and this would have direct implications on the need for management of the resource. Most of the medicinal plants sold by the Chinese *sinsehs*, Ayurvedic outlets, or the Indonesian *jamu* shops are imported in a more or less final form from their native

¹The term local medicinal plants and traditional medicine are herewith used interchangeably in the study.

countries, and hence do not rely on the forest resource in the country. One obvious caveat of adopting this scope is that there might be the odd case (or more) that some of the Chinese and Indonesian medicinal products do use Malaysian plant material towards the preparation of decoctions. In fact there is some fragmented information available to suggest that some of the Chinese sinsehs do currently harness the Orang Asli to collect some plants which are good substitutes to imports from China, and represent a less expensive option. In this case it should be noted that the current study provides a conservative estimate of the resource use from the forests.

Third, in establishing the economic significance of local medicinal plants we have focused on the industry as a whole, and not confined our investigation to a specific medicinal plant. The rationale here being that this former approach will provide forest managers and planners with a broader base of information critical for the management of the resource.

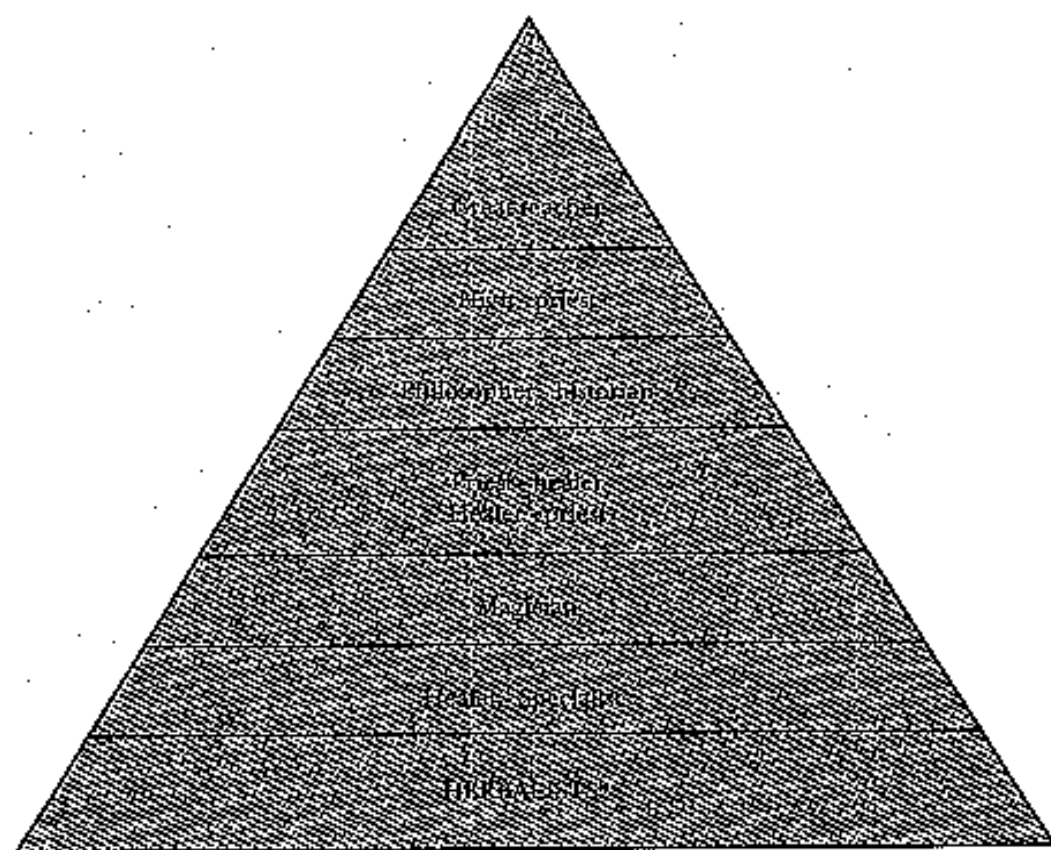


Figure 1. Diagram showing the categories of traditional healers in pyramid hierarchy (Werner 1993)

*Herbalists: this level is of relevance to this study (see text)

Methodology

To achieve the aims and objectives set out above in Box 2, the study was conducted in five stages:

i. Preparatory phase

This stage comprised a literature review of medicinal plants in Peninsular Malaysia and elsewhere. Also a series of meetings was held with the key government agencies, research institutions, universities and leading medicinal plant stakeholders (NPCB, Traditional Medicinal Association, Orang Asli practitioners, and sales outlets) to get an understanding of the issues involved.

ii. Preparation of fieldwork

Survey methodologies/questionnaires were developed to gather information from consumers and producers (manufacturers and practitioners) to establish the demand and economic activity associated with local medicinal plants. This stage of the study entailed pre-testing and revision of the survey methodology (questionnaire design, pilot tests, refinement of questionnaires) and confirmation of the sample sites/population, etc. Relevant existing background information (e.g. socio-economic data) was assembled for the surveys.

iii. Field surveys

Interviews were conducted through a combination of direct interviews and mailing techniques.

iv. Data analysis

The field surveys were followed by data analyses to assess the relative importance of medicinal plants in the economy.

v. Synthesis of results

This stage involved the synthesis of the results to arrive at plausible, realistic management options for incorporating medicinal plant management into the broader goals of forest management.

Two sets of questionnaires were designed: the consumer survey to establish the demand for local medicinal plants and the manufacturer (practitioner) survey to establish the economic activity associated with local medicinal plants. These questionnaires are provided in Annex 1.

Consumer demand for medicinal plants

The aim of the consumer questionnaire is to establish the trend in the demand for local medicinal plants, as well as to get an indication of their WTP for traditional medicine. The questionnaire was designed to be simple and self-explanatory to ensure

that there would be no ambiguity in understanding or responding to the questions. There are three parts to the questionnaire: background, consumption of medicinal plants, safety and efficacy issues (see Annex 1). Two interview techniques were used: direct and indirect (through mail surveys).

The questionnaire was tested prior to being fielded. This was done through a pilot group survey, conducted on a small random sample of respondents. Following this pilot test the questionnaire was refined. The pilot test also allowed the interviewers to undergo the practical training as well as ensure uniformity of approach during the interview session. The pilot survey results were not however, used in the main analysis.

The consumer group to be interviewed was carefully defined (urban), and the subsequent selection of respondents was to be consistent with the set aims of the project. To limit the scope of the study and to make it manageable, the consumer surveys were confined to the Klang Valley, to get an indication of the growing urban demand. The respondents for the consumer survey were selected to reflect different socio-economic backgrounds. To achieve this, 400 mail surveys were sent out to residential locations which represent a continuum of real estate prices from low, medium to high. These surveys each had a covering letter outlining the main aims of the project, and had an enclosed stamped and addressed envelope for the return of the forms.

Initially the plan was to interview the general public in shopping malls and other specific locations, but this did not prove feasible as they were often not willing to be interviewed and/or were often in a rush. For this reason the direct interviews were conducted at government and private sector offices, and industries. Here again an attempt was made to capture the different ranks of employees. A total of 134 respondents were interviewed in this manner.

To establish economic activity associated with local medicinal plants

Establishing the economic activity associated with the local medicinal plant trade would give an indication of how significant this trade was, and its trend in current and projected terms. To achieve this, interviews were to be conducted with a representative sample of small, medium and large manufacturers cum practitioners of medicinal plants. The terms manufacturers and practitioners are used interchangeably in this study, and they refer to the herbalists category in Figure 1, including those who prepare and sell medicinal plants. They may have direct clients (if their practices are small) or they may sell the products to sales outlets (for the medium to larger practices) or they may engage in both direct and bulk sales.

The initial plan was to make a systematic selection of practitioners cum manufacturers through the use of NPCB registers. This, however, did not prove feasible for various reasons and an alternative approach had to be adopted for the selection of the practitioners to be interviewed. Three sources of information were used for this:

- the Traditional Medicinal Society,

- visit to sales outlets (shops or side stalls) where the labels of traditional medicine were examined for the names of the manufacturers, and
- by word of mouth.

The first two sources of information provided access to large and medium sized practitioners, whilst the third source provided names of the smaller/single practitioner.

Although the consumer survey was confined to the Klang Valley (so as to capture the growing urban demand for medicinal plants) the search for practitioners cum manufacturers of medicinal plants revealed that the practices were located throughout the country. A total of 46 practitioners were interviewed in this study, and these were located in the following states: Perak (1), Kedah (14), Kelantan (9), Terengganu (4), Pahang (3), Johor (6), Melaka (5) and Negeri Sembilan (4)².

The questions posed to the practitioners covered three main aspects:

- background information on the age and size of practice,
- the safety and efficacy aspects, and
- information on the source and supply of the raw materials for medicinal plant production.

The questionnaire used for the interviews with the manufacturers cum practitioners is presented in Annex 2.

Results

Consumer survey for medicinal plants

Of the 400 mail surveys sent out, 66 were returned with replies, representing a response of 16.5 per cent. In addition to this, there were 134 respondents from the 'direct' interviews, giving a total consumer response of 200. The aggregate results of the questionnaire are presented in Annex 2. These results are preliminary (as the study is still on-going), but some of the key findings are highlighted here.

Background of respondents

Table 1 provides a summary of the key socio-economic indicators. Of the 200 respondents, the gender distribution was quite balanced, on race: most of the respondents were Malays (89%), and with regard to income, the distribution followed a normal curve with maximum number of respondents falling in the middle income range. As mentioned earlier, the analysis here is preliminary. The analysis will look at broadly dividing the respondents into three income groups: low (income less than RM 1,000), medium (RM 1,001- 4,000) and high (RM > 4,000), and the WTP for medicinal plants will be explored against this income distribution pattern.

²The only Peninsular States not included in this part of the survey are Perlis and Pulau Pinang. These states are largely supplied through practitioners from Kedah and Perak, and are not in themselves active from the practitioners perspective.

Table 1. Results of consumer survey for traditional medicine (demand survey)

Section 1: Background of respondents ^a							
1 Gender	2 Race	3 Age (years)	4 Marital Status	5 Number in household	6 Living arrangements	7 Education level	8 Income (RM)
Female	Malay	11 - 20	Single		Family	Primary	≤ 500
87	178	1	74	596	20	8	14
(44%)	(89%)	(1%)	(87%)			(4%)	(7%)
Male	Chinese	21 - 30	Married	>15 years	Friends	Secondary	501 - 1000
113	15	106	123	338	46	93	67
(56%)	(8%)	(53%)	(62%)		(47%)		(34%)
	Indian	31 - 40	Widowed	< 15 years	Alone	Tertiary	1001 - 2000
	7	61	8	258	6	99	76
	(3%)	(30%)	(2%)			(50%)	(38%)
	Orang Asli ^b	41 - 50	Separated		Other		2001 - 3000
		28	0		8		20
		(14%)					(10%)
		51 - 60					3001 - 4000
		4					4
		(2%)					(2%)
							4001 - 5000
							9
							(5%)
							>5001
							10
							(5%)

Consumption of medicinal plants

Some of the key results of the consumer survey indicate that:

- 71 per cent of the respondents used traditional medicine.
- of the users, 35 per cent used traditional medicine as a tonic, 16 per cent for specific ailments and 48 per cent for both uses.
- the use for tonic was mostly for general health improvement (56%) compared to 17 per cent for beauty treatment and 25 per cent for both purposes.
- the frequency of use as tonic is largely daily, followed by weekly whilst a smaller amount is consumed on a monthly basis.
- as would be expected, the prescription for specific ailments is not consumed as regularly. However, what is interesting is that the expenditure on it tends to be comparable (and even marginally higher) to that expended on tonic.
- it is important to capture the different uses of medicinal plants.
- 97 per cent of the respondents supported the idea that the government should set standards and controls on traditional medicines.

^aFor percentage calculation, rounding off error may occur.

^bThe Orang Asli survey is currently being undertaken.

The survey emphasized the use of medicinal plants for general health purposes (as a tonic) versus that as prescription for a specific ailment. In responding to the period of time over which the user had consumed the medicinal plant (both as tonic and for ailment); it was possible to get an indication of the trend of use over time. It is noted from Figure 2 that the usage of medicinal plants in both contexts has been increasing over the years - and has increased almost fivefold in the last five years. Excluding those that do not purchase local traditional medicine, most of the user-respondents spent between RM 20-40 per month on traditional medicine (Figure 3). The survey revealed that most of the respondents used modern medicine more frequently than traditional medicine, almost two to one. On average the total expenditure on modern medicine is higher (Figure 4). However, the mean monthly expenditure per user-respondent on tonic was RM 31, for specific ailments RM 27 and for modern medicine RM 28. This is an interesting insight because it shows that for the 'converted' the WTP, for local traditional medicine is comparable to that for modern medicine.

There are also broad indications that the WTP for traditional medicine is higher than what consumers are currently paying (*i.e.* a consumer surplus exists). When asked if the prices of traditional medicine were expensive, 21 per cent said that they were cheap, 69 per cent moderate and 10 per cent said they were expensive (of those who responded). Asked if they would be willing to pay more for safer forms of medicine, 73 per cent responded affirmatively, 8 per cent said no, whilst 19 per cent said not sure.

The results indicate that there is a positive trend with regard to the use of medicinal plants; and 75 per cent of those interviewed felt that the use should be encouraged (Q 28). The main problems cited, in order of priority with regard to medicinal plant trade were:

- misuse
- lack of supply
- ignorance
- processing method
- lack of publicity
- misinformation.

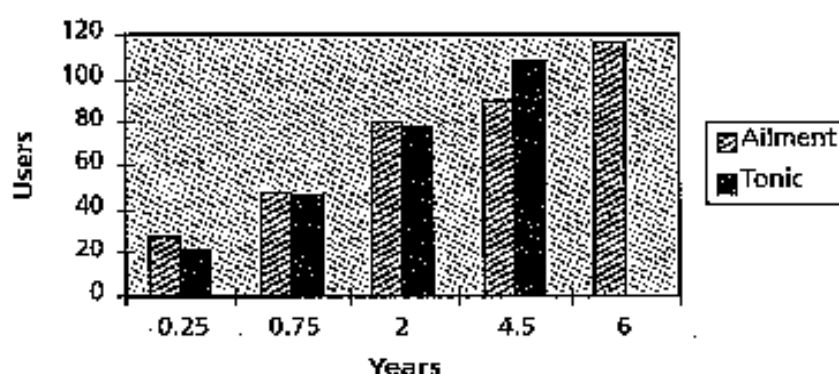


Figure 2. Consumer of traditional medicine

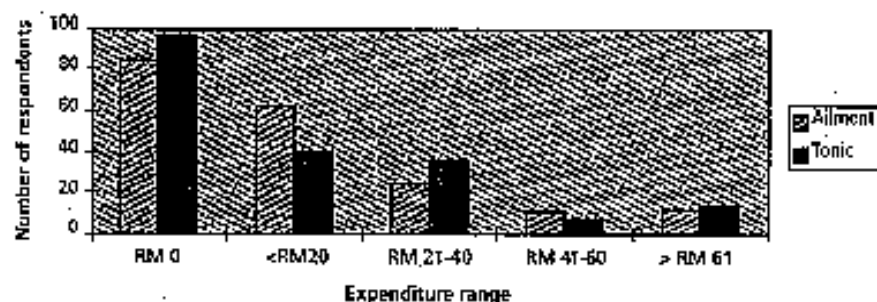


Figure 3. Monthly expenditure on traditional medicine

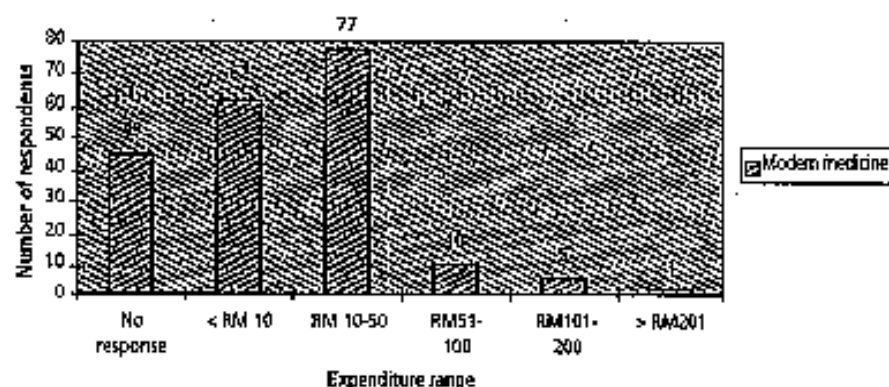


Figure 4. Monthly expenditure on modern medicine

Economic activity associated with local medicinal plants

Practitioner survey

The results of the interviews conducted with the practitioners are presented in Annex 2.

The results from the first part of the survey on the background of the practitioners provided interesting insights into the behaviour and attitudes of the practitioners. Although some of these may not be startling results in themselves, the quantified nature of the results provides the empirical evidence to take these results one step further.

Background of practitioners

The profiles of the 46 practitioners cum manufacturers interviewed are as follows:

- 28 (61%) of them have been in business for more than 10 years, *i.e.* it is a fairly stable business,

- 13 (28%) of them have been in business between 6-10 years, *i.e.* the industry is fairly dynamic,
- five (11%) of them are fairly new practices, and in business for < five years, *i.e.* it is still an attractive proposition.

The age of the 'lead' practitioner in each practice was 30 years and above: being fairly evenly spread out between the different age classes. However, it was observed that there were no lead practitioners below 30 years of age. This could be for a number or combination of reasons:

- (i) the lack of capital,
- (ii) the younger generation does not have the necessary skills and knowledge,
- (iii) the younger generation are hesitant to enter the industry.

Seven of the 46 practitioners were a single-man business; these single practitioners obviously were the sole trustees of the formulas for the medicinal plants. Excluding these, in almost 80 per cent of the practices less than three employees knew the formulations for the medicinal plant products prepared. Even in these cases the indication is that some of the critical information is often withheld from the employees.

In two-thirds of the practices the lead practitioner had informal notes on the formulations, but there was a general (66%) unwillingness for these to be published, even if they should be compensated for the information. In fact, when the practitioners were asked what could be the average payment they might expect per formulation that they would share, all of them abstained from stating any amount.

In terms of the 'acquired knowledge' and 'training' on medicinal plant formulations and prescription: this was largely through ancestral and other informal interactions (Figure 5). As much of the information on Malay (and Orang Asli) medicinal plants has been handed down through the family heritage and through informal learning, it means that there is no systematic way to ensure that this information is 'coded' in the longer term. Much of Malay traditional medicine has been preserved through the generations through oral tradition. The formulas or recipes of the medication constitute a heavily guarded family heritage in most cases and there is very limited documentation of these formulas.

These four issues relating to age of lead entrepreneur, non-sharing of key information with employees, reluctance to publish this information, and 'informal training' are important issues which have to be addressed for the longer term 'survival' interests of the medicinal plant industry⁵.

⁵Of course these issues have to be addressed together with those relating to a sustainable supply of the raw material for the production and preparation of medicinal plants - both from the forests or through cultivation cum import, if the medicinal plant industry as a whole is to be sustained.

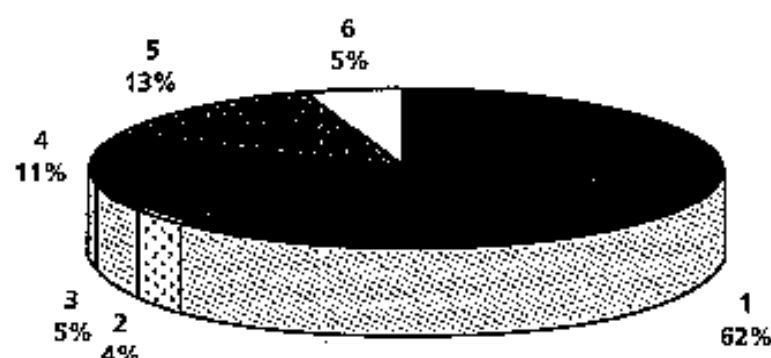


Figure 5. Source of 'indigenous knowledge' medical plants

Note: 1 = ancestry, 2 = associations, 3 = documented, 4 = self-taught, 5 = informal conversations, 6 = others (from Orang Asli etc.)

These issues have to be addressed concurrently with ensuring a sustainable flow of raw material to the industry. In terms of raw material for the medicinal plants, 31 (67%) of the practices rely on forest only, three (7%) from totally cultivated sources, and 12 (26%) from a combination of forest and cultivated sources (Figure 6). A list of all the plants used by the practitioners in the preparation of the medicinal plants is presented in Annex 3, together with their scientific names. Ideally a resource inventory of these in the forests would provide an idea of their availability in the wild, and the precise course of action which should be taken to improve their management. Although this was initially a part of the project it had to be omitted because of time and resource constraints.

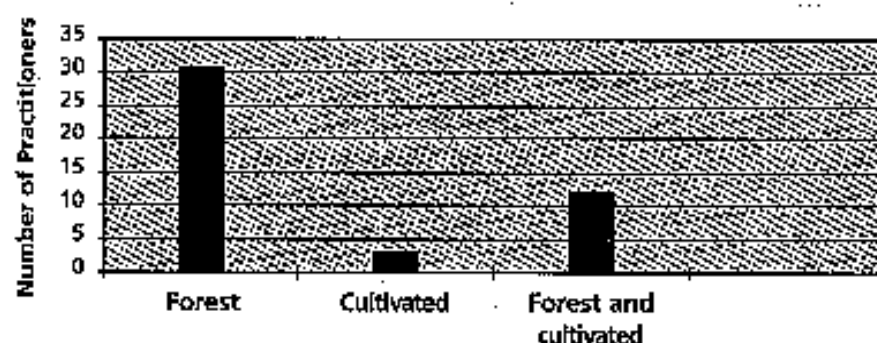


Figure 6. Source of raw material for medicinal plant preparation

The raw material for the medicinal plants is supplied to the practitioners mostly through middle-men and through self-collection, although some are purchased from market sources. The latter is in some cases imported from overseas (Figure 7).

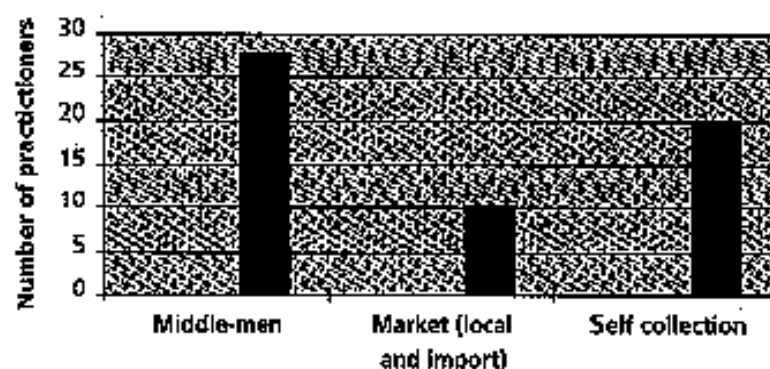


Figure 7. Suppliers of raw material to practitioners

Of the practices interviewed, 30 had notes for self-reference, whilst the rest relied on memory. Most of the latter were single-man practitioners. Asked if they would be willing to publish these formulas should they be compensated/paid for their information; 33 of them declined and only 13 thought it to be a good idea. The secrecy placed upon this information can be likened to intellectual property rights. (intellectual property rights are issues which are of fundamental concern to the practitioners and they safeguard these secrets very closely). It was interesting to note that when asked what they should be paid for their formulas, the practitioners found it difficult to answer the question; all of them abstained from answering the question.

Safety and efficacy issues

The second part of the survey dealt with safety and efficacy issues. The main points emerging from this analysis are:

- Just under half of the practitioners were registered with the Traditional Medicinal Society. When asked if the government should take any action on those not registered, there seems to be a camaraderie among these practitioners: 31 of them chose not to answer the question, whilst a small number (3) of them felt that those not registered should be banned from operating; another few felt that they should be required to attend courses to ensure that they comply with safety and efficacy issues.
- Most of the practitioners (44) pointed out that complying with the GMP would lead to an increase in overhead expenses; some (10) of them indicating increases of > 100 per cent.
- Only eight of the 46 practitioners produced medicines using scientific principles. Most of them agreed on the need for more research into this area.
- On competition, more than half (25 of 46) felt that there was competition from foreign sources of traditional medicine, largely from the Indonesians. There was a mixed response on the reasons for the competition: from ease of availability, lower costs and higher effectiveness.

- Almost all of them (44) felt that the number of practitioners (locally and foreign) was on the increase; the reasons cited for these in decreasing order of importance were: demand, government endorsement/support for the use of medicinal plants, improved technology, and its effectiveness.
- When asked to prioritise or arrange in sequence the seriousness of the problems/constraints to the continued trade in medicinal plants, the following is the order:
 - Difficulty in getting raw material
 - Government support
 - Capital
 - Skilled manpower
 - Lack of knowledge on processing
 - Insufficient publicity/technology/low prices(lack of control)
 - Competition from other traditional medicines/difficulty in marketing/lack of information on management of its trade/younger generation not interested.

Indications of scale of economic activity

Of the 46 practitioners interviewed, the number of employees ranged from zero (single man practices) to 68. On the basis of the number of employees, the practices were divided into small (0-5), medium (6-20) and large (> 20). Table 2 summarises the key indicators of these categories of practices. The results showed that whilst the sale trends of the smaller practices were mixed - with more than 50 per cent increasing, about 30 per cent relatively stable, and a smaller percentage decreasing - the sale trend for both the medium and large-scale practices was on the rise.

Table 2. Economic activity associated with practitioner survey

Scale of practice	Small	Medium	Large	Total
Number of practices	23 (25)	15	4 (6)	46
Percentage of each practice	54 %	33 %	13 %	100 %
Range of workers in each scale	0 to 5	6 to 10	> 10 (68)	
Mean monthly costs (RM)	1,046	38,987	152,850	
Mean monthly revenue (RM)	2,263	98,067	258,250	
Mean monthly net income (RM)	1,217	59,080	105,400	
Mean annual net income (RM)	14,603	708,960	1,264,800	
Total for scale of industry	335,880	10,634,400	5,059,200	16,029,480

Note: There are 25 small practices and 6 large practices, but the data analysis was based on 23 and 4 respectively for each of these categories: the remaining four did not provide sufficient information for the economic activity to be carried out.

These results could be extrapolated to get an estimate of the economic significance of the industry through the use of these two indicators:

- to get an idea of trend analysis of small, medium and large practitioners cum manufacturers
- to get an idea of the total number of practices in Peninsular Malaysia
- to extrapolate the scale of economic activity to get an indication of the total magnitude of the industry.

Conclusions and recommendations

The study is not yet completed, but the results provide some preliminary indications that both the consumer demand and the scale of economic activity within the local medicinal plant industry is growing. The trends for both of these is positive but the magnitude needs to be determined on the basis of more detailed analysis.

The source of raw material for these medicinal plants as the industry and demand grows is then an issue of major concern and the Forestry Department as custodians of the source of much of the raw material would need to formulate a consolidated plan for the integration of these concerns into their existing management systems.

References

- AHMAD MAHMUD. 1993. Registration of traditional medicine in Malaysia. Pp. 234-244 in Chan, K.L., Abas Hj Said, Amirin Sadikun, Yuen, K.H., Mohd, Zaini Asmawi & Zhari Ismail (Eds.) *Trends in Traditional Medicine Research. Proceedings of the International Conference on the Use of Traditional Medicine and Other Natural Products in Health Care*, 8-11th June 1993, Penang, Malaysia. School of Pharmaceutical Sciences, University of Science, Malaysia, Penang.
- ANONYMOUS. 1994. MPTMA 20th Turnover Survey of Pharmaceutical Business, Malaysia.
- BALICK, M.J. & MENDELSON, R. 1992. Assessing the economic value of traditional medicines from tropical rainforests. *Conservation Biology* 6: 128-130.
- BROWN, K. 1992. Medicinal Plants, Indigenous Medicine and Conservation of Biodiversity in Ghana, CSERGE Working Paper GEC 92-36. University of East Anglia, Norwich.
- BURKILL, I.H. 1935. *A Dictionary of the Economic Products of the Malay Peninsula*. Crown Agents for the Colonies, London.
- BURKILL, I.H. & HANIFF, M. 1930. The Malay village medicine. *Gard. Bull. Str. Settl.* 6: 264-322.
- CHAN, K.L., ABAS HJ. SAID, AMIRIN SADIKUN, YUEN, K.H., MOHD, ZAINI ASMAWI & ZIHARI ISMAIL. (Eds.) 1993. *Trends in Traditional Medicine Research. Proceedings of the International Conference on the Use of Traditional Medicine and Other Natural Products in Health Care*, 8-11th June 1993, Penang, Malaysia. School of Pharmaceutical Sciences, University of Science, Malaysia, Penang.
- FARNSWORTH, N.R. & MORRIS, R.W. 1976. Higher plants: the sleeping giants of drug development. *Am. J. Pharmacology* 148: 46-52.
- FARNSWORTH, N.R., AKERELE, O. & BINGEL, A.S. 1985. Medicinal plants in therapy. *Bull. World Health Organisation* 63: 965-981.
- FARNWORTH, N.R. & SOEJARTO, D.D. 1991. Global importance of medicinal plants. In: Conservation of Medicinal Plants. Akerele, O., Heywood, V. & Syngé, H. (Eds). Cambridge University Press, Cambridge, United Kingdom.
- FRIM. 1995. Konvensyen Kebangsaan Tumbuhan Ubat (National Convention of Medicinal Plants). 13-15th October, Forest Research Institute Malaysia, Kepong.

- GIMLETT, J.D. & BURKILL, I.H. 1930. The medical book of Malayan medicine. *Gard. Bull. Str. Settl.* 6: 323-474.
- HALIZA MOHD. RIJL. 1989. A study on practitioners and users of traditional medicine in the Federal Territory and Selangor. In: Soepadmo, E., Goh, S.H., Wong, W.H., Laily, D. & Chuah, C.H. (Eds.). *Malaysian Traditional Medicine. Proceedings of the Seminar on Malaysian Traditional Medicine*. 10-11 June, 1988, Kuala Lumpur. Institute of Advanced Studies, University Malaya and Malaysian Institute of Chemistry.
- HALIZA MOHD. RIJL. 1995. Malay traditional medicine in northern Peninsular Malaysia. Report submitted to the Director General of Health, Malaysia. Division of Social and Health Behavioural Research, Institute of Medical Research, Kuala Lumpur.
- HASSLER, C.M. 1995. Functional foods: the Western perspective. In: *Proceedings of the First International Conference of East-West Perspective on Functional Foods*. 26-29th September, Singapore.
- HURST, P. 1990. *Rainforests Politics-Ecological Destruction in Southeast Asia*. Zed Books, London.
- IUCN, WHO & WWF. 1993. *Guidelines on the Conservation of Medicinal Plants*. International Union for the Conservation of Nature and Natural Resources, Gland, Switzerland.
- KHOZIRAH SHAARI, AZIZOL ABD. KADIR & ABD. RAZAR MOHD. ALI. 1991. *Medicinal Products from Tropical Rain Forests*. Proceedings of the Conference, 13-15th May, Forest Research Institute Malaysia, Kepong.
- KOJIMA, K. 1995. Control of Health Claim on Foods in Japan. In: *Proceedings of the First International Conference of East-West Perspective on Functional Foods*. 26-29th September, Singapore.
- KRESS, M. 1995. Medicinal chest from the Malaysian jungles. *Wings of Gold*. April 16-22.
- KUMARI, K. 1995. Mainstreaming biodiversity conservation: A Peninsular Malaysian case. *International Journal Sustainable Development and World Ecology* 2: 182-198.
- KUMARI, K. 1996. The economic value of traditional medicinal plants: A case study in Peninsular Malaysia. Revised Terms of Reference for Project B3. Submitted to ODA.
- KUMARI, K., BELT, T. & FURTADO, J.I.F. 1997. Mainstreaming biodiversity for sustainable development: A practical approach. CSERGE Working Paper GEC University of East Anglia, Norwich.
- LAMBERT, J., SRIVASTAVA, J. & VIETMEYER, N. 1996. *Medicinal Plants; Rescuing a Global Heritage*. Agricultural and Natural Resources Dept. The World Bank, Washington DC.
- LATIFF, A., ISMAIL, G., OMAR, M., SAID, I.M. & KADRI, A. 1984. A multivariate approach to the study of medicinal plants in Malaysia. *Journal of the Singapore National Academy of Sciences* 13: 101-113.
- MUHAMMAD ZAKARIA & MUSTAFA ALI MOHD. 1994. *Traditional Malay Medicinal Plants*. Fajar Bakti Sdn. Bhd., Kuala Lumpur.
- MNPS. 1994. *Eighth Asian Symposium on Medicinal Plants, Spices, and other Natural Products (ASOMPS VIII)*. 12-16th June, Air Keroh Village, Melaka. Malayan Natural Products Society in cooperation with UNESCO.
- NG, L.T. & AZIZOL, ABD. KADIR. 1995. Industry of medicinal and aromatic plants from Malaysian rainforests: Potentials and problems. Paper presented at the 12th Malaysian Forestry Conference on 'Sustainable Forest Management and Biodiversity Conservation - the Challenges Ahead'. 20-26th November, Miri Sarawak.
- ONG, H.C. 1997. Inventory of medicinal plants at Rimba Ilmu, the Botanical Gardens at the University of Malaya, Malaysia. University Malaya, Kuala Lumpur.
- PEARCE, D.W. & MORAN, D. 1994. *The Value of Biodiversity*. Earthscan: London.
- PEARCE, D.W. & PUROSHOTAMAN, S. 1992. Protecting Biological Diversity: The Economic Value of Pharmaceutical Plants. Global Environmental Change Working Paper 92-27. Centre for Social and Economic Research of the Global Environment, University of East Anglia and University College London.
- PRESCOTT-ALLEN, R. & PRESCOTT-ALLEN, C. 1982. *What's Wildlife Worth? Economic Contributions of Wild Animals and Plants to Developing Countries*. Earthscan, London.
- PRINCIPLE, P.P. 1991. Valuing the biodiversity of medicinal plants. In: Akerele O., Heywood, V. & Syngc, H. (Eds.) *Conservation of Medicinal Plants*. Cambridge University Press, Cambridge, United Kingdom.
- RUTTENBECK, H.J. 1991. Economic Analysis of Tropical Forest Conservation Initiatives: Example from West Africa. WWF-UK, Godalming.

- SABARIAH, S. 1989. Ethnobotanical investigation in three villages in the district of Sering, Kota Bahru, Kelantan. In: Soepadmo, E., Goh, S.H., Wong, W.H., Laily, D. & Chuah, C.H. (Eds.) *Malaysian Traditional Medicine. Proceedings of the Seminar on Malaysian Traditional Medicine*. 10-11 June, 1988, Kuala Lumpur. Institute of Advanced Studies, University Malaya and Malaysian Institute of Chemistry.
- SOEPADMO, E., GOH, S.H., WONG, W.H., LAI, D. & CHUAH, C.H. 1989. *Malaysian Traditional Medicine. Proceedings of the Seminar on Malaysian Traditional Medicine*. 10-11 June, 1988, Kuala Lumpur. Institute of Advanced Studies, University Malaya and Malaysian Institute of Chemistry.
- SOEPADMO, E. 1995. Conservation status of medicinal plants in Peninsular Malaysia. In: Khozirah Shaari, Azizol Abd. Kadir & Abd. Razak Mohd. Ali (Eds.) *Proceedings of the Conference on Medicinal Products from Tropical Rain Forests*. 13-15th May, Forest Research Institute Malaysia, Kepong.
- TYLER, V.E. 1986. Plant drugs in the Twenty-first Century. *Economic Botany* 40: 279-288.
- UPM. 1991. *First National Seminar on Ethnobotany*. 16-18th September, Universiti Pertanian Malaysia, Serdang.
- WADHAWA, B. 1994. The Sustainable Utilization of Indonesian Medicinal Plants: A Study of Conservation Initiatives within the Indonesian Traditional Medicine Community.
- WENG, W. & CHEN, J. 1995. The Eastern perspective on foods based on traditional Chinese medicine. In: *Proceedings of the First International Conference of East-West Perspective on Functional Foods*. 26-29th September, Singapore.
- WERNER, R. 1993. *Transcultural Healing - The Whole Human*. University of Malaya Press, Kuala Lumpur
- WORLD BANK. 1993. *World Development Report 1993: Investing in Health*. World Bank, Washington, D.C.
- ZHARI ISMAIL & AZIMATOI HAWARLAH 1995. Status and opportunities in natural product industry in Malaysia. MIGHT Business Forum Towards Developing Malaysia as an International Player in Pharmaceutical Healthcare and Medicinal Device. 25 January 1995. Prime Minister's Dept. Kuala Lumpur.



Plate 1. A Tongkat Ali (*Eurycoma longifolia*) plant growing in lowland rain forest.
Photo: Forestry Department

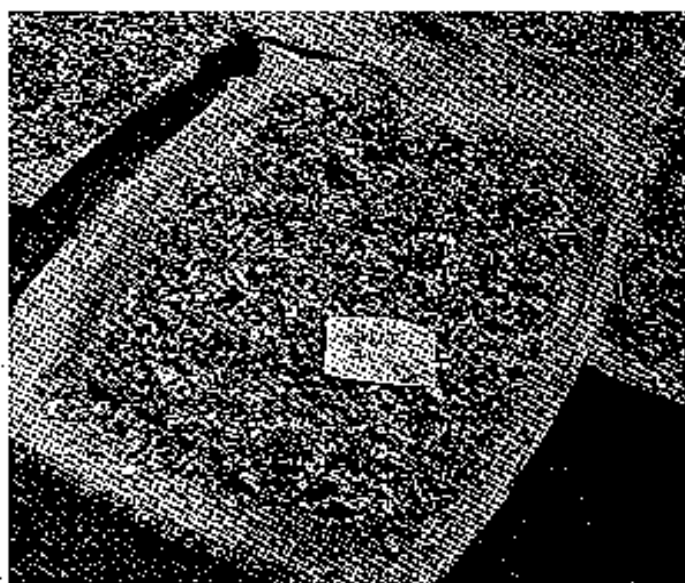


Plate 2. Chips of Tongkat Ali being dried in the sun.
Photo: Forestry Department

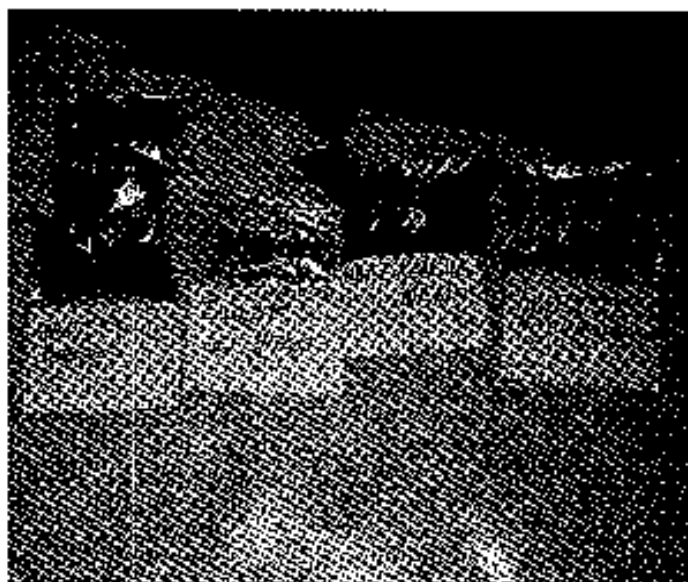


Plate 4. Various kinds of processed medicinal plants for sale.
Photo: Forestry Department

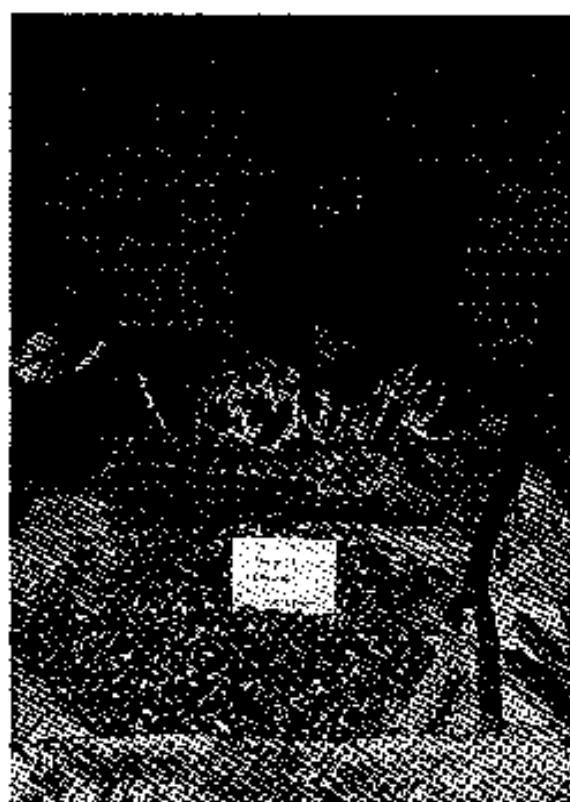


Plate 3. Small-scale processing of Tengkuak biawak (*Allomorphia malaccensis*).
Photo: Forestry Department

ANNEX 1

QUESTIONNAIRE 1: **CONSUMER SURVEY FOR MEDICINAL PLANT CONSUMPTION** **(DEMAND SURVEY)**

Section I : Background of Respondent

Serial Number

Name : _____

Address : _____

Occupation : _____

1.	Sex	Male	☐	1
		Female	☐	2

2.	Ethnic	Malay	☐	1
		Chinese	☐	2
		Indian	☐	3
		Orang Asli	☐	4

3.	Age(year)	11 - 20	☐	1
		21 - 30	☐	2
		31 - 40	☐	3
		41 - 50	☐	4
		> 51	☐	5

4.	Marital Status	Single		1
		Married		2
		Widowed		3
		Separated		4

If single, move to question 5, otherwise continue

- 4.1 How many people in the household
- 4.2 How many > 15 year ?
- 4.3 How many < 15 year ?
- 4.4 How many wage earners ?

5.	If not married, are you staying with	Family		1
		Relatives		2
		Others		3
		Alone		4

6.	Education level	Primary		1
		Secondary		2
		Tertiary		3

7.	Monthly gross salary (RM)	< RM500		1
		501 - 1000		2
		1001 - 2000		3
		2001 - 3000		4
		3001 - 4000		5
		4001 - 5000		6
		> 5001		7

13.	How did you come to use traditional medicine?		
	Family tradition		1
	Friends		2
	Media		3
	Doctor		4
	Pharmacy		5

14. What/Who encouraged you to use traditional medicine?

Price		1
Effectiveness		2
Family tradition		3
Convenient supply		4
Media		5
Religious belief		6
Doctor		7

15. For what purpose do you use traditional medicine?

General tonic		1
Specific ailment		2
Both		3

If not used as a tonic, go to Question 16.

15.1 If used as a tonic, for what specific purpose

Beauty		1
General health		2
Both		3
Others		4

15.2 If used as a tonic, how frequently is it used

Daily		1
Weekly		2
Monthly		3

15.3 As a tonic how long have you been using it

< 6 month		1
6 - 12 months		2
> 1 - 3 year		3
> 3 - 6 year		4

15.4. How much you spent for tonic per month

< RM 20		1
RM 21 - 40		2
RM 41 - 60		3
> RM 60		4

16. If used for treatment of an ailment, what types of ailments did you treat?

17. Did you take different traditional medicine for each ailment?

Yes		1
No		2

18. How long have you been using it?

< 6 month		1
6 - 12 month		2
>1 - 3 years		3
>3 - 6 years		4
> 6 years		5

19. How much do you spend on prescription per month

< RM 20		1
RM 21 - RM 40		2
RM 41 - RM 60		3
> RM 60		4

Section 3 : Safety and Efficacy of Traditional Medicinal Products

20. In what form do you feel most confident/safe in consuming traditional medicine?

Tablets /capsules		1
Loose dried product		2
Fresh herbs		3

21. Where do you usually purchase your traditional medicine from?

Registered pharmacy		1
Regular store		2
Middleman		3
Door to door sales		4
Healer/Bomoh		5
Make it yourself		6

22. Where would you feel most confident to purchase your traditional medicine?

Registered pharmacy		1
Regular store		2
Middleman		3
Door to door sales		4
Healer/Bomoh		5
Make it yourself		6

23. What's your opinion about the price of traditional medicine?

Cheap		1
Moderate		2
Expensive		3

24. What do you think of the quality of traditional medicine?

Not satisfactory		1
Satisfactory		2
Very satisfactory		3

25. If the above response is 'not satisfactory' then do you think the government should set

standards and controls?

Yes	☐	1
No	☐	2
Not sure	☐	3

26. Would you be willing to pay more than what you pay now for safer forms of prescription?

Yes	☐	1
No	☐	2
Not sure	☐	3

27. Do you think that the trade in traditional medicine should be regulated by the government?

Yes	☐	1
No	☐	2

28. Should traditional medicinal use be 'officially' encouraged by the government?

Yes	☐	1
No	☐	2

29. Which of these do you think the traditional medicinal trade suffers from?

lack of publicity	☐	1
Ignorance	☐	2
Misuse	☐	3
Misinformation	☐	4
Processing method	☐	5
Lack of supply	☐	6

30. Which form of medicine do you use more often?

Modern Medicine		1
Traditional medicine		2

31. How much do you spend on modern medicine per month?

< RM 10		1
RM 10 - 50		2
RM 51 - 100		3
RM 101 - 200		4
RM 200		5

QUESTIONNAIRE 2: MANUFACTURER SURVEY FOR MEDICINAL PLANTS (ECONOMIC ACTIVITY)

Section 1: Manufacturer's Background

Serial Number

Name: _____

Address : _____

1	2	3	4
No. of year in business	Age of the primary entrepreneur	Number of workers	Number of workers fully skilled in processing of medicinal plants

5. Does the manufacturer have recorded information on the formulations of the traditional medicine?

Yes ☐

No ☐

6. If 'yes', are they willing to have these published if they are paid by a specified agency?

Yes ☐

No ☐

7. What is the average estimate payment which should be received for each formulation?

RM _____

Section 2: Safety and Efficacy

8. Is the company a member of the Traditional medicine Society?

Yes

No

9. In your opinion should the government take stern action against the manufacturers who are not registered with the Traditional Medicine Society?

Yes

No

10. If yes, what action should be taken by the government?

Totally stop the manufacturing

Totally stop the implementation until it is registered

Making it compulsory to attend courses

Others (stated) _____

11. Are all the medicinal products produced registered with the National Pharmaceutical Control Bureau (NPCB)?

Yes

No

12. If not, what is the percentage of medicinal products that are not registered?

13. If the government procedures of 'good manufacturing practice' (GMP) are followed totally, will it increase the cost of production?

Yes

No

14. If yes, what is the percentage of estimate cost that will be increased?

15. Are the traditional medicinal products processed in a scientific manner?

Yes

No

16. Do you agree that the government should undertake control measures to ensure the quality of traditional medicine ?

Agree
Not agree

17. In marketing the traditional medicine, is there competition with the medicinal products from India, China, and other countries?

Yes
No

18. If 'yes', is the competition because of ...

Low quality
Low price
Medicine from other countries is more effective
Medicine from other countries is more accessible
Other (state) _____

19. Do you think that the number of manufacturers has increased?

Yes
No

20. If 'yes', is it because of...

Demand
Effectiveness
Government support
Easier processing technology
other (state) _____

21. In your opinion what are the main problems faced by traditional medicinal industry?
(arrange according to priority)

_____ Less publicity
_____ Not totally support by the government
_____ Difficult to get raw material
_____ Less technology
_____ Insufficient knowledge on processing
_____ Competition from other traditional medicine
_____ Less man power
_____ Young generation less interested
_____ Low prices/lack of price control

Table 2. Information on production of traditional medicinal products

Name of practitioner:			Size of practitioner (small, medium or large):				Type (Malay, Orang Asli)				
Treatment for ^a	Name of medicinal product	Raw materials used	Supplier of raw materials	Source of raw material in forest:	Trading unit	Total production	Trend of production of product	Knowledge on formulation from:	Quantity produced per month	Cost price per unit (RM)	No. of units traded/ vol. of trade
		Root (R), Bark (B), Stem (S), Leaf (L), Fruit (F), Flower (FL), Whole (W)	Middle man (MM), Import (I), Market (M), Orang Asli (OA)	Lowland (L), Peat forests (P), Mangrove (M), Hill (H), Montane (M) Is it available at source: Yes (Y) or No (N) If Yes, is it easier (E) or more difficult (D) than before (express in % terms)	Box (R), Bottle (B), Weight (W), Tablet (T)	Now (1977) 2 (1) year before 5 (3) years before	Increasing (I), Decreasing (D), Static (S)	Self (S), Ancestral (A), Group (G), Document (D)			

Product 1	R. B. S. L. F. FL. W	MM. I. M OA	L. P. M. H. M	B. BO. W. T	I. D. S	S. A. G D		
Product 2	(same as above)	(same as above)	Y. N E % D % (same as above)	(same as above)	(same as above)	(same as above)		
Product 3	(same as above)	(same as above)	(same as above)	(same as above)	(same as above)	(same as above)		
Product n	(same as above)	(same as above)	(same as above)	(same as above)	(same as above)	(same as above)		

Notes

¹ description of what the medicinal plant is prescribed for: specific or general ailments

² root (R), bark (B), stem (S) leaf (L), fruit (F), flower (FL), whole (W)

³ circle the relevant part

⁴ supplier: middleman (MM), imported (I), market (M), Orang Asli (OA) (If imported, where from)

⁵ cultivated (C), forest (F): habitat/ecosystem: lowland (L), peat forests (P), mangrove (M), hill (H), montane (M)

⁶ trading unit: box (B), bottle (BO), weight (W), tablet (T)

⁷ is sale increasing (I), decreasing (D) or same (S), any quantitative indicators

⁸ source: self (S), family lineage (F), community (C), form of transmission: mouth (M), documented (D).

RESULTS OF CONSUMER SURVEY FOR TRADITIONAL MEDICINE (DEMAND SURVEY)

Section 1 : Background of Respondents⁶

1 Gender	2 Race	3 Age (years)	4 Marital Status	Number in household	5 Living arrangements	6 Education level	7 Income (RM)
Female 87 (44%)	Malay 178 (89%)	11 - 20 1 (1%)	Single 74 (37%)	596	Family 20	Primary 8 (4%)	≤ 500 14 (7%)
Male 113 (56%)	Chinese 15 (8%)	21 - 30 106 (53%)	Married 123 (62%)	>15 years 338	Friends 45 (47%)	Secondary 93	501 - 1000 67 (34%)
	Indian 7 (3%)	31 - 40 61 (30%)	Widowed 3 (2%)	< 15 years 258	Alone 6	Tertiary 99 (50%)	1001 - 2000 76 (38%)
	Orang Asli ⁷	41 - 50 28 (14%)	Separated 0		Other 3		2001 - 3000 20 (10%)
		51 - 60 4 (2%)					3001 - 4000 4 (2%)
							4001 - 5000 9 (5%)
							>5001 10 (5%)

⁶For percentage calculation, rounding off error may occur

⁷The orang Asli survey is currently being undertaken

Section 2: Medicinal Plant Consumption

8. Number that use traditional medicine:

Users	Non-users	Total
142 71 %	58 29 %	200 100 %

9. Number of non-user respondents who purchased it for others:

Purchased	Did not purchase at all	Total
13 22 %	45 78 %	58 100%

10. Non-user respondents bought it for:

Family	Relatives	Others
13 100 %	0 0 %	0 100 %

11. Number in family of non-users who do use traditional medicines

All the rest	Some
3	10

12.

13. Knowledge on traditional medicine from:

		Yes	No	% Yes
13.1	Family tradition	103	97	52 %
13.2	Friends	121	79	61 %
13.3	Media	168	32	84 %
13.4	Doctor	194	6	97 %
13.5	Pharmacy	194	6	97%

14. Factors which encourage the use of traditional medicine:

	Factor	Yes	No	% Yes
14.1	Price	174	26	87 %
14.2	Effectiveness	76	124	38 %
14.3	Family tradition	152	48	76 %
14.4	Convenient supply	173	27	87 %
14.5	Media	188	12	94 %
14.6	Religious Belief	192	8	96 %
14.7	Doctor	196	4	98 %

15. Purpose for the use of traditional medicine:

Non-users	General tonic	Specific ailment	Both	Total
47 24 %	54 27 %	25 13 %	74 37 %	200 100 %

15.1 Specific use as a tonic for:

Not-used	Beauty	General health	Both	Other	Total
93 47 %	18 9 %	60 30 %	27 14 %	2 1 %	200 100 %

15.2 Frequency of use as a tonic:

Not-used	Daily	Weekly	Monthly	Total
93 47 %	64 32 %	25 12 %	18 9 %	200 100 %

15.3 Period of time for which tonic has been used

Not-used	< 6 months	6 - 12 months	1 - 3 years	3 - 6 years	Total
93 47 %	21 11 %	26 13 %	30 15 %	30 15 %	200 100 %

15.4. Expenditure on tonic per months:

Not used	< RM 20	RM 21 - 40	RM 41 - 60	> RM61
93 47 %	45 22 %	38 19 %	9 5 %	15 8 %

16.

17. Respondents who purchase traditional for specific ailments:

No response	Yes	No
46 23%	112 56%	42 21%

18. How long have they used traditional medicine:

Not-used	< 6 months	6 - 12 months	1 - 3 years	3 - 6 years	Total
85	27	21	31	10	26

19. Total expenditure on prescription (RM) per month:

Not used (RM 0)	< RM 20	RM(21-40)	RM(41-60)	>RM 61	
85 43 %	63 32 %	26 13 %	12 6 %	14 7 %	200 100%

Section 3 : Safety and Efficacy of Traditional Medicinal Products

20. Form of traditional medicine that respondent is most confident to use:

Not used/no response	Tablet/Capsule	Loose dried product	Fresh herbs
48 24%	75 38%	10 5%	67 34%

21. Outlets from which respondent most frequently purchased traditional medicine:

	Outlet	Yes	No	Ranking
21.1	Registered pharmacy	147	53	4
21.2	Regular store	143	57	5
21.3	Middleman	147	53	4
21.4	Door-to-door sales	184	16	2
21.5	Bomoh/healer	189	11	1
21.6	Make it yourself	180	20	3

22. Outlet which respondent would feel most confident to purchase:

	Outlet	Yes	No	Ranking
22.1	Registered pharmacy	80	120	6
22.2	Regular store	189	11	4
22.3	Middleman	194	6	2
22.4	Door-to-door sales	196	4	1
22.5	Bomoh/healer	191	9	3
22.6	Make it yourself	183	17	5

23. Opinion of respondent on the price of traditional medicine:

No response	Cheap	Moderate	Expensive	Total
45 23 %	33 17 %	107 54 %	15 8 %	200

24. Respondents view on the quality of traditional medicine:

No response	Not satisfactory	Satisfactory	Very satisfactory
45 23%	6 3 %	132 66 %	17 9 %

25. Should the government set standards and control on traditional medicines:

Yes	No	Not sure
194 97 %	6 3 %	0 0 %

26. Would respondents be willing to pay more for safer forms of prescription of traditional medicine:

No response	Yes	No	Not sure
45 23 %	113 57 %	12 6 %	30 15 %

27. Should trade in traditional medicine be regulated by the government:

No response	Yes	No	Not sure
45 23%	136 68%	13 7%	6 3%

28. Should use of traditional medicine be 'officially' encouraged by the government

No response	Yes	No
45 23%	149 75%	6 3%

29. Problem faced by the traditional medicinal trade:

	Problem	Yes	No
29.1	Lack of publicity	117	83
29.2	Ignorance	167	33
29.3	Misuse	184	16
29.4	Misinformation	110	90
29.5	Processing method	164	36
29.6	Lack of supply	169	31

30. Which form of medicine respondent uses more:

No response	Modern medicine	Traditional medicine
47 24%	99 50%	54 27%

31. Expenditure on modern medicine per month:

No response	< RM 10	RM (10 - 50)	RM (51 - 100)	RM (101 - 200)	>RM 201
45 23%	62 31%	77 39%	10 5%	5 3%	1 1%

ANNEX 3

LIST OF MEDICINAL PLANTS & PRODUCTS USED BY THE MANUFACTURERS
AND THEIR SCIENTIFIC NAMES

No.	Local Names	Scientific Names
1.	Akar beluru / Sentok	<i>Entada phaseoloides</i>
2.	Akar gajah beranak / Selayar Hitam	<i>Goniotalamus scortechinii</i>
3.	Akar lidah Jin / Meroyan putih	<i>Hedyotis capitellata</i>
4.	Akar tengkuk biawak hitam	<i>Ficus callicarpa</i>
5.	Asam gelugor	<i>Garcinia atroviridis</i>
6.	Asam jawa / Cclagi	<i>Tamarindus indica</i>
7.	Asam keping	<i>Garcinia atroviridis (fructus)</i>
8.	Ati-ati	<i>Coleus blumei</i>
9.	Batang wali / Patarwali / Akar scruntum / Akar Putarwali	<i>Tinospora tuberculata</i>
10.	Bawang merah	<i>Allium cepa (bulbous)</i>
11.	Bawang putih	<i>Allium sativum (bulbous)</i>
12.	Bayam duri	<i>Amaranthus spinosus</i>
13.	Bebaru / Buah keras laut	<i>Thespesia populnea</i>
14.	Belerang	<i>Sulphur</i>
15.	Belimbing buluh / Belimbing asam	<i>Averrhoa bilimbi</i>
16.	Belimbing manis / Belimbing besi	<i>Averrhoa carambola</i>
17.	Beras-beras	<i>Chasalia chartacea</i>
18.	Betik / Kates / Papaya	<i>Carica papaya</i>
19.	Bongelai hitam	<i>Zingiber ottensii</i>
20.	Bonglai	<i>Zingiber cassumunar (rhizome)</i>
21.	Bonglai kayu	<i>Oroxylum indicum</i>
22.	Bunga biru / Kelang	<i>Clitoria ternatea</i>
23.	Bunga cakar ayam / Kerak nasi	<i>Hedyotis diffusa</i>
24.	Bunga pakma / Pakma / Patma	<i>Rafflesia hasseltii</i>
25.	Bunga tahi ayam	<i>Lantana camara</i>
26.	Cabai	<i>Piper longum (fructus)</i>
27.	Cabai akar	<i>Piper longum (radix)</i>
28.	Cabai cina	<i>Piper chaba</i>
29.	Cabai jawa	<i>Piper retrofractum (fructus)</i>
30.	Cabai lubang	<i>Piper nigrum</i>
31.	Cabai pintal	<i>Helicteres isora</i>
32.	Cabai tali	<i>Helicteres cyminum</i>
33.	Capa / Telinga Kerbau	<i>Blumea balsamifera</i>
34.	Ceka emas	<i>Acalypha indica</i>
35.	Cekor / kencur	<i>Kaempferia galanga (rhizome)</i>
36.	Cekor manis	<i>Phyllanthus reticulatus / souropus albilans</i>
37.	Cekur / Kencur	<i>Kaempferia galanga</i>

38.	Cendana kayu	<i>Santalum album</i>
39.	Cengkeh - bunga	<i>Eugenia aromatica</i> (flower, bud), clove
40.	Cengkih / Bunga cengkih	<i>Eugenia aromatica</i>
41.	Cina baru	<i>Artemisia vulgaris</i>
42.	Cina puteh bunga	<i>Ervatamia coronaria</i>
43.	Cuci darah akar	<i>Desmos chinensis</i>
44.	Cucur atap	<i>Baeckea frutescens</i> (folium)
45.	Darah tinggi/cerita	<i>Andrographis paniculata</i>
46.	Daun kaduk / Sirih duduk	<i>Piper sarmentosum</i>
47.	Daun kari	<i>Murraya koenigii</i>
48.	Daun pecah belimbing / Bremek	<i>Strobilanthes crispus</i>
49.	Dcdalu	<i>Schefflera heterophylla</i>
50.	Delima / Dalima	<i>Punica granatum</i>
51.	Dukong anak / Turi hutan / Amin buah	<i>Phyllanthus niruri</i>
52.	Dulang / Kayu raja/ Trengguli	<i>Cassia fistula</i>
53.	Durian belanda	<i>Annona muricata</i>
54.	Ekur anjing / Ekur angin / Suripandak	<i>Plantago major</i>
55.	Gadong cina	<i>Smilax china</i>
56.	Gahru kayu	<i>Aquilaria malaccensis</i>
57.	Gajus / Ketereh	<i>Anacardium occidentale</i>
58.	Gambir	<i>Uncaria gambir</i>
59.	Gandasuli	<i>Hedychiium coronarium</i>
60.	Gandula / Lembayung / Remajong	<i>Basella alba</i>
61.	Gelang pasir / Segan jantan / Rumpu beremi	<i>Portulaca oleracea</i>
62.	Gelenggang Kecil / Gelenggang besar	<i>Cassia alata</i>
63.	Halba	<i>Trigonella foenum-graecum</i>
64.	Halban	<i>Vitex pubescens</i>
65.	Halia	<i>Zingiber officinale</i> (rhizome)
66.	Halia bara	<i>Zingiber officinale</i>
67.	Halia hantu/rimba	<i>Globba panicoides</i> (rhizome)
68.	Halia hutan	<i>Globba wallichii</i> (rhizome)
69.	Hati-hati / Bangun-bangun	<i>Coleus amboinicus</i>
70.	Hempedu bumi	<i>Andrographis paniculata</i>
71.	Hiya / Baru cina	<i>Artemisia vulgaris</i>
72.	Inai	<i>Lawsonia inermis</i> (folium)
73.	Ingu	<i>Ferula asafoetida</i>
74.	Jaddam	<i>Aloein</i> (bitteraloes)
75.	Jambu Batu / Jambu burung	<i>Psidium guajava</i>
76.	Jarak	<i>Ricinus communis</i>
77.	Jarak cina / jarak landi	<i>Jatropha gossypifolia</i>
78.	Jarong	<i>Achyranthes aspera</i>
79.	Jarum emas / Rumpu siku-siku	<i>Striga asiatica</i>
80.	Jemuju	<i>Trachyspermum ummi</i>
81.	Jerangau / Dringo	<i>Acorus calamus</i>
82.	Jering	<i>Pithecellobium kiringa</i>
83.	Jeruju	<i>Acanthus ebracteatus</i>
84.	Jintan	<i>Carum carui</i> (semen)
85.	Jintan hitam	<i>Nigella sativa</i> (semen)

86. Jintan manis	<i>Foeniculum vulgare</i> (semen)
87. Jintan puteh	<i>Cuminum cyminum</i> (semen)
88. Julung (Akar) / Akar bulus / menjulung	<i>Ancistrocladus tectorius</i>
89. Kacang kota / ketepeng / hutan	<i>Cassia occidentalis</i>
90. Kacip fatimah	<i>Labisia potheria</i>
91. Kait-kait	<i>Uncaria callophylla</i>
92. Kanching baju / Pokok betong / Senerung betina / Penawar upas	<i>Corchorus capsularis</i>
93. Kangkong	<i>Ipomoea aquatica</i>
94. Kani - biji	<i>Croton caudatus</i> (semen)
95. Kantan	<i>Phaeomeria speciosa</i>
96. Kantan - bunga	<i>Phaeomeria speciosa</i>
97. Kapur baru	<i>Dryobalanops aromatica</i> , tree Camphor from
98. Kasturi - kayu	<i>Juniperus chinensis</i>
99. Kayu manis cina	<i>Glycyrrhiza glabra</i>
100. Kayu manis- kulit	<i>Cinnamomum zeylanicum</i>
101. Kayu putih / gelam	<i>Melaleuca leucadendron</i>
102. Kecubung	<i>Datura fastuosa</i>
103. Kecubung (putih / hitam)	<i>Datura metel</i>
104. Kedaung - biji	<i>Parkia roxburghii</i>
105. Kedekai - biji	<i>Chebulic myrobalans</i> (semen)
106. Kelapa	<i>Cocos nucifera</i>
107. Kelempayan / Laran / Kadam / Kelampai	<i>Anthocephalus chinensis</i>
108. Kembang cina / Kembang tapak dara / Kembang tembaga / Bunga serdadu	<i>Catharantus roseus</i>
109. Kemenyan hantu	<i>Hedyotis capitellata</i>
110. Kemunting	<i>Rhodomerytus tomentosa</i>
111. Kemunting cina	<i>Vinca rosea</i>
112. Kentut - daun	<i>Paederia foetida</i> (folium)
113. Keras - buah	<i>Aleurites moluccana</i> (semen)
114. Keremak bukit	<i>Alternanthera sessilis</i>
115. Kermak / Keremak / Bayam Kremak / Daun tolot	<i>Alternanthera sessilis</i>
116. Kesemek / Buah samak / Buah kaki	<i>Diospyros kaki</i>
117. Kesum	<i>Polygonum minus</i>
118. Ketapang	<i>Terminalia catappa</i>
119. Ketumbar	<i>Coriandrum sativum</i> (semen)
120. Ketumpang Air	<i>Peperomia pellucida</i>
121. Kewangi	<i>Ocimum basilicum</i>
122. Kulai / Boli	<i>Cratoxylon indicum</i>
123. Kumis / misai kucing	<i>Orthosiphon grandiflorus</i>
124. Kunyit	<i>Curcuma domestica</i> (rhizome)
125. Kunyit - akar	<i>Coscinum petiolare</i>
126. Kutum / Ketum / Biak	<i>Mitragyna speciosa</i>
127. Lada hitam / Sulah / putih	<i>Piper nigrum</i> (semen)
128. Lada-lada / Lelada	<i>Ervatamia malaccensis</i>
129. Lalang / Alang-alang	<i>Imperata cylindrica</i>
130. Lawang - biji	<i>Cinnamomum cassia</i>

131. Leletup / Letup	<i>Physalis</i>
132. Lempoyang	<i>Zingiber aromaticum</i> (rhizome)
133. Lenggundi / Lagundi / Lemuning	<i>Vitex negundo</i>
134. Lengkuas	<i>Alpinia galanga</i>
135. Lengkuas ranting / Lengkuas kecil	<i>Alpinia conchigera</i>
136. Letup-letup / Ceplukan	<i>Physalis minima</i>
137. Lidah buaya	<i>Aloe vera</i>
138. Limau	<i>Citrus</i>
139. Limau besar	<i>Citrus maxima</i> (fructus)
140. Limau besar / Limau abong	<i>Citrus grandis</i>
141. Limau kasturi	<i>Citrus microcarpa</i> (fructus)
142. Limau nipis	<i>Citrus aurantifolia</i> (fructus)
143. Limau purut	<i>Citrus hystrix</i> (fructus)
144. Lubi-lubi	<i>Flacourtia inermis</i>
145. Malu-malu / Semalu	<i>Mimosa pudica</i>
146. Manggis	<i>Garcinia mangostana</i>
147. Manis - akar	<i>Albizia myriophylla</i> (herba)
148. Manis - kayu	<i>Cinnamomum zeylanicum</i>
149. Mata ayam	<i>Ardisia crenulata</i>
150. Mata pelanduk	<i>Ardisia crispa</i>
151. Mati laki / Bunga raya	<i>Hibiscus rosa-sinensis</i>
152. Medang gambong / Mengabong	<i>Vernonia arborea</i>
153. Medang pahit / Kayu pahit	<i>Quassia borneensis</i>
154. Melati / Melur	<i>Jasminum sambac</i>
155. Mempelas	<i>Tetracera indica</i>
156. Mengkudu / Bengkudu	<i>Morinda citrifolia</i>
157. Mengkudu akar / Mengkudu hutan	<i>Morinda umbellata</i>
158. Mengkudu hutan	<i>Morinda elliptica</i>
159. Mentulang	<i>Alangium longiflorum</i>
160. Merkunyit / Mengkunyit	<i>Coscinium blumeianum</i>
161. Merungai / Lembugai / Ramunggai / Kachang Kelor / Buah kelentang	<i>Moringa oleifera</i>
162. Mindi kecil / Margosa	<i>Melia azedarach</i>
163. Minyak panas	<i>Methyl salicylate</i>
164. Misai Kucing / Remujung	<i>Orthosiphon grandiflorus</i>
165. Pakan	<i>Vitis cinnamomea</i>
166. Pakma - bunga	<i>Brugmansia lowii</i> , flowers of
167. Paku gajah / Paku gantang / Jantan kaki	<i>Angiopteris evecta</i>
168. Pala	<i>Myristica fragrans</i>
169. Pala - buah	<i>Myristica fragrans</i> , nutmeg (semen)
170. Pandan	<i>Pandanus odoratus</i>
171. Pacet	<i>Paraneria levigata</i>
172. Pegaga - daun	<i>Hydrocotyle asiatica</i> (herba)
173. Pelaga - biji	<i>Amomum kepulaga</i> (semen)
174. Pelawas - daun	<i>Calycopteris floribunda</i> (folium)
175. Pengugur	<i>Justicia spacanthaceae</i>
176. Peria	<i>Momordica charantia</i>
177. Periuk Kera / Periuk kerengga	<i>Nepenthes mirabilis</i>
178. Petai	<i>Parkia speciosa</i>

179. Petai belalang	<i>Leucaena leucocephala</i>
180. Pidina - daun	<i>Mentha arvensis</i> (herba)
181. Pinang	<i>Areca catechu</i>
182. Pisang kaki	<i>Diospyros kirkii</i> -abanaceae
183. Pokok batu pelir kambin	<i>Rauwolfia serpentina</i>
184. Pokok celaka	<i>Plumbago zeylanica</i>
185. Pokok getang / Kerabu / Galang	<i>Spilanthes acmella</i>
186. Pokok Jepun / Jerman	<i>Eupatorium odoratum</i>
187. Pokok Kelulut putih	<i>Sida acuta</i>
188. Pokok pagar	<i>Carmona retusa</i>
189. Pokok pinang	<i>Areca catechu</i>
190. Pokok Serai	<i>Andropogon citratus</i>
191. Periuk kera	<i>Nephentes gracilis</i>
192. Pudina	<i>Mentha arvensis</i>
193. Pulai / Palai lilin	<i>Alstonia scholaris</i>
194. Pulau sari	<i>Alyxia stellata</i>
195. Pulut-pulut	<i>Urena lobata</i>
196. Putal kedul	<i>Barringtonia racemosa</i>
197. Putih - akar	
198. Putih - kayu	<i>Melaleuca leucadendron</i>
199. Rancang besi	<i>Freylinetia malaccensis</i>
200. Rembega / Kemengu	<i>Calotropis gigantea</i>
201. Rumpat aur / Rumpat tahi itik	<i>Commelina nudiflora</i>
202. Rumpat kelurut / Rumpat jaranmg	<i>Lophatherum gracile</i>
203. Rumpat tahi ayam	<i>Ageratum conyzoides</i>
204. Rumpat teki / kancing baju jintan	<i>Kyllinga brevifolia</i>
205. Saga manis / akar saga/saga telik	<i>Abrus precatorius</i>
206. Saladri / Celery	<i>Apium graveolens</i>
207. Sambrantu - buah duri	<i>Sindora sumatrana</i>
208. Selasih	<i>Ocimum sanctum</i>
209. Selasih hitam / Kemangi / Selasih putih	<i>Ocimum basilicum</i>
210. Selasih Hutan / Sepuluh	<i>Hyptis suaveolens</i>
211. Semalu	<i>Mimosa pudica</i>
212. Semangkuk / Puding	<i>Nothopanax scutellarium</i>
213. Sembong	<i>Bhumea balsamifera</i>
214. Sena maki - daun	<i>Cassia angustifolia</i> (folium)
215. Senduduk	<i>Melastoma imbricatum</i>
216. Senduduk / Kenduduk	<i>Melastoma malabathricum</i>
217. Sengkuang / Singkong	<i>Pachyrhizus erosus</i>
218. Senting / Kacang kota / Menting	<i>Cassia occidentalis</i>
219. Serai	<i>Cymbopogon citratus</i>
220. Serai wangi	<i>Cymbopogon nardus</i>
221. Seranting / Tehung aga	<i>Leonurus sibiricus</i>
222. Serapat - kayu	<i>Hippocratea indica</i>
223. Seri gading	<i>Nyctanthes arbor-tristis</i>
224. Seruntai laut / Pokok seruntai / Screnah laut / Saruni / Serunai / Serunai laut	<i>Wedelia biflora</i>
225. Sesudu	<i>Euphorbia nerifolia</i>
226. Setawar / Setenteng	<i>Costus speciosus</i>

227.	Sintok - kayu	<i>Cinnamomum sintok</i>
228.	Sirih / Sirih cina	<i>Piper belle</i>
229.	Sudu ayah	<i>Nerium oleander</i>
230.	Tahi angin	<i>Usnea barbata</i> (herba)
231.	Tambak bukit / Sembong hutan / Rumput sepagi	<i>Vernonia cinerea</i>
232.	Tampang / Tampang manis / Keledang berok	<i>Artocarpus lakoocha</i>
233.	Tapak sulaiman	<i>Phyllagathis rotundifolia</i>
234.	Tawas	Sulphate of aluminium & potassium (alum)
235.	Teh	<i>Camellia sinensis</i>
236.	Teja Badak / Kayu manis hutan	<i>Cinnamomum iners</i>
237.	Tempuyung	<i>Sonchus arvensis</i>
238.	Temu iring	<i>Curcuma aeruginosa</i> (rhizome)
239.	Temu lawas	<i>Curcuma xanthorrhiza</i> , (rhizome)
240.	Terung meranti / Terong perat / Kunti	<i>Solanum nigrum</i>
241.	Terung belanda / Terung belah	<i>Solanum torvum</i>
242.	Tongkat ali / Bidara pahit	<i>Eurycoma longifolia</i>
243.	Tongkat ali hitam	<i>Polyalthia bullata</i>
244.	Turi	<i>Sesbania grandiflora</i>
245.	Turi - daun	<i>Sesbania grandiflora</i> (folium)
246.	Tutup bumi / Tapak sulaiman	<i>Elephantopus scaber</i>
247.	Ubi gadong	<i>Dioscorea hispida</i>
248.	Ubi jaga	<i>Smilax myosotiflora</i>
249.	Urang aring / Rumput kumang putih	<i>Eclipta prostrata</i>
250.	Sekati lima	<i>Aganosma marginata</i>
251.	Sehelai setahun	<i>Gastrochilus</i>

REPORT ON MARKET STUDY OF MALAYSIAN RATTAN AND BAMBOO PRODUCTS

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Rattan and bamboo represent some of the non-forest produce which are of considerable economic value to the timber industry in Malaysia. Both the materials had not only supported the development and well-being of the rural economy, but in recent years, they have shown great potential for development into significant export earners. For example, in 1995, exports of rattan furniture alone totalled RM 91.5 million or USD 36.6 million based on an exchange rate of RM 2.5 to USD1 (1995). Although products such as basketry, matting and handicraft made of rattan and bamboo have yet to be exported in significant volumes, they have made some inroads into the international market. This report, which represents the first of a series of reports on markets for Malaysia's rattan and bamboo products, examines the marketability of these products and their potential in the various markets. Market competitiveness *vis-a-vis* other competing products was analysed and the report concluded with recommendations on some appropriate marketing strategies for Malaysia's companies seeking to penetrate the international market.

Key words: Rattan and bamboo products - markets - marketability - marketing strategies - export prospects

Introduction

The objectives of the project were:

- (i) to analyze the major markets for the various types of bamboo and rattan products that are being or could be produced competitively in Malaysia; and
- (ii) to devise appropriate strategies for Malaysian firms seeking to penetrate these export markets.

Progress and current status of the study

The market study is to cover three major export market regions for these products, namely, the European Community, Asia-Pacific and North America.

As at September 1996, market studies that have been completed were for markets in the EU and Asia-Pacific, for both rattan and bamboo products. The study to the United States will be conducted in November 1996 and the project is expected to be completed some time in January 1997.

This paper will, therefore, report on the two market studies that have been completed.

Report on Europe

The European Union (EU) is among the world's major markets for rattan furniture. However, the trade in rattan furniture accounts for only about 2-3 per cent of the total European furniture trade. Imports of rattan furniture into the EU are shown in Table 1. The main importing countries are Germany, the Netherlands, the UK and France. Germany and the Netherlands, the two biggest markets, both showed a rising import trend whilst import by other European countries has been on a decline.

Table 1. Import of rattan furniture by country (million ECU)

	1991	1992	1993	Malaysia's % market share 1993
Germany	52.5	53.3	57.3	2
The Netherlands	39.2	39.3	44.5	4
UK	30.3	35.6	33.6	16
France	37.0	29.6	30.9	2
Italy	15.3	15.7	14.9	-
Denmark	13.9	13.6	11.8	8
Belgium/Luxembourg	14.0	13.9	11.1	2
Spain	12.0	15.8	11.8	6
Other	5.6	10.1	3.5	-
Total	219.8	227.1	218.9	6

Source: EUROSTAT

Malaysia's export performance

Malaysia's export to the EU has not performed as well as in other markets such as the United States and Japan. Within the EU market itself, Malaysia's exports have been fluctuating. While exports to Germany and the Netherlands had been on the increase, performance elsewhere had been generally weak.

Malaysia's share within the market is small, averaging about 6 per cent. It is only in the UK that Malaysia has a significant proportion of the market. The share of supplying countries to the European markets (Table 2) clearly shows the domination of supplies from Indonesia. The Philippines, the second largest supplier, has lost its market share in recent years. China, on the other hand, is increasingly becoming an important supplier.

Malaysia's weak performance is due to several reasons. Malaysian exporters have long focused their exports on low quality, standard styles and designs targetted for the low-end of the European market and most often the designs were replicas.

Table 2. Major exporters of rattan furniture to the EU (million ECU)

	1991	1992	1993	% market share in 1993
Indonesia	76.8	86.5	109.2	50
The Philippines	41.1	33.9	33.9	15
China	18.6	22.3	23.8	11
Malaysia	16.6	14.8	12.5	6
Thailand	14.7	10.6	10.6	5
Taiwan	6.9	5.1	5.4	2
Others	45.3	59.9	23.5	11
Total	219.5	227.1	218.9	100

Source: EUROSTAT

Market characteristics and recent trends

Each market has different requirements in terms of design and quality specifications. In many of the important market segments, the trend is towards better quality and design, and wicker furniture, in which Malaysia is less competitive than other supplier countries such as Indonesia and China. In Germany and the Netherlands, design and strict quality control are essential elements to market expansion.

The Netherlands

The Netherlands has a small medium-end but large low-end market for rattan furniture which act as import centres for large supermarket groups selling low-cost furniture as well as in Benelux and Germany.

The market has been very much dominated by Indonesia due to the long-established trade relationship and political link. Most of the importers have established joint-production with Indonesian companies.

There is a tendency for this market to buy better quality furniture. The market perception is that quality Malaysian furniture is too expensive and designs lack originality. For this reason, it would be difficult for Malaysia to expand or break the Indonesian dominance.

Belgium

Belgium is a relatively large market for rattan furniture but is very demanding in terms of design and quality requirements. The bulk of sales is priced in the medium and low-range segments of the market. Makro and Metro are the two major large

volume discount retailers for rattan furniture. There is excessive competition especially in the low-end market as exporters compete for the same buyers. Malaysian products have been limited in terms of product design and quality to compete with Indonesia, Thailand and the Philippines.

There is a growing market for medium-range quality products but Malaysia has to improve on design and quality as well as widen the range of items to gain a bigger share of this market.

France

France is mainly a medium to high-end market for rattan furniture. The low-end market is small. Design and quality are the two most important elements sought after by consumers. There is a supply gap in the medium-end market. This market can only be captured by Malaysian exporters through upgrading on product design and quality.

Rattan furniture has lost its prestige as a quality product as the market is inundated with increased sales of low quality and low-priced items. Rattan furniture is not considered an important item, and to many retailers, rattan furniture sales represent less than 1 per cent of their turnover.

Malaysia's rattan furniture is still relatively unknown in the market except for those companies which have participated in the Paris Furniture Fair.

Denmark

Denmark, a relatively small market for rattan furniture has a small high-end but a growing medium-end market. Currently, the low-priced, low quality segment of the market is depressed, and has somewhat diminished due to excessive price cutting and non-delivery problems.

Rattan furniture is popular in this country since conservatories or garden rooms, became a trend in the late 70's and early 80's. The conservatory is regarded as the room to be enlarged when a house is upgraded or expanded.

The rattan furniture market is growing and good prospects are envisaged in the future as conservatories become a permanent feature of a house. In addition, a substantial amount of imports into Denmark are re-exported to other Scandinavian and German markets.

Germany

Germany is the biggest market for rattan furniture in Europe. The bulk of the market is for solid cane and wicker furniture of medium quality for the middle price range. This market has a small high quality market segment.

Quality has been and is always the most important element. Malaysian products are considered of low quality but rather highly priced. Importers usually deal

directly with manufacturers in exporting countries. They would insist on market exclusivity for product distribution and would work with only a few exporters.

German importers buy mainly unfinished items. The finishing work on fabric and cushions is done domestically. Many German manufacturers have turned to sub-contracting due to increasing raw material and labour costs.

Italy

Italy has a well-established domestic production in the medium to high quality designed rattan furniture such as those produced by Roberti, Casa del Bambu and Verashin. Italy has been a major exporter to the other EU countries.

It has a well developed linkage with Indonesia in the rattan furniture business through firms such as Sigca and Bardola in Genoa. The import market is dominated by Indonesia with China and the Philippines as secondary suppliers. Malaysia is relatively unknown in this market.

The domestic market for rattan furniture is divided into two categories:

- imported unfinished items with the finishing and fabric work done by domestic manufacturers/importers. Products are often medium priced and very competitive *vis-a-vis* domestic production.
- high quality items manufactured by the domestic producers with their own designs.

United Kingdom

Conservatories are still by far the most important market sector for rattan furniture and this is expected to remain so in the future. This sector takes up about 80-90 per cent share of the UK market for rattan furniture. The market is growing with conservatories becoming a permanent feature as a garden room in more houses.

The market is mainly a low to medium quality retail market and mass merchandising has concentrated on low quality and low-priced furniture. At present, this market has been adversely affected by major non-delivery problems and excessive price cutting.

There is a substantial medium quality and medium-priced retail market which is growing faster than the low-priced market segment.

Conclusion

In general the market demand in the EU for rattan furniture is expected to move towards medium-priced and medium quality products. Improvement on product design, range and finishing will be required.

There is a need to work closely with buyers in Belgium, Germany, France and the UK on design and quality. Malaysian furniture is often overshadowed by that from Indonesia and the Philippines in these markets. A more organised marketing effort is needed to understand the market and product requirements.

Exporters should focus marketing their products in Germany, Belgium and the UK where the markets are expected to continue growing, particularly in the medium quality product range. Exports to the Netherlands and Denmark should be maintained.

Exporters should shift to the medium or high-end of the market since it is no longer competitive to produce low quality items due to rising raw material and labour costs.

Report on Asia

Both South East Asia and East Asia were major suppliers of high quality rattan poles, cores and peel to world markets. Due to supply availability, exports of rattan furniture, matting and basketware from this region had, therefore, gained prominence.

The major furniture exporters in this region were Indonesia, the Philippines and the Peoples' Republic of China. Malaysia and Thailand were exporters of a medium scale whilst smaller export volumes were recorded from Vietnam, Hongkong and Taiwan (Table 3).

Table 3. Major exporters of rattan furniture (USD million)

	US\$ million†
Indonesia	300
Philippines	120
PR China	120
Malaysia	35 - 40
Thailand	20
Vietnam	5 - 10
Hong Kong	5 - 10
Taiwan	5 - 10

Note: † represents average for 1993 - 1994

Trade development

Changes in supply availability and industrial policies adopted by some producing countries had brought about an evident shift in the sources of supply as well as the product-mix offered by some of the rattan producers/exporters. Some of the developments and changes that have taken place could be summarised as follows:

- The rapid increase in the production of rattan furniture by Indonesia following the progressive ban on its exports of unprocessed and unconverted poles from 1986 - 1988, and the subsequent expansion in its exports of rattan furniture from under US\$ 20 million in 1988 to US\$ 300 million 1993 - 1994, have had significant effect on all importers of rattan cane and rattan furniture.
- The rattan market also witnessed the rapid expansion in the production of rattan products in south China amounting to US\$ 100-120 million in 1993 despite the lack of a secure raw material base.
- The stability of the Philippines, rattan exports at US\$ 110-120 million in the form of mixed material furniture *i.e.* rattan combined with other materials, was obvious evidence that the Philippines has, to a certain extent, overcome the difficulties in rattan supplies.
- In the shorter term, both Malaysia and Indonesia were hit by supply shortage in 1994-1995, combined with a sharp increase in the prices of raw rattan of about 60- 80 per cent. Exports of rattan products fell in these two years.
- The market also witnessed a shift in production from high to low wage/cost areas such as from Taiwan to Indonesia and now to Vietnam, Hong Kong to South China and Singapore to China.

Malaysia's rattan exports and prospects

With a declining supply of raw rattan, the options available to Malaysia in its effort to sustain its exports of rattan products could be limited.

The industry could try to source its raw material externally *e.g.* from Vietnam, explore the use of lesser known species, and/or upgrade its production range towards higher quality. However, the issue of maintaining a consistent supply of rattan canes, particularly those of 28-36 mm dimensions has to be addressed urgently. Sharp and sudden fluctuations in both supply and prices of raw rattan would have detrimental effects on the development of the industry as they would affect both production planning and propensity for any long-term capital investment. In this respect, analysis of supply potential in terms of harvestable resources and economic availability for harvest is strongly recommended. Stocking arrangements would also help to provide a basis for planned export production and shipment.

Production of rattan furniture from Malaysia will decline but it is felt that its contribution to added value can be enhanced, if Malaysia could shift to medium and medium-high quality furniture, and abandon the very low end of the mass market to South China and Vietnam.

Lower volumes and higher unit value added through improved quality and use of mixed materials could be the future pattern for Malaysia's furniture exports.

Report on bamboo: Case study - bamboo industry in China

Forest resources in China

China has an average roundlog production of 277 million m³. However, for the last five years, its timber deficit averaged 12.3 million m³ annually. Statistics have shown that land area for forestry is 261.31 million hectares, of which forested land is 119.48 million hectares, or 45.7 per cent of the total. Over the years, China has depleted her resources through recurrent wars, land reclamation and indiscriminate felling. Although the amount of growing stocks of the forests is approximately 9.52 billion m³, timber production from available matured forests is estimated to be at only 2.6 billion m³.

With the rapid economic growth and continual increase of population, the gap between the demand and supply of some principal forest products has widened. Even though China has sought to increase timber supply through its nationwide and consistent afforestation drive since 1949, domestic production still falls short of local requirements.

Bamboo resources

The deficit and the increased requirement for timber resources has allowed the development and utilisation of other materials, such as bamboo, to grow significantly.

The Third Nation-wide Forest Resources Inventory statistics showed that the area of bamboo forests in China is 3.5 million hectares, with a growing stock of 80 million tons. The annual yield of bamboo is 8 million tons, and that of bamboo shoots is 1.25 million tons. The bamboo forests are mainly distributed in Fujian, Jiangxi, Sichuan, Zhejiang, Hunan and Guangdong provinces.

The bamboo resources in China are noted for their variety. There are over 400 species, belonging to 40 genera compared with 60 genera and 1200 species that are distributed in the world. The most common and widely-used species is *Phyllostachys pubescens*, locally known as 'mou' or 'moso' bamboo.

The area of *Phyllostachys pubescens* forests in China is 2.53 million hectares, or 71.2 per cent of the total bamboo area. Whilst the total number of harvestable culms was estimated at about 7.9 billion tons, the availability of commercial culms is 100 million tons. The annual consumption of *Phyllostachys pubescens* is about 1.5-1.6 million tons, of which 40-50 per cent are used as construction materials, 20 per cent in making products and articles, 15-20 per cent for pulping and 10-15 per cent for other uses.

The output from China's bamboo forests accounts for one-third of the world's production. In 1994, total bamboo production from China amounted to about 7 million tons. Exports of bamboo and bamboo products totalled US\$ 220 million in 1994.

Table 4. Bamboo forest resources in China.

Area: '000 hectares
Culms: units

Region	Area	<i>P. pubescens</i>		Other bamboos	
		area	culms	area	culms
Sichuan	342.1	19.2	77,540	322.9	21,302,140
Henan	7.0	0.8	5,120	6.2	3,194,730
Guangdong	316.6	86.3	183,680	230.3	2,019,340
Fujian	609.2	573.0	797,490	36.2	1,050,980
Yunnan	143.9	14.4	128,580	129.5	812,020
Anhui	176.4	151.7	316,680	24.7	709,370
Zhejiang	486.2	442.7	671,280	43.5	493,800
Jiangxi	534.0	529.1	957,360	4.9	387,610
Hubei	123.8	61.2	94,170	62.6	274,500
Jiangsu	23.0	11.0	42,790	9.0	270,450
Shaanxi	38.4	-	-	38.4	152,070
Hainan	7.2	-	-	7.2	10,980
Guizhou	49.6	46.4	4,057,850	3.2	1,340
Shanxi	0.6	-	-	0.6	-
Shanghai	2.7	-	400	2.7	-
Shandong	0.4	-	-	0.4	-
Hunan	522.0	506.0	624,390	16.0	-
Guangxi	163.2	81.6	-	81.6	-
Total	3,516.8	2,526.4	7,937,330	1,019.9	30,681,330

Utilisation

Following China's policy of substituting wood with other non-wood fibre materials, the development of the bamboo industry has been significant. Besides the traditional usage of bamboo for the manufacture of paper, construction material, household articles and furniture, different bamboo-based products have also been developed. Such products are bamboo plywood, bamboo mat plywood, bamboo laminated wood, particle board and moulded products.

Compared with wood, bamboo has many advantages such as a faster growth rate, earlier maturity, higher recovery, and greater versatile in its usage. For example, except for *Phyllostachys pubescens* which could only be harvested in about five or six years, other bamboos take just about one or two years. Generally, bamboo also has a fine and close texture, is pliable and tough with good mechanical properties for purposes such as bending and stressing.

Bamboo mat plywood and bamboo plywood are major products that have gained wide application in China as floor panels and truck flooring. The bamboo mat plywood is a product produced during the last ten years. There are about forty mills producing plywood mats, situated mainly in Sichuan, Zhejiang, Jiangxi, Hunan, Anhui, Hubei and Henan provinces.

Production of the bamboo mat plywood involves the selection of bamboo, cutting off, scrapping, cutting open, skin peeling, cutting the inner skin of bamboo to form thin strips and weaving the bamboo mat. These processes are completed manually and take up nearly half of the production time. Many mills prefer to order mats from rural areas that grow bamboos so that the processes of getting the material ready and mat weaving could be done by the rural folks. Very few mills would undertake all the processes in the factory as these processes are time-consuming.

The bamboo mat plywood can be used to make decorative board, plastic overlay plywood and others. Its modulus of rupture (MOR) is higher than wood particle-board. The bamboo mat plywood is a good structural material. However, its usage is affected by its inconsistent quality since its production is largely manual.

Besides the bamboo mat plywood, there is also a demand for other bamboo-based panel products since wood panels have always been looked upon as uneconomical because most of it would have to be imported. New uses for bamboo boards are as cabin boards in the automobile industry and as concrete formwork in the construction industry. With the rapid development of the Chinese economy, in particular, the construction industry, uses of bamboo panels will increase if the industry could overcome the problem of quality consistency.

Prospects

One of the main characteristics of the bamboo industry in China is that it is closely linked to the cottage industry in the rural areas. Most of the farmers, for example in the Zhejiang area, plant bamboo as a second crop with rice as the main crop. Between the rice harvests, most of the villagers will either work in the bamboo factory or in their homes processing bamboo. Bamboo is used extensively in the rural areas. Besides bamboo shoots and some bamboo which is exported to Japan mainly as garden materials such as fences and gates, more than 80 per cent of the bamboo are used locally. There are plans by the Chinese government to develop the industry for export particularly value-added products such as flooring and boards. However, as a market for imports, China offers little prospects due to the volume of its production. It is estimated that China has the world's largest bamboo production and the cost of the material is significantly low.



Plate 1. Malaysian rattan furniture.
Photo: Pohmay Craft

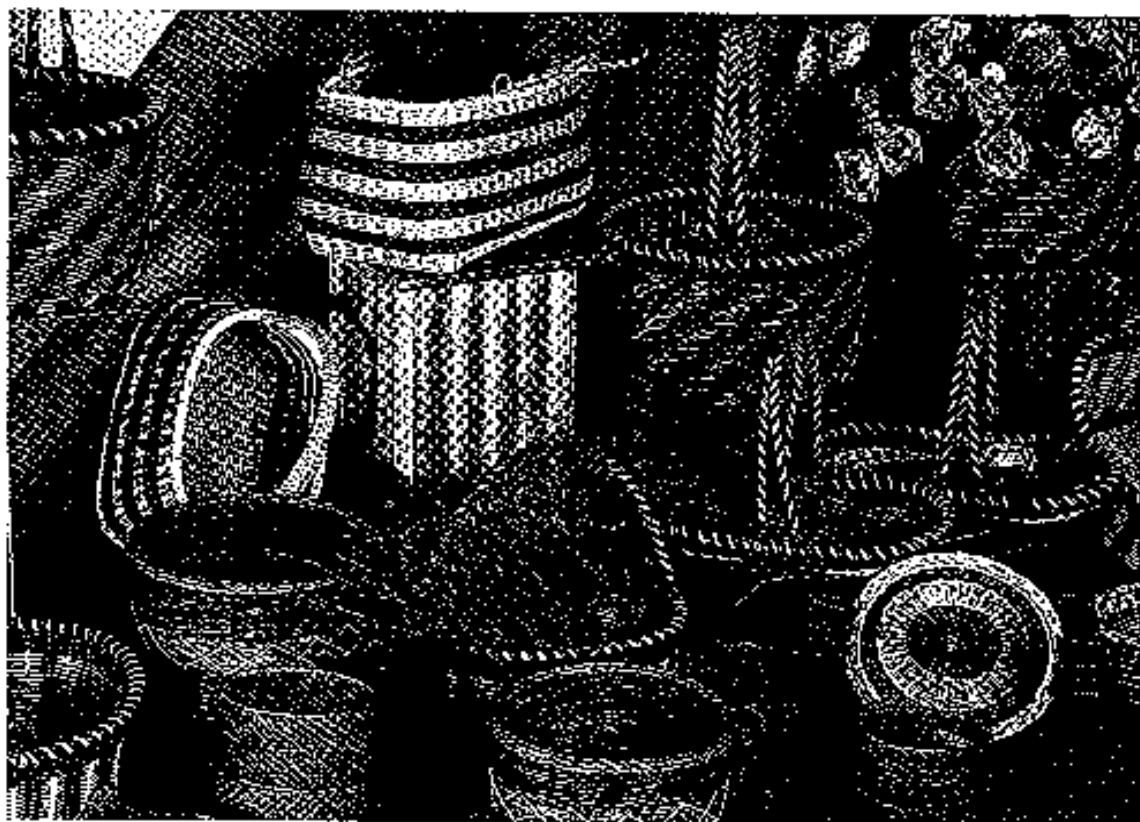


Plate 2. Various handcraft items made from rattan, bamboo and pandan.
Photo: Malaysian Handicraft Development Corporation

WATERSHED PROTECTION VERSUS TIMBER PRODUCTION IN THE HULU LANGAT FOREST RESERVE

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In this paper a preliminary attempt is made to assess the trade-off between watershed protection and logging in the Hulu Langat Forest Reserve. The trade-off is made explicit by means of a valuation of both the market benefits of timber production and the non-market benefits of maintaining the forest's natural hydrological cycle. The use of non-timber forest products from the reserve is also assessed, but is relatively minor in comparison with the other productive values generated in the catchment. Benefits, cost and hydrological impacts are simulated for two land-use options, total protection and reduced impact logging, across four catchments in the Reserve. The results suggest that there is little reason to forego logging in the catchment. The economic benefits generated by logging are considerable, in the order of \$6.7 million. Hydrological analysis of the first catchment demonstrates that logging is unlikely to alter sedimentation rates sufficiently to affect the provision of water by the Hulu Langat dam to downstream water treatment plants. Analysis of the effects of sedimentation on hydroelectric production in three other catchments, however, suggest that logging will reduce production benefits. When summed, however, the negative effect of logging on hydroelectric production (\$210,000) is minimal in comparison with returns to logging. Although the results are site specific the paper thus demonstrates the need for care in assuming that logging in hillslope forested catchments will always lead to the loss of important watershed values.

Keywords: Timber - watersheds - sedimentation - hydroelectricity - valuation

Introduction

Allocation of land in the tropics between competing uses is a contentious topic. This is particularly so in the case of tropical forest lands. Over the last few decades many developing countries, such as Malaysia, have derived income and employment from cutting the rich wood resources contained in these forests and converting forest land

to agriculture and other uses. Such countries are effectively liquidating their stock of forest capital in exchange for other forms of capital (*e.g.* financial and agricultural land) in their pursuit of economic development.

Recently, concern over rates of tropical deforestation have reached a crescendo, particularly in the developed world. Biologists and environmentalists have long emphasised the role of tropical forests in providing non-wood goods and services (*e.g.* subsistence products for local people, biodiversity, carbon storage and watershed protection). Recognition of this role and the increasing perception that these non-wood goods and services produce important global benefits has now extended beyond biologists and environmentalists to capture the imagination and attention of economists, the general public, politicians and the business community. In this paper, we consider the case of Malaysia, a country rich in tropical forest resources, and focus primarily on a single, local environmental function provided by these forests, the watershed or hydrological function.

In the Malaysian context, timber and water are often the most important goods and services provided by hillside forest catchments. These catchments provide virtually all of the fresh water used in Malaysia for agriculture, industry, household and recreational uses. In 1995, approximately 7,000 million litres per day of treated water were consumed in Malaysia. Water output capacity is expected to grow as demand increases rapidly. In 1995 output capacity grew by 8.9%. Malaysia has abundant hydroelectric power resources, with a potential generating capacity of some 29,000 MWs. Installed hydroelectric capacity in 1992 supplied almost 5 million kWh, or approximately 14.5% of Malaysia's annual power needs. Forest watersheds covering a total area of 270,000 ha play a crucial role in supporting major dams and reservoirs in three states (Kedah: Pudu and Muda Dams; Trengganu: Kenyir Dam; and Perak: Temenggor Dam). In 1995 electricity consumption increased by 14.6% and is expected to continue to grow rapidly in the coming years.

In Peninsular Malaysia, log consumption by the two main processing industries (sawntimber and plywood) was 9.2 million cubic metres in 1994. Given what appears to be an excess of production capacity, the peninsula is hard-pressed to meet local demand for logs. Log production levels have levelled off at roughly 10.2 million cubic metres in recent years, yet the government forest conservation policy calls for a reduction of the annual coupe from production forests (from 52,250 ha to 45,100 ha per year under the Seventh Malaysia plan) and an intensive agricultural management programme whereby the clearance of State land forest would decline. Thus, meeting existing local demand for raw logs from currently accessible forest will be increasingly difficult, resulting in increasing pressure to log hillside catchments.

In sum, demand in Malaysia can be expected to increase for both the timber and water supply services provided by hillside catchments. Given that these services are not fully consistent, one with the other, the need for an integrated approach to the management of these catchments becomes of paramount importance. As detailed elsewhere, current land-use allocation policy in Malaysia is inflexible and does not incorporate recent findings regarding the hydrological impacts of land-use change in the humid tropics (Aylward *et al.* in press). Nor does current policy take account of the economic impacts of these hydrological changes or the economic opportunity

cost implicit in foregoing timber values in designating catchments for protection. In order to improve policy-making, therefore, it would be useful to explicitly assess the economic trade-off that may exist between managing such catchments for timber production or for their role in water supply.

This paper presents a preliminary attempt to apply available economic and hydrologic methodologies to this problem. Following an overview of the study site, the land-use options that are evaluated in the study are presented.

Materials and methods

Study Site

The Hulu Langat Forest Reserve (HLFR) is located in the state of Selangor, Peninsular Malaysia within an hour's drive of Kuala Lumpur. The HLFR ranges in altitude from 120 m asl to 1,265 m asl and is covered with dipterocarp forest. Prior to the establishment of the Langat Dam, the HLFR had been managed for timber production. In the catchments under consideration all harvesting had stopped by 1987. The principal river emerging from the HLFR is the Langat River which is used to augment water supply to Kuala Lumpur and the Klang Valley region.

In order to ensure water supply during low flow periods, the Langat dam was built in 1976. Impounding 37.5 million m³ of water at full capacity, the dam regulates water flow to water treatment plants 13 km downstream. Dead storage capacity is 2.4 million m³ and live storage is 35.1 million m³. The treatment plants have an offtake capacity of 0.386 million m³ per day (141 million m³ per annum). Based on monthly rainfall patterns the annual dry period was estimated at 68 days. Assuming a daily water deficit of 0.13 million m³ at the intake for the treatment plants during these dry periods, the annual volume of water from the Langat Dam utilised by the treatment plant is calculated to be 8.84 million m³. The average sale price of water from the treatment plants is \$0.132/m³ and thus the gross annual production value of treated water associated with the Langat Dam is \$1.15 million.

In addition to the dam, the HLFR also is home to two "run of stream" mini hydroelectric power plants operated in succession with a capacity of 1.56 MW (33 kV). This is equivalent to a maximum annual production of 13.5 million kWh. The water intake for these plants comes from sediment ponds located at the outlet of three separate catchments. The ponds are simple concrete dams with reinforced concrete banks. The facility is privately owned and electricity produced is sold to the national electricity supply company for an average of \$0.066/kWh. Gross annual revenues (at full capacity) from the plants are approximately \$900,000.

¹All monetary figures cited in the text are in US dollars converted at 2.5 RM/\$ as the rate in effect at the time of preparation of this paper. Figures in the tables are presented in both \$ and RM.

Four catchments - those supplying the installed economic infrastructure described above - were chosen for the analysis (Figure 1 and Table 1). Catchment C1 (3,551 ha) provides water to the Langat Dam, whilst catchments C2 (473 ha), C3 (265 ha) and C4 (455 ha) supply the hydroelectric plants. Other downstream uses of water are negligible. A survey of the use of non-wood forest products from the HLFER revealed that collection is limited to a small number of families and that extraction is rarely undertaken in the catchments under consideration in this study (Mohd. Shahwahid *et al.* 1997). Tourism and recreation activities in the HLFER are confined to the Chongkak catchment which joins the Langat River downstream from the hydroelectric and water supply outlets.

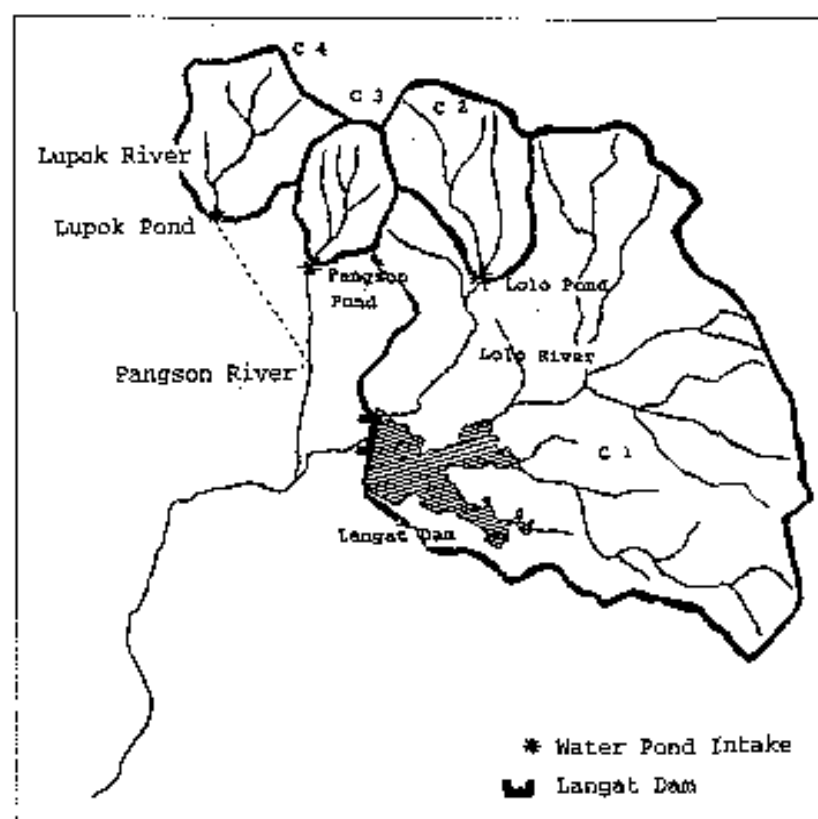


Figure 1. Hulu Langat Forest Reserve Study Site

Table 1. Land-use options

Land-use options	Total Protection	Reduced Impact Logging	
	Area (ha)	Loggable area (ha)	Buffer area (ha)
Catchment C1 (3,551 ha)	3,551	2,871	680
Catchment C2 (473 ha)	473	387.8	85.2
Catchment C3 (265 ha)	265	217.4	47.6
Catchment C4 (455 ha)	455	373	82
Subtotal C2-C4	1,193	978.2	214.8
Total C1-C4	4,744	3,849.2	894.8

Land-use options

Two land-use options for the catchments were evaluated in the study: (1) Total Protection (TP) and (2) Reduced Impact Logging (RIL). The first option models the existing situation in which the catchments act solely as a water supply source for the dam and hydroelectric power plants. The second option simulates the effect of introducing logging into the catchments under a reduced impact version of the Selective Management System (SMS), the prevailing method of logging natural hill forest reserves in the productive permanent forest estate in Malaysia. Based on the objective of obtaining cutting cycles of 30 years or more, SMS cutting limits are 50 cm dbh for dipterocarps and 45 cm dbh for non-dipterocarp species. Minimum residual stocking is required to be 32 or more marketable trees of good quality from diameter class 30 to 45 cm or its equivalent per hectare.

Guidelines for reducing the impact of logging methods include a variety of methods to ameliorate negative environmental impacts of harvesting. These methods include climber cutting, mapping of forests, improved layout of roads and skid trails, directional felling, minimal use of bulldozers, buffer strips and post-harvest removal of landings and stream obstructions. In the simulation undertaken by the study, buffer strips of 20 metres were imposed in the reduced impact logging option. The effect of additional conservation measures is captured by an across the board reduction in the sediment rate under selective logging (based on the authors' experience). Thus, the principal effects of the second option are a reduction in logged area due to buffer strips and the reduction of sediment yield due to conservation measures.

Methods

The principal objective of the study is to compare the total financial returns expected under each of the land-use scenarios. If the total returns under the RIL scenario are larger than those under the TP scenario, then the study will have shown that the timber benefits that could be produced in the study area outweigh the potential downstream consequences to water supply and hydroelectricity. In other words, those reaping the logging benefits would be in a position to more than compensate the water supply and hydroelectricity interests for any damage to their production caused by changes in hydrological conditions due to logging. Another way of conceptualising the evaluation process is as an evaluation of logging and its potential externalities. Logging when performed in the catchments will generate on-site timber benefits, but will also change downstream production. These latter 'externalities' are simply the net changes in downstream production caused by moving from a protection to a logging scenario. If these externalities are larger than the timber benefits then logging generates negative returns to the economy and should not be undertaken (and *vice versa*).

The valuation component of the study involves assessing the costs and benefits of logging activities and estimating the productivity impacts of sedimentation on water

supply and hydroelectric power generation. In the case of the end products (timber, water and hydroelectricity), a residual value, or stumpage value approach is used to derive per unit prices that can be applied to production quantities at the point of use (uptake of water or cutting of timber). This approach involves estimating gross prices for end use products and deducting production costs. For example, the price of water as sold by the treatment plant is adjusted for the unit production costs at the plant. The remaining per unit surplus is then used as the value of the product as produced by the watershed, or in the case of water supply by the Langat Dam. Net present values are calculated over a single, thirty-year cutting cycle using a 10 per cent discount rate.

Results and discussion

Hydrological Analysis

In the hydrological analysis, sedimentation rates are derived for the different land-use scenarios in each catchment. For the purposes of the simulation in the HILFR, the authors chose values based on empirical research previously undertaken by Lai (1993) in an adjacent catchment, Batangsi River.

The total sediment yield in the first year following selective logging option is estimated at 40.97 t/ha/yr. Logging activities produce 28.3 t/ha/yr of suspended sediment and 12.67 t/ha/yr of bed-load (heavier material travelling along the bottom of streams). Given a sediment density value of 1.5 t/m³ total sediment yield is 27.31 m³/ha/yr. Given that the data comes from a study of normal logging, instead of reduced impact logging, it is assumed that only 60 per cent of this amount is generated. The recovery rate of sediment yield from logged forest is assumed to decrease by 5.26 m³/ha per year until the sixth year when it returns to pre-logging levels based on research by Baharuddin (1988, 1995). A natural sedimentation rate in undisturbed forest area is assumed to contribute 0.67 m³/ha/yr of sediment. Sediment delivered from the road system itself is assumed to contribute 90 per cent of the sediment yield of which 46 per cent comes from the main road. In order to include the erosive effect of the main road system (7 per cent of total area), additional sediment is derived from this source and is assumed to continue during the whole timber cutting cycle since the main road has to be maintained for forest rehabilitation activities.

Based on these parameters the sedimentation effects for Catchment C1 were calculated for each of 30 cutting blocks over a thirty-year cycle. The amount of sediment trapped by the Langat Dam (the trap efficiency) was assumed to be 100 per cent. The resulting totals for sedimentation and loss of storage capacity in the Langat Dam are presented in Table 2. The loss of storage capacity is calculated as 0.6 per cent in the case of the TP option and 2.8 per cent under RIL.

In the case of Catchments C2, C3 and C4 just three annual coupes were simulated due to the small size of the catchment. The result is that these catchments generate large quantities of sediment in the first five to eight years and then return to the background rate for the remainder of the time horizon. In the case of the sediment

ponds, trap efficiencies of 70 per cent were assumed. Maximum annual sedimentation rates for the ponds during the logging and recovery period exceeded 10,000 m³, with background levels ranging from 265 m³ to 473 m³. Total sediment delivered to these catchments is shown in Table 2 for the thirty-year period.

Table 2. Cumulative sedimentation after one cutting cycle

	Sedimentation (m ³) over 30 years	
	Total Protection	Reduced Impact Logging
Catchment 1 - Sedimentation	106,530	497,244
Catchment 1 - Loss of Storage Capacity	0.6%	2.8%
Catchment 2 - Sedimentation	14,190	39,905
Catchment 3 - Sedimentation	7,950	22,370
Catchment 4 - Sedimentation	13,650	38,380

Valuation of water supply, hydroelectricity and timber

In the case of the Langat Dam which supplies water to the treatment plant, the estimation of productivity effects can be based on the potential impacts of the sediments on both project life and annual water supply. Based on Bali (1981) the authors assume that the dam would lose its technical efficiency at 50 per cent of total live storage. However, as described earlier, even under the logging scenario the expected loss of storage capacity in year 30 comes to just 2.8 per cent. For this reason the authors conclude that logging would not affect the productivity of catchment C1 in its use for water supply.

As there is no change in production between the different land-uses, the production benefit attributable to the low-flow water input from the Dam is the same under each scenario. Yearly production is multiplied by the selling price (\$0.132) and subsequently adjusted for production costs to calculate total production benefit. The real rate of growth in the price of water is assumed to be zero as the price of water used in the calculation is set by government and is valid over many years. Production costs are assumed to be \$0.08/m³ and to rise at 2 per cent per year. The present value of water provided by the Langat Dam to the water treatment plant in low-flow periods comes to \$3.08 million.

In the case of hydroelectric generation, the effect of sedimentation on productivity is caused by the silting up of the sediment ponds in Catchments 2, 3 and 4. This necessitates increased dredging of the ponds and maintenance of equipment. During dredging the plants must be idle. As a result, an increase in sedimentation affects productivity by increasing maintenance costs and reducing production of hydroelectricity. Using the annual sediment totals for the three catchments idling time and required maintenance are calculated. Table 3 shows that the effect of logging is to increase the cost of lost production by a factor of seven and to increase maintenance costs three-fold. The net effect is a four-fold increase as total costs attributable to sedimentation are \$73,000 under the TP scenario and \$283,000 under RIL.

Production benefits at full capacity are expected to be \$1.17 million. These are calculated given a selling price of \$0.066 and initial unit production costs of \$0.05. As with water supply production, costs are expected to rise 2 per cent annually, while selling prices remain constant in real terms. Including the effects of increased sedimentation in both the TP and RIL scenarios leads to total production benefits of \$1.10 million and \$0.88 million respectively (Table 3). The net negative externalities of logging in terms of their impact on hydroelectricity production are thus \$210,000 or approximately 20 per cent of net benefits accruing to the hydroelectricity producer under the total protection scenario.

Briefly, the returns from logging under the RIL scenario are \$6.7 million. Key parameters in the calculation of timber returns include annual increases of 3.5% in the real price of logs and of 2 per cent in real harvesting costs. The returns are equivalent to \$1,400/ha when averaged over the entire area of the four catchments, a reasonable figure for stumpage values in the Malaysian context.

Table 3. Valuation of foregone hydroelectric production and maintenance costs

	Total Protection	Reduced Impact Logging	Net Externality
(present values in millions)	\$ (RM)	\$ (RM)	\$ (RM)
Foregone Production	0.021 (0.053)	0.152 (0.381)	0.131 (0.328)
Maintenance Costs	0.052 (0.129)	0.130 (0.326)	0.079 (0.197)
Subtotal Costs	0.073 (0.182)	0.283 (0.707)	0.210 (0.525)
Hydropower Benefits	1.168 (2.919)	1.168 (2.919)	-
Net Hydropower Benefits	1.095 (2.737)	0.884 (2.211)	0.210 (0.525)

Evaluation of land-use options

Totalling up the net present values of the three different types of economic goods and services provided by the catchment areas under each of the land-use options (Table 4) leads to the conclusion that the returns under the logging option (\$10.6 million) are superior to those under the existing land-use of total protection (\$4.17 million). Breaking the difference down, it is clear that the benefits from timber production (\$6.68 million) more than compensate for the loss of \$210,000 of net benefits in hydroelectricity production (externalities). Thus, it is clear that when viewed simply as a trade-off between logging and watershed protection, the current level of protection accorded to the HLFR is unwarranted. Whether this result can be generalised to state that logging is a better land-use of these catchments depends on whether logging would affect other potentially significant values, such as global biodiversity value and carbon sequestration value, that forest protection may provide.

Table 4. Net benefits of the land-use options

	Total Protection	Reduced Impact Logging	Net Effect of Logging
(present values in millions)	\$ (RM)	\$ (RM)	\$ (RM)
Timber	0	6.68 (16.69)	+6.68 (+16.69)
Treated Water	3.08 (7.69)	3.08 (7.69)	-
Net Hydropower Benefits	1.10 (2.74)	0.89 (2.22)	-0.21 (- 0.53)
Total Benefits	4.17 (10.44)	10.64 (26.60)	+6.47 (+16.17)

Breaking the results down by catchment it is easy to see that in Catchment C1 logging does not impair the production of treated water. This demonstrates complementarity between the production of timber and water supply. That is, the two undertaken together produce a higher net present value than undertaking either by itself. In the case of the effects on Catchments 2, 3 and 4, although external costs are incurred by moving to a logging scenario the same complementarity is demonstrated when viewing the logging and hydroelectric operations as a whole. Clearly, the logging scenario may be regarded as an equitable outcome only if the logging operation covers the incremental costs and loss of production experienced by the hydroelectric producer. However, the point is that the logging operator should be able to accomplish this without greatly affecting logging profitability. An alternative would be for the logging operator to invest instead in enlarging the hydroelectric producer's holding ponds to the point where the maintenance and idling schedule would not change under logging. If such an investment is in fact less expensive than direct compensation (of the \$210,000) then the chosen valuation method will have overstated the value of the externality.

Conclusions

The findings reported in this paper regarding the potential negative effects of logging on hydroelectricity generation is important for Peninsular Malaysia as many small hydroelectric plants with similar sediment pond constructions are situated throughout the peninsula. However, the mitigation of such costs by construction of larger ponds should also be considered. At the same time the finding that logging may be compatible with water supply regulation in watersheds with large dams may be useful in evaluating the choice between logging and timber production in other similar watersheds throughout the country.

Nevertheless, it is important not to generalise too much from this study, given that the results are based on the unique conditions present in the HLEF and involve calculation of the value of only a single environmental service provided by undisturbed forests (control of sedimentation). For example, had the Langat Dam been built with a smaller capacity a different choice amongst the land-use options may have been the result. Finally, it is clear that there is scope for further research on logging versus watershed protection trade-offs in order to increase the usefulness of such

results for policy-making. Three areas that require further investigation include: (1) estimation of economic, or shadow, prices for treated water and hydroelectric power, (2) an increase in the number of sites and the type of downstream values evaluated in order to proceed towards the ability to make more general recommendations for policy purposes, and (3) the valuation of other forest attributes so that they may be incorporated alongside hydrological externalities in the cost-benefit framework.

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References

- AYLWARD, B., MOHD SHAHWAHID M.O., AWANG NOOR A.G., ABDUL RAHIM N. AND ZULKIFLI Y. Logging vs. watershed protection in tropical forests: An overview of the issues in Malaysia. Environmental Economics Programme Discussion Paper Series London: IIED. (In press).
- BAHARUDDIN, K. 1988. Effect of logging on sediment yield in a hill dipterocarp forest in Peninsular Malaysia. *Journal of Tropical Forest Science* 1(3): 1-15.
- BAHARUDDIN, K. 1995. Effect of logging operation on soil physical properties and soil erosion in a hill dipterocarp forest of Peninsular Malaysia. *Research Pamphlet No. 119*. Kuala Lumpur: Forest Research Institute Malaysia.
- BALI, N. 1981. *Manual of Conservation*. Kuala Lumpur: Department of Drainage and Irrigation.
- LOO, F.S. 1993. Sediment yield from logged, steep upland catchments in Peninsular Malaysia. IAHIS Publication 216.
- MOHD SHAHWAHID H.O., AWANG NOOR A.G., ABDUL RAHIM N., ZULKIFLI Y. & RAGAME U. 1997. Economic benefits of watershed protection and trade-off with timber production: A case study in Malaysia. EEPSEA Research Report Series Singapore: Economy and Environment Program for Southeast Asia.

VALUATION AND ANALYSIS OF CONSUMER DEMAND FOR FOREST RECREATION AREAS IN PENINSULAR MALAYSIA¹

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Forest Recreation Areas (FRAs) in Malaysia are one element of a forestry strategy directed towards the sustainable use of the remaining areas of tropical forest. FRAs provide informal recreational opportunities, free of charge to the public. In this study the recreational value of FRAs was estimated using a contingent valuation method and an individual travel cost model. The validity of the techniques and results were assessed by comparing the results of the two methods for three FRAs. The aggregate benefits of FRAs exceed the costs of their provision, and more could be justified on benefit/cost grounds. Despite this, FRAs are unlikely to result in the conservation of large areas of tropical forest in Malaysia.

Keywords: Recreation - forests - travel - cost models - consumer surplus - contingent valuation

Introduction

The perceived need to preserve significant areas of what remains of the world's tropical forests, or to manage them on a sustainable basis, is an issue of intense international concern. Causes of deforestation vary between countries, from fuelwood gathering and overgrazing, to shifting cultivation, the expansion of agriculture, and commercial logging (Winpenny 1991). Whilst the value of forest output of timber is readily quantifiable in economic terms, the value of preserving forests is comprised largely of intangible 'public good' benefits.² Recently, attempts have been made to quantify the benefits of managing tropical forests on a sustainable basis; however, some of these benefits are not quantifiable using conventional market-based methods.

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²Public goods are distinguished by two essential characteristics: an increase in consumption by one individual does not reduce availability to others (non-rivalry), and the owner/provider of a public good cannot prevent others from consuming it (non-excludability) (Baumol & Oates 1988, pp. 18-19).

These non-marketed benefits of preserving tropical forests can be summarised under a number of headings:

- (1) climate (forest soils and trees hold between 20 and 100 times more carbon than the crops and soils which replace them, thus deforestation has consequences for global warming, and local microclimates);
- (2) water (tropical forests play an important role in ensuring water quality and flows);
- (3) geomorphology (tree cover preserves slope stability, soil nutrients, and helps to prevent sedimentation);
- (4) biodiversity (preserving tropical forests maintains wildlife habitat);
- (5) other public goods (tropical forests yield a variety of other public goods such as open access recreation, and a variety of semi-pure public goods available to local people, such as food sources, medicinal plants, resins, oils, rattan, tannin, flowers, honey, and other non-timber forest products).

The value of such non-marketed benefits of forestry in Malaysia have been recently summarised by Abdul Razak (1995).

The purpose of the present study was to assess the 'public good' value of forests in Malaysia in terms of their recreational benefits. The study also aimed to test and evaluate alternative methods for measuring consumer demand for Forest Recreation Areas (FRAs).

Benefits of forests in Malaysia

The permanent forest estate in Malaysia is managed by State and Federal authorities and consists of:

- (1) protected forest areas (to ensure favourable climatic and physical conditions in the country, the safeguarding of water resources, soil fertility, environmental quality, preservation of biological diversity, and the minimisation of damage by floods and river erosion including damage to agricultural land);
- (2) productive forest areas (to supply in perpetuity different forest products);
- (3) amenity forest areas (to provide recreational opportunities);
- (4) research and educational forest areas (to satisfy demands for research, education, and conservation of biodiversity).

The demand for amenity forest areas for recreation began to emerge in the 1960s. Between 1971 and 1975 forest recreation areas were developed on a small scale, but incorporating only basic facilities. The Third Malaysia Plan (1976-1980) increased the number of FRAs to 23, and by 1985 the number had grown to 39. During the Fifth Malaysia Plan (1986-1990) the number of FRAs increased to 53, and by 1994 the total had grown to 74, spread throughout all the states of Peninsular Malaysia. These FRAs cover some 6,361 hectares, and between 1981 and 1993 incurred some RM 26,570,000 in expenditure (Chin & Chee, 1994) (RM 1 = US \$0.45, in 1995).

Recent years of rapid economic growth, urbanisation, industrialisation and improvements in communications have resulted in increased mobility of people and a growing demand for outdoor recreation. This is reflected in the increasing number of visitors to FRAs, especially during weekends and school holidays. It is anticipated that, in order to satisfy future demand, more outdoor recreation areas will have to be developed in the future.

Malaysian forests contain a wide variety of landscapes, faunas, floras, rivers and unique geological features all of which enhance outdoor recreation. Recreational activities within forests range from active pursuits such as hiking, camping and swimming, to more passive occupations such as investigating the varied ecology of the forests, visiting historic and scenic attractions, or simply enjoying the peace and tranquillity offered by the forests. To encourage these, and other activities, seats, picnic areas, play areas, information centres, and changing rooms, are provided at many sites.

Economic benefits of FRAs

The main output of FRAs, open access recreation, is unpriced. If an FRA is provided then the price of access to forest recreation, for those sections of the population living near the FRA, will be reduced. The welfare benefits of providing an additional FRA are equivalent to the consumer surplus that accrues to visitors over and above the price of access to the site.

Actual payments are not required for entry to FRAs, hence it is not possible to construct a conventional demand curve for forest recreation based on price and visit data. Moreover, one individual's visit to an FRA does not reduce its availability to others and, in the absence of congestion,³ does not reduce the utility that others derive from visiting an FRA. Hence, in theory conventional market pricing is inefficient as a means of valuing the forest resource. Nevertheless, given ownership and exclusion rights by State Forestry Departments, visitors could be excluded and a price for admission charged. FRAs are not close substitutes for each other⁴ and are locally fixed in supply; therefore rather than measure marginal additions to the supply of FRAs, this study estimated the recreational value of a subset of existing FRAs.

The economic framework adopted for this study derives from an indirect utility function, in which the individual's utility is represented as a function of, among other things, prices, income, and environmental goods including FRAs. Within this framework the utility derived from an FRA can be estimated as being equivalent to the maximum amount of money that can be taken from an individual such that his utility would be the same as it would have been without the FRA. This is an equivalent surplus measure; and represents the maximum that an individual would be willing to pay for the provision of the FRA.

³Congestion does not generally occur in FRAs: it has only been reported occasionally at one or two sites for one or two days at peak holiday period.

⁴FRAs are spatially dispersed across the whole of Peninsular Malaysia, and mainly used by local people who would not necessarily travel to another FRA.

The equivalent variation on open-access non-priced recreation can be estimated through some form of contingent valuation method (CVM). The study also estimated the Marshallian consumer surplus on FRAs by employing an individual travel-cost model (ITCM), and this was used as a check on the construct validity⁵ of the CVM estimates.

Contingent valuation

Contingent valuation estimates the value of goods by setting up a hypothetical market, and asking respondents the maximum amount of money they would be willing to pay to acquire the goods.⁶

The questionnaire used in this study was designed to conform to various National Oceanic and Atmospheric Administration (NOAA 1993) guidelines for the appropriate conduct of CVM studies. Thus, after carefully pre-testing the questionnaire, a willingness-to-pay (WTP) elicitation format was adopted for the contingent valuation question. Prior to this question being asked, respondents were reminded of substitute sites, other recreational activities, and alternative expenditure possibilities, and were provided with an accurate description of the goods that they were being asked to value. Finally, probability sampling was used to obtain personal interviews, and an effort was made to minimise non-response.

The valuation question was based on an open-ended CVM format, in which respondents were asked the maximum sum that they would have been willing to pay to gain access to the FRA for their current visit. This simple approach was adopted in preference to the dichotomous choice question format recommended in the NOAA guidelines, because the use values of FRAs were being estimated rather than their non-use values. More importantly, there are private sites similar to state FRAs where an entrance charge is made and most visitors to FRAs can be assumed to be aware of these charges and the additional facilities offered by these private sites. Thus, the majority of visitors can be expected to make regular comparisons between the sites that they are able to visit, and their decision as to which site to visit should be based on a trade-off between their utility for the income lost to gain access and utility for the facilities available. This should mean that most visitors would be able to estimate the maximum amount that they would pay for access before deciding to visit another recreational site.

Dichotomous choice questions can offer certain methodological advantages over open-ended CVM formats (Willis 1995); however, WTP estimates based on dichotomous choice data are typically several times greater than those derived using data from open-ended CVM questions (Schulze *et al.* 1996). It is possible that dichotomous choice formats encourage respondents to over-estimate their WTP for goods through

⁵The American Psychological Association (1974) distinguishes three types of validity: content, criterion, and construct validity. Construct validity involves the degree to which the CV WTP value relates to other measures predicted by theory. Within construct validity, convergent validity refers to the correspondence between the CV measure and other measures of the same theoretical construct, e.g. a TCM measure (see Mitchell & Carson, 1989).

⁶Or the minimum sum they would accept as compensation for its loss.

a phenomenon known as 'yea' saying, and these formats may produce less accurate results than carefully constructed open-ended questions, particularly when respondents are familiar with the goods and clear about the increase or decrease in amenity that they are being asked to value (Fisher 1996).

Currently, a number of questions are being posed regarding the ability of CVM to produce reliable and robust estimates of values for environmental and private goods. These arise from concerns about strategic behaviour, hypothetical bias, information effects, the sequencing of questions and the resultant problems of embedding and scope effects (Hanemann 1996).

There are no definitive tests for strategic behaviour, but the modest WTP amounts, lower than WTP for similar private recreational goods, along with the absence of bi-modal WTP amounts, suggests that such behaviour was either absent in the sample or led to an underestimate of the value of FRAs. Hypothetical CVM questions can produce unrealistic answers, but FRAs are well-defined goods with which respondents are familiar, and for which it would be feasible to levy an entry charge. There was no evidence from debriefing sessions with interviewers that respondents viewed the CVM questions as purely hypothetical. WTP is a function of the amount of information given to respondents (Samples *et al.* 1986), which is a particular problem in the valuation of non-marketed environmental goods which are unfamiliar, of low personal relevance, and dependent on respondent preferences which are only constructed within the context of the CVM interview (Ajzen *et al.* 1996). FRAs are familiar to respondents,⁷ have higher relevance since they are visited, and have as substitutes other recreational activities which attract a charge. Embedding occurs when respondents indicate that they are willing to pay the same or more for a subset of goods when compared to their WTP for the larger set of goods of which the subset forms a part. Tests for embedding were beyond the scope of this study, but the magnitude of the WTP estimates for admission to FRAs does not suggest embedding was a major problem, especially in relation to the frequency of visits to each FRA (average 4.0 per year) and to all other outdoor recreational facilities (average 10.2 per year).

Experimental design and visitor survey

In designing the CVM study, FRAs across states in Peninsular Malaysia were classified into different types (Wan Sabri 1994) and a stratified random sample of FRAs was selected from this classification to act as survey sites. An appropriate sample size was determined for each site and a visitor questionnaire was developed to estimate the benefits of access to FRAs through both CVM and travel-cost questions. Enumeration of visitors was carried out at each FRA to estimate annual visitation rates, thereby providing a basis for aggregating benefits.

⁷60.8% had previously visited the FRA they were being asked to value; and 54.9% had visited another FRA during the preceding 6 months.

FRAs were classified into five quality levels by an ordered ranking of natural resources, natural recreational resources, recreational activities, and other facilities, to produce a sampling frame. Twenty FRAs were selected to represent the various quality ratings of FRAs, proportions within states, and location of FRAs in suburban, rural, and remote rural areas. This was a large proportion of the total 74 FRAs, and represented the maximum number permissible given the resources available for the project. In choosing the specific sites, consideration was also given to intuitive and anecdotal information on the number of visitors attracted to each site: sites were selected on the basis that they were likely to attract enough visitors to ensure that the survey was cost-effective in terms of Forestry Department manpower, who were employed as interviewers.

The questionnaire survey elicited information on respondents' visits to FRAs; their preferences and activities; and their socio-economic and demographic characteristics. The questionnaire was structured to provide respondents an opportunity to reflect on their use of FRAs, and the availability and use of substitute recreational areas and activities. A random sample of visitors to FRAs was selected by interviewing on a next-to-pass basis. CVM requires a sufficient number of observations to ensure statistical validity.

A pilot survey was carried out over a full day in two FRAs in the State of Selangor: Kanching and Sungai Tekala. This was followed by a debriefing of the Forestry Department interviewers. A second pilot survey was carried out at the same FRAs, to test the minor modifications made to the original questionnaire. A workshop was held over three days to brief the State Forestry co-ordinators, interviewers and enumerators on their roles, function, responsibilities and the application of the questionnaire. The survey was undertaken between March and June 1995 and covered week days, weekends and public holidays.

To ensure quality control over the survey, State co-ordinators made regular checks on the work carried out by the surveyors and enumerators; and submitted completed questionnaires and survey material to the Federal co-ordinator each month. The Federal co-ordinator visited all of the designated FRAs in the study, and held discussions with surveyors and enumerators to clarify any areas of concern.³

Contingent valuation results

Mean WTP values are the most appropriate measures of benefit, since in economic theory they are a cardinal measure of the utility that individuals; or an average individual, would derive from the FRA. However, the median bid is unaffected by large bids in the upper tail of the distribution (unlike the mean); and the median bid may also be considered as the amount of money which a democratic (one individual one vote) decision-making system would allocate to FRA policy. Trimmed estimates can be employed to mitigate the effect of outliers: one or two such outliers can increase average WTP dramatically, and can increase the magnitude of sampling error if they

³This worked well with the exception of one FRA: Gunung Arong in Johor, where unsatisfactory survey material in the CVM part of the questionnaire was returned.

are not representative of the population distribution of WTP. Some respondents may state a zero WTP while in fact having a positive WTP for forest recreation (e.g. as a protest or for strategic motives). To avoid making decisions on the honesty of individual observations, the upper and lower 5 per cent of the sample distribution of WTP bids were trimmed and the mean recalculated. Estimators modified by omitting biased and illegitimate responses may provide the most accurate estimate of population WTP. In this study biased and illegitimate responses were identified by a series of questions designed to discover why respondents answered the CVM questions as they did. Illegitimate responses are defined as those where stated WTP can be shown not to reflect true WTP, for example, where there is evidence of strategic or protest behaviour in the CVM response.

Table 1 documents the results of the CVM question for each FRA. Sample mode and median WTP per visit is RM 1 for most sites, indicating that the distribution of bids has a more normal distribution than usually found in CVM studies. Sample means vary but within expected limits. Modified mean WTP values are greater than simple reported values because of downward biases in responses. For example, removing illegitimate bids increases sample mean WTP from RM 1.22 to RM 1.46 per visit.

These results were subject to construct validity tests, in terms of their consistency with theoretical expectations (theoretical validity), and the degree to which they conformed to estimates of utility derived from TCMs (convergent validity). Theoretical validity was assessed by estimating a bid curve for the WTP amounts. The dependent variable, WTP for FRA, is explained in terms of independent variables which give rise to this monetary value:

$$WTP_i = f(Y_i, Pr_i, S_i)$$

where:

- Y_i = income
- Pr_i = preferences, and
- S_i = substitute goods

These are variables which economic theory suggests should determine WTP for recreation at a given FRA. The results of the theoretical validation exercise for the WTP estimates for one site, Telok Bahang (site 15), are outlined in Table 2. Variables were included on the basis of *a priori* logic in economic theory, but the model only reports those variables that were significant at the 0.15 statistical significance level or lower.

Table 1. Consumer surplus values per visit for FRAs

		Mode	Median	Mean WTP Simple	Mean WTP Trimmed	Mean WTP Modified
01	G. Arong, Johor	data error on survey	data error on survey	data error on survey	data error on survey	data error on survey
02	G. Pulau, Johor	1.00	1.50	1.97	1.63	2.15
03	Gua Cerita, Kedah	0.00	0.00	0.61	0.52	1.32
04	Sg. Teroi, Kedah	0.00	0.00	1.57	0.88	2.71
05	Jeram Linang, Kelantan	1.00	1.00	1.05	0.99	1.05
06	Ayer Keroh, Melaka	1.00	1.00	0.88	0.84	1.18
07	Gallah, N. Sembilan	2.00	2.00	1.97	1.86	2.29
08	Ulu Bendol, N. Sembilan	1.00	1.00	1.18	0.90	1.33
09	Kenong, Pahang	4.00	5.00	4.38	4.38	4.85
10	Lentang, Pahang	1.00	1.00	0.75	0.69	0.98
11	Sg. Pandan, Pahang	1.00	1.00	1.02	1.02	1.24
12	Kuala Woh, Perak	1.00	1.00	1.01	0.99	1.22
13	Bukit Larut, Perak	1.00	1.00	1.51	1.32	1.62
14	Bukit Kubu, Perak	0.00	1.00	0.72	0.63	1.27
15	Telok Bahang, Penang	1.00	1.00	1.16	1.07	1.41
16	Sg. Chongkak, Selangor	1.00	1.00	1.19	1.17	1.38
17	Kanching, Selangor	1.00	1.00	1.17	1.00	1.42
18	Sg. Tua, Selangor	1.00	1.00	1.52	1.35	1.79
19	Sekayu, Terengganu	1.00	1.00	0.98	0.96	0.98
20	Lata Tembakah, Terengganu	1.00	1.00	0.88	0.71	1.05
	Average for all areas	1.00	1.00	1.22	1.03	1.46

N = 5606 for mean WTP per adult

N = 5046 for trimmed mean WTP per adult

N = 4677 for adjusted mean WTP per adult

Table 2. Theoretical validation of maximum WTP per adult day visit to Telok Bahang, Penang (Site 15)

variable	coefficient	std error	Prob > T
intercept	2.49683	0.19693	0.0001
A1	0.27885	0.10930	0.0114
A2	-0.16547	0.08969	0.0664
A7	0.01667	0.01039	0.1170
B8c	-0.28730	0.11905	0.0166
B8d	-0.21261	0.10246	0.0392
Malay	-1.22472	0.16468	0.0001
Indian	-1.30133	0.19113	0.0001
Chinese	-1.39938	0.17756	0.0001
Uni	0.39821	0.13541	0.0036
B9c	-0.18347	0.08281	0.0278
U20	0.41632	0.25293	0.1012
O60	1.15619	0.69017	0.0953
HINC	0.15536	0.03793	0.0001
HSIZE	-0.05293	0.01573	0.0009

Analysis of variance

Source	DF	sum of squares	mean sq	F Value	Prob > F
model	14	104.11770	7.43698	24.376	0.0001
error	220	67.12077	0.30509		
total	234	171.23847			

R-square 0.6080

Adj R-sq 0.5831

- A1 = first visit
 A2 = respondent on day visit
 A7 = number of day trips made to open access recreational sites per year
 B8c = purpose of visit: stopover on way to another destination
 B8d = purpose of visit: enjoy scenic beauty
 B9c = respondent has picnicked at site
 U20 = respondent aged 20 years or less
 O60 = respondent over 60 years old
 HINC = approximate household income ('000 RM) per month
 HSIZE = household size

The regression coefficients generally exhibited the appropriate sign, and the model appears to be intuitively plausible in explaining the WTP results. For example, the fact that a respondent was on a first visit to the FRA increased WTP (suggesting that WTP decreases as the number of visits to the site increases). Respondents on a day visit to the FRA valued the visit less than those on holiday; whilst those who used the FRA simply as a stopover on the way to another destination, and those whose purpose was simply to enjoy the scenic beauty or to have a picnic, were willing to pay less compared to those engaged in more purposeful recreation at the site. WTP at the Telok Bahang FRA was positively related to income, and negatively related to household size. The direction of the signs on these variables are as expected *a priori*. However, the number of day trips made to open access recreational sites per year, which was included as a

variable indicative of, or a proxy for, the availability of substitutes was positively instead of negatively related to WTP. The statistical significance of this coefficient is not high, so the positive sign may have resulted by chance; alternatively, this FRA can be viewed as complimentary goods: one whose value is enhanced by the presence of others, which suggests that it may form part of a local recreation network. For other variables the direction of the sign is indeterminate *a priori*. Thus, in the event, the site was valued more highly by the young and old compared to middle aged individuals. The indigenous population were willing to pay less than people from outside Peninsular Malaysia for access to the FRA. The size of the coefficients on the variables are also interesting: compared to visitors from outside Peninsular Malaysia, visitors of Chinese ethnic origin valued the FRA least, followed by individuals of Indian origin. In contrast, the Malay ethnic group, whilst still willing to pay less than people from outside Malaysia, valued it the most highly of all the ethnic groups. The signs of the coefficients on the variables in the model are evidence of the consistency between the WTP responses of respondents and the theoretical expectation of factors determining WTP estimates. Furthermore, the R^2 value for this model at 60.8% is extremely high for a CVM study. The high R^2 value is evidence of consistency, if not accuracy of true WTP.⁹

The individual travel cost method

For FRAs, travel cost models (TCMs) estimate the same theoretical construct as CVMs.¹⁰ TCMs estimate the recreation demand curve, and hence consumer surplus, by observing the number of visits to the FRA (quantity) in relation to price (*i.e.* the cost of a visit). The individual travel-cost model (ITCM) defines the dependent variable as the number of visits to an FRA made by each visitor over a specified period, say one year.

⁹Theoretical validity may still be exhibited even if respondents underesimate their true WTP, as long as there is a systematic downward bias, in which case the direction of the signs on the coefficient retain their direction although their size is reduced.

¹⁰Assuming consumer surplus on each visit to an FRA is small, there are no strong income effects, and recreational substitutes exist for an FRA.

The ITCM was specified as:

$$V_{ij} = f(C_{ij}, E_{ij}, S_i, Y_i, A_i, H_i, N_i, M_i)$$

where:

- V_{ij} = number of visits made by individual i to site j
- C_{ij} = individual i 's total cost of visiting site j
- E_{ij} = individual i 's estimate of the proportion of the day's enjoyment which is attributable to the FRA
- S_i = dummy variable; whether individual i had visited other FRA sites
- Y_i = income of individual i 's household
- A_i = age of individual i
- H_i = size of individual i 's household
- N_i = size of individual i 's party
- M_i = dummy variable: whether individual i is a member of an outdoor organisation

Integrating over the ITCM function permits consumer surplus per visit to be calculated.

The dependent variable was specified as the number of visits made by a respondent to an FRA over the preceding six months. The cost or price of access to an FRA was measured by the amount that an individual paid on public transport, or incurred by using private transport¹¹ to visit the FRA. Since travel costs and travel time are correlated, estimated time costs were monetarised and added to travel costs in order to avoid multicollinearity.

The opportunity cost of travel time is determined by an exceedingly complex array of institutional, social, and economic relationships, and yet its value is crucial in the choice of types and quantities of recreational experiences. The equilibrium labour market model only applies to groups such as the self-employed, where individuals have discretionary work schedules and where earnings decline in proportion to absence from work. In the rest of the labour market some disequilibrium prevails, which severs the substitution between time and income, at the margin, for groups such as students,

¹¹The latest estimates of the unit running cost of an average car (RM/km in 1992 prices) were

cost element	financial cost	economic cost
fuel cost	0.110	0.060
lubricant oil	0.009	0.009
tyre cost	0.009	0.008
maintenance	0.053	0.045
depreciation	0.062	0.051
total	0.243	0.173

Source: Malaysian Government: Highway Planning Unit

retired and unemployed people, and also for employees on fixed hour employment contracts, unless overtime work is available (McKean *et al.* 1995). A value of time based on disequilibrium in the labour market was derived from gross domestic product, hours worked, and labour market composition to reflect employees, self-employed, and non-economically active individuals.

In terms of the provision of recreational goods, other recreation sites act as substitutes for FRAs. Greater distance from an FRA may mean greater proximity to a substitute site. Failure to include substitute sites in a travel-cost model constitutes an omitted variable problem, leading to an overestimation of visits to, and the value of, an FRA. Where substitute sites are imperfect substitutes no problem arises. A perfect substitute for an FRA should, in theory, result in recreationalists only visiting one site: the one with the lowest travel cost. However, in terms of outdoor recreation, perfect substitutes do not generally exist because all sites have different quality characteristics and no-one site is a perfect substitute for another. An attractiveness index can be used to classify existing imperfect substitute recreation sites, and this approach was adopted in the present study.¹² The importance of substitute sites and alternative recreational opportunities was assessed in two ways: first by asking respondents how many other FRAs they had visited apart from this one; and second by calculating trips to FRAs as a ratio of the individual's total annual number of recreational day trips to forests, countryside, mountains, and other sites.

There is no standard specification for the functional form of a TCM. Some functional forms have inherent disadvantages (Willis & Garrod 1991a): for a linear functional form there will be some critical cost above which negative visits will be predicted by the model; and whilst logarithmic forms are useful for elasticity estimates and avoid negative values for the dependent variable, both the double log and semi-log (independent) functional forms imply infinite visits at zero cost. On the other hand the double log model also predicts infinite consumer surplus whenever demand for recreation is inelastic. Various criteria can be used to judge the appropriateness of a particular functional form: (1) statistical fit, (2) conformity to economic theory, (3) predictive ability, and (4) criterion and construct (convergence) validity.¹³

¹²A random utility model (RUM) was not employed because (a) FRA sites are spatially dispersed and cannot be regarded as substitutes for each other; (b) the study aimed to cover all FRAs, hence to develop RUMs for each FRA and measuring visits to local substitute sites would have increased the survey work in direct proportion to the number of substitute sites for each FRA: an extremely expensive task, and one beyond the scope of this project. Moreover, the RUM has a major shortcoming: it cannot explain, as a TCM does, the number of trips an individual makes to a site in a given season, nor the total number of visits a site attracts from the surrounding population.

¹³For the latter criterion, see Mitchell and Carson (1989).

A linear specification implies an under-estimate of consumer surplus for those visitors who make only one trip to an FRA. In addition, for those individuals who visit the FRA more than once, the estimated consumer surplus of a single visit clearly under-estimates their total consumer surplus. Thus, in the case of FRAs, the use of single visit estimates to approximate total consumer surplus per visitor, regardless of the number of visits made, ensures that the linear functional form always gives lower bound estimates (Willis & Garrod 1991a). The implication of this approach is that while any further visits after the first may possibly produce decreasing marginal consumer surplus, the overall total consumer surplus will increase.

By sampling on site at FRAs, the study excluded any individuals who chose not to recreate at FRAs; and consequently selects a sample based only on positive integer values of the dependent variable, thus altering the distribution of the error term. Studies by Bockstael *et al.* (1984), Balkan and Kahn (1988), and Willis and Garrod (1991b) have shown that consumer surplus estimates derived from OLS models of such data produce over-estimates of the true magnitude of consumer surplus, due to truncation bias. Hence in this case a maximum likelihood (ML) estimator that took account of the truncated nature of the data was used to estimate the travel-cost model.

As an example, the linear truncated ML model for Jeram Linang FRA, in Kelantan State, is presented in Table 3. Variables were included on the basis of a *priori* logic in economic theory, but the model again reports only those variables which are significant at the 0.15 statistical significance level. The variables in this maximum likelihood model make sense intuitively: visits to the FRA are negatively related to time and travel cost of gaining access to the site. On the other hand, the number of visits an individual makes to Jeram Linang FRA is positively related to being single and living at home with parents; being educated only to a primary or secondary level (relative to a higher education level); having visited other FRAs in the previous six month period; and engaging in fishing at this site.

Consumer surplus estimates for individual visits to the site were then calculated by substituting values from the linear equation and integrating over the demand function. These results are reported in Table 4, which documents the average economic benefit of the marginal visit for each visitor to the three FRAs. For purposes of comparison, it is necessary to concentrate on the value of the marginal visit, rather than a value based on the average number of visits, since the CVM estimates were also based on the value of the current (marginal) visit to each visitor.

Table 5 compares the ITCM and CVM results. Clearly the CVM and ITCM results are not dissimilar. Both methods produce the same ordering of economic value for the marginal visit to the three FRAs: in all cases the value for the marginal visit to Jeram Linang is lowest, and that for Gunung Pulai is the highest. However, for two of the three sites the ITCM estimates are greater than the CVM estimates.

Table 3. Maximum likelihood estimates of visits to Jeram Linang FRA, Kelantan (site 5)

variable	coefficient	std. error	T-ratio	Prob: t > x	mean of x
ONE	-4.00525	1.25289	-3.197	0.00139	1.00000
X3	-0.64479	0.24658	-2.615	0.00893	2.34940
X10	-11.07460	1.64099	6.749	0.00000	0.26216
X27	5.78721	1.09867	5.267	0.00000	0.18919
X29	6.04067	2.31138	2.613	0.00896	0.04594
X30	3.20342	1.17677	2.722	0.00548	0.13784
X4	0.48544	0.23220	1.925	0.05426	0.97297
X45	8.02514	3.22890	2.485	0.01294	0.00540
X51	-1.97990	1.10616	-1.790	0.07347	0.25135

Log-Likelihood = -605.22

- X3 = combined time and travel cost (using a standard hourly rate of RM 9.16/hr as the opportunity cost of time)
 X10 = first visit
 X27 = single, living with parents
 X29 = educated to primary level
 X30 = educated to secondary level
 X4 = other FRAs visited in 6 month period
 X45 = fished at this site
 X51 = engaged in nature walking at this site

Table 4. Consumer surplus estimates for Jeram Linang (Kelantan), Gunung Pulai (Johor), and Telok Bahang (Penang), per adult per marginal visit.

(1995 RM prices; with travel time costs of RM 9.16 per hour)

FRA	Petrol cost	Full running cost
Jeram Linang	0.78	1.80
Telok Bahang	2.38	2.98
Gunung Pulai	3.74	9.32

Table 5. Comparison of CVM and ITCM results

(consumer surplus per visit per adult)

FRA	CVM	ITCM
Jeram Linang	1.05	0.78
Telok Bahang	1.41	2.38
Gunung Pulai	2.15	3.74

The comparison of CVM with revealed preference (RP) estimates (such as TCM measures) has played a key role in assessing the validity of CVM. Of course RP estimates are themselves random variables which are sensitive to details of product definition, functional form of the RP methods (here ITCM), and other technique-specific assumptions such as the value of time, multipurpose visits, and the definition of substitutes. Thus both techniques, CVM and ITCM, measure the quantity demanded, and hence consumer surplus, with some error. Consequently, neither of the measures can be assumed to be a true measure of the construct.

Studies comparing CVM and RP estimates (mainly TCM estimates) have generally found that CVM estimates are smaller, but not grossly smaller than their RP counterparts. The overall CVM/TCM ratio in this study is 0.67. American studies have found the CVM/RP ratio (for trimmed or modified CVM WTP results) to average 0.77 (Carson *et al.* 1996). Hence the CVM and TCM results in this study appear reasonable, providing convergent validity support for the non-market valuation estimates of FRAs.

Of course, correspondence between CVM and TCM measures does not prove the accuracy of either set of measures, but rather contributes to the credibility of both. Cummings *et al.* (1986) point out that price elasticity can vary enormously for specific goods, and that the accuracy of values estimated by indirect market methods is likely to be no better than $\pm 50\%$. However, using $\pm 50\%$ for reference accuracy, the hypothesis that the CVM and ITCM measures are the same cannot be rejected. Hence the CVM estimates of the value of FRAs can be interpreted as reliable and robust.

Aggregate benefits of FRAs

A separate survey enumerated all visitors to each FRA on each interview day. The number of visits recorded at each site was grossed up to annual visit numbers on the basis of the proportion of days sampled. Where no holiday dates were included in the sample, Sunday visit numbers were assumed to be representative of holidays, since Saturday is half a working day in Malaysia. Where a public holiday falls on a Sunday, the following day is a public holiday, thus reducing the number of ordinary Mondays in the sample. Such events were incorporated in the grossing up calculations, as was the considerable variation in some public holidays between States in Malaysia.

The number of visits to each FRA is recorded in Table 6. The number of visits to sites varied enormously, from some sites (Sungai Chongkak, Kanching, and Sekayu) which received over a quarter of a million visits per year; to remote rural sites (Kenong and Gua Cerita) which received less than 5,000 visits per year. Modern urbanised sites (such as Sekayu and Telok Bahang) attracted many more visits per year than remote rural, natural, or wilderness-type sites (such as Kenong, Gua Cerita, Gunung Pulai). Annual visit rates increased as the quality of the site improved; sites with poor natural resources, facilities, and recreational activities and opportunities (such as Gallah) attracted few visitors compared to Lata Tembakah, which scores high on these attributes. The annual economic value of each FRA is recorded in Table 6. These are lower-bound estimates, since they are based on the value of the marginal visit.

Table 6. Visits to and values of FRAs

FRA site		Adult visits	Child visits	Total visits	Total values estimated by CVM WTP
1.	Gunung Arong (Johor)	28,319	12,786	41,105	survey error
2.	Gunung Pulai (Johor)	36,119	26,357	62,476	99,796
3.	Gua Cerita (Kedah)	3,106	96	3,202	4,158
4.	Sungai Teroi (Kedah)	23,098	11,980	35,078	82,602
5.	Jeram Linang (Kelantan)	142,271	76,790	219,061	185,476
6.	Ayer Keroh (Melaka)	109,442	71,388	180,830	126,525
7.	Gallah (N. Sembilan)	3,677	2,249	5,926	10,939
8.	Ulu Bendul (N. Sembilan)	63,266	54,090	117,356	110,648
9.	Kenong (Pahang)	424	491	915	2,056
10.	Lentang (Pahang)	87,119	37,788	124,907	96,713
11.	Sungai Pandan (Pahang)	61,351	35,851	97,202	97,227
12.	Kuala Woh (Perak)	78,494	11,648	90,142	101,004
13.	Bukit Larut (Perak)	19,173	7,010	26,183	36,318
14.	Bukit Kubu (Perlis)	31,113	26,657	58,070	56,155
15.	Teluk Bahang (Penang)	115,356	119,266	234,622	230,634
16.	Sg. Chongkak (Selangor)	204,061	73,759	277,820	309,756
17.	Kanching (Selangor)	246,378	66,576	312,954	378,484
18.	Sungai Tua (Selangor)	150,332	65,191	215,543	321,283
19.	Sekayu (Terengganu)	203,883	76,343	280,226	250,192
20.	Lata Tembakah (Terengganu)	134,924	52,305	187,229	153,177
TOTAL		1,742,226	828,621	2,570,847	2,653,144

Unfortunately, data on the costs of each individual FRA were not available for comparison with these benefit estimates. Nevertheless, from the aggregate economic benefits of these 20 FRA sites, it is clear that benefits exceed costs for the FRA programme as a whole. Capitalising the benefits at reasonable real (as opposed to nominal) discount rate (opportunity cost or time preference) of 5 per cent, produces a value for these 20 FRAs of RM 53.06 million. This exceeds the expenditure on the whole FRA programme under all the Malaysian Five Year Plans compounded to 1996 at 5 per cent, *i.e.* RM 49.33 million. Whilst the benefit/cost ratio of individual FRAs might vary, and the costs of some FRAs might exceed the economic benefits they produce, over the programme as a whole, the benefits of FRAs clearly exceed costs, probably by a factor of about two.

Conclusions

The contingent valuation method was used to estimate the value of Forest Recreation Areas in Peninsular Malaysia. The value of the existing FRAs, based on respondents' expressed willingness to pay to gain access, averaged RM 1.46 for adult visitors, with values for children being approximately half those of adults. As a validation check, individual travel-cost models were developed for three FRAs. The ITCMs estimate consumer surplus of between RM 0.78 and RM 3.74 for the three FRAs for the marginal visit.

Both the CVM and ITCM results are in the same 'ball-park'; they match in terms of the relative ranking of benefits over the three FRAs; have good theoretical constructs; and have a CVM/ITCM ratio which is consistent with those of other studies making similar comparisons. The results also appear to be more robust than those derived by previous studies valuing recreation in Malaysia.

For example, a study by Hassan (1993) employed a zonal travel-cost model (ZTCM) to value recreation at three sites in the Klang Valley of Selangor State: (1) Taman Pertanian Malaysia (Malaysian Agriculture Park), a 1,300 hectare park covering agricultural heritage, virgin forest reserve, with recreational facilities; (2) Mimaland, a 113 ha privately owned site characterised by natural forest 18 km from Kuala Lumpur; and (3) Taman Subang Ria, a 19 ha site, mostly comprising a lake, with a surrounding jogging track. The demand function for each site was based on travel costs (assumed to include opportunity costs of alternative activities forgone, costs of food and drinks, fares and fuel costs, plus entrance charges). The study did not indicate how these costs were derived, nor their amounts. The sample size: 80 respondents at Taman Pertanian Malaysia; 70 at Mimaland; and 50 at Taman Subang Ria, appears much too small to produce accurate estimates of visit rates for a ZTCM, where the visitor sample has to be disaggregated by zone of origin in order to calculate a visit rate per capita from each zone of origin to each site. Nevertheless, despite these short-comings, a simple bivariate linear regression model for each site was used both to generate visitor numbers and to estimate average consumer surplus per visit. These varied from 400,878 visitors and RM 1.17 at Taman Pertanian Malaysia; 316,852 and RM 1.80 at Mimaland; and 27,983 and RM 1.90 at Taman Subang Ria; for visitors and consumer surplus per visitor respectively in 1991 prices.

Another ZTCM by Shaib (1994), of visitors to Langkawi island, was similarly reticent in detailing the assumptions and measurement of the variables in a semi-log dependent variable model, which included variables for trip cost, value of travel time, household income, actual travel time, cost of travel to the alternative site, attractiveness index of the alternative site, and attractiveness index of Langkawi. Again the sample size was small ($N=280$) given the distribution across 21 zones.¹⁴ The analysis reported no multicollinearity problems between money and time costs! The model estimated that a one hour increase in travel time would reduce the visit rate by 5.6% annually; an income coefficient of demand of 0.006%¹⁵ for a Ringgit change in household income; a highly significant positive cross-price elasticity of demand;¹⁶ and a positive relationship between visits and the attractiveness index for Langkawi. Following McConnell and Strand (1981), the opportunity cost of time was estimated from the ratio of b_2/b_1 [coefficient of travel time value / coefficient of car trip cost]

¹⁴11 of the 21 zones recorded less than 5 visits to Langkawi.

¹⁵That is, for a zone of 100,000 population, a RM 1 increase in mean house hold income would induce an increase of 600 visits annually.

¹⁶That is, the greater the distance and cost of reaching the alternative site, the greater the visit rate to Langkawi.

to be 92.2% of average income. The main problem with the study, however, appears to be the extremely large consumer surplus per visit of RM 425.41;¹⁷ and with an estimated 120,000 domestic visitors, the huge annual value of RM 51,049,000. This problem probably stems from the disaggregation of the cost variables in the model: the relevant cost to the individual visiting Langkawi is the total cost of all the elements. Including several separate cost elements which are correlated may reduce the coefficient on the pure travel cost variable, thus increasing consumer surplus because of the way in which Shaib's model is specified.

A more robust study was undertaken by Abdullah (1994) using a dichotomous choice (DC) contingent valuation (CV) at the Tasik Perdana recreational area, which is immediately adjacent to the central business district in Kuala Lumpur. The area covers 91.9 ha and comprises three recreational zones: (1) an active recreational zone of tennis courts, gymnasium, squash courts, and sports club; (2) a jungle zone and bird park; and (3) a general public use zone, including flower gardens, orchid garden, butterfly garden, and deer park. Entrance charges apply to the bird park, orchid garden, butterfly park, and for active recreational facilities. The DC CV study asked 632 visitors: "If the annual membership fee of the club was RM 'X' in 1991, would you have joined the club so that you could have continued to use the recreational area throughout the year?" RM 'X' ranged from RM1 to RM500. The values were chosen to represent a 'reasonable' entrance fee to many privately managed recreational facilities for the middle income group.¹⁸ From a logit model,¹⁹ the estimated mean willingness-to-pay (WTP) was RM 84, with a median value of RM 36.

DC methods produce higher estimates of WTP than open-ended CV methods. The central location of Abdullah's (1994) site in Kuala Lumpur; the above average quality of its facilities compared to those at most FRAs; and the greater proportion of higher income groups using the Tasik Perdana recreational area compared to FRAs; all suggest a higher WTP value for Tasik Perdana compared to the WTP values derived in this study.

The WTP values estimated for FRAs in this study permit a number of policy conclusions to be derived. First, more FRAs could be developed, since benefits are likely to exceed costs, and hence improve welfare, as well as safeguarding some areas of tropical forest. The economic benefits of any new FRAs will depend upon the value per visit and the number of visitors; which will in turn depend upon the availability of substitute sites. Hence the location of new FRAs should be considered in relation to existing FRAs and competing private recreational sites. Second, some FRAs could be privatised, since they would be able to charge an entrance fee that would exceed capital and running costs. The selling price for each FRA could simply be determined by the difference between the capitalised expected revenue and capitalised running costs, subject to a contract to meet specified environmental and service standards.

¹⁷ This is equivalent to almost one month's earnings for a manual worker in Malaysia.

¹⁸ 19.2% of respondents in the survey were government employees, with an average monthly income of RM1285.

¹⁹ The logit model outperformed a probit model in terms of the percentage of correct predictions, McFadden-R², and the log-likelihood ratio.

However, in terms of protecting large areas of tropical forest, FRAs have a limited role to play. Existing FRAs cover a relatively small area in Peninsular Malaysia, about 6,000 ha. Whilst forest recreation is growing in terms of the number of visitors, forest recreation as presently constituted in Malaysia is unlikely ever to require vast expanses of forest. Thus whilst FRAs raise the public consciousness of tropical forests, their preservation will depend upon other economic motives.

References

- ABDUL RAZAK BIN MOHAMMED ALI. 1995. Prominent findings of forestry research in Malaysia. *FORSPA Publication No. 10*. 40 pp. CAB International, Kuala Lumpur.
- ABDULLAH, NIK MUSTAPHA R. 1994. Constructed market approaches: contingent valuation. Paper presented at an Overseas Development Administration - Forestry Department Peninsular Malaysia Training Workshop on the Valuation of Non-Timber Goods. FOPM, Kuala Lumpur.
- American Psychological Association. 1974. *Standards for Educational and Psychological Tests*. 178 pp. APA, Washington DC.
- AJZEN, I., BROWN T.C. & ROSENTHAL, L.H. 1996. Information bias in contingent valuation: effects of personal relevance, quality of information, and motivational orientation. *Journal of Environmental Economics and Management* 30: 43-57.
- BALEAN, E. & KAHN, J.R. 1988. The value of changes in deer hunting quality: a travel-cost approach. *Applied Economics* 20: 533-539.
- BAUMOL, W.J. & OATES, W.E. 1988. *The theory of environmental policy* (2nd edition). 272 pp. Cambridge University Press, Cambridge.
- BOCKSTAEI, N.E., HANEMANN, W.M. & STRAND, I.E. 1984. Measuring the benefits of water quality improvements using recreation demand models. Report CR-811043-01-1. 139 pp. US Environmental Protection Agency, Washington DC.
- CARSON, R.T., FLORES, N.E., MARTIN, K.M. & WRIGHT J.L. 1996. Contingent valuation and revealed preferences methodologies: comparing the estimates for quasi-public goods. *Land Economics* 72: 80-99.
- CHIN, T.Y. & CHIE, T.V. 1994. Status of social forestry in Malaysia. Paper presented at an Indonesia-Malaysia Seminar on Social Forestry, Sanggau, West Kalimantan. 15 pp. Forestry Department Peninsular Malaysia, Kuala Lumpur.
- CUMMINGS, R.G., BROOKSHIRE, D.S. & SCHULZE, W.D. 1986. (Eds.) *Valuing Environmental Goods: An Assessment of the Contingent Valuation Method*. Rowman and Allanheld, Totowa, NJ.
- FISHER, A.C. 1996. The conceptual underpinnings of the contingent valuation method. Pp. 19-37 in: Bjornstad, D.J. & Kahn, J.R. (Eds.) *The Contingent Valuation of Environmental Resources: Methodological Issues and Research Needs*. Edward Elgar, Cheltenham.
- HANEMANN, W. M. 1996. Theory versus data in the contingent valuation debate. Pp. 38-60 in: Bjornstad, D.J. & Kahn, J.R. (Eds.) *The Contingent Valuation of Environmental Resources: Methodological Issues and Research Needs*. Edward Elgar, Cheltenham.
- HASSAN, MOHD NASIR. 1993. Valuing ecotourism of recreational parks in Malaysia. Pp. 135-151 in: *Proceedings of a Conference on Ecotourism in Malaysia: Prospects and Potential Impacts*. 6 - 9 September 1993. Kuala Lumpur.
- McKEAN, J.R., JOHNSON, D.M. & WALSH, R.G. 1995. Valuing time in travel cost demand analysis: an empirical investigation. *Land Economics* 71: 96-105.
- McCONNELL, K.E. & I.E. STRAND. 1981. Measuring the cost of time in recreation demand analysis. *American Journal of Agricultural Economics* 63: 153-156.
- MITCHELL, R.C. & CARSON, R.T. 1989. *Using Surveys to Value Public Goods: The Contingent Valuation Method*. 463 pp. Resources for the Future, Washington DC.
- National Oceanic And Atmospheric Administration, 1993. Report of the Panel on Contingent Valuation. *Federal Register* 58: 4601-4614.

- SAMPLES, K.C., DIXON, J.A. & GOWAN, M.M. 1986. Information disclosure and endangered species. *Land Economics* 62: 306-312.
- SCHULZE, W.D., MCCRELLAND, G., WALDMAN, D. & LAZO, J. 1996. Sources of bias in contingent valuation. Pp. 97-116 in: Bjornstad, D.J. and Kahn, J.R. (Eds.) *The Contingent valuation of Environmental Resources: Methodological Issues and Research Needs*. Edward Elgar, Cheltenham
- SHAHB, AIMAD. 1994. Travel cost method. Paper presented at an Overseas Development Administration - Forestry Department Peninsular Malaysia Training Workshop on the Valuation of Non-Timber Goods. 28 pp. FDPM, Kuala Lumpur.
- WAN SABRI WAN MANSOR. 1994. Recreation resource characteristics and classification of forest recreation areas for sustainable management. Report to the Forestry Department Peninsular Malaysia. 86 pp. University Pertanian Malaysia, Kuala Lumpur.
- WILLIS, K.G. & GARROD, G.D. 1991a. Valuing open access recreation on inland waterways: on-site recreation surveys and selection effects. *Regional Studies* 25: 511-524.
- WILLIS, K.G. & GARROD, G.D. 1991b. An individual travel cost method of evaluating forest recreation. *Journal of Agricultural Economics* 42: 33-42.
- WILLIS, K.G. 1995. Contingent valuation in a policy context: the National Oceanic and Atmospheric Administration Report and its implications for the use of contingent valuation methods in policy analysis in Britain. Pp. 118-143 in: Willis, K.G. and Corkindale, J.T. (Eds.) *Environmental Valuation: New Perspectives*. CAB International, Wallingford, Oxfordshire.
- WINTPENNY, J.T. 1991. *Values for the Environment: A Guide to Economic Appraisal*. 277 pp. HMSO, London.



Plate 1. Lata Jarum, 80 km from Raub, Pahang is an attractive forest recreation area with waterfalls, a river with clear water, camping and picnic areas set in a cool and scenic forest.

ANALYSIS OF TWO ALTERNATIVE HARVESTING SYSTEMS IN PENINSULAR MALAYSIA : SENSITIVITY ANALYSIS OF COSTS, LOGGING DAMAGE AND BUFFERS

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An economic study of two alternative timber harvesting systems was carried out in Peninsular Malaysia to evaluate and compare existing and improved harvesting systems in terms of their costs, efficiency and productivity. Two models were developed, one for the Jengai Forest Reserve under the new or improved system and one for the Tembat Forest Reserve under the old or existing system. The results showed that distance and diameter² were significantly related to delay-free cycle time in both areas in felling, while in skidding, distance and number of logs were significant in Jengai and distance and diameter were significant in Tembat. Logging cost excluding cost of conservation, premium, and royalty under the new system was RM 50.89 m³ or 4% lower than logging cost under the old system of RM 52.91 m³. Under average conditions, it takes 0.31 hours to fell a tree under the new system compared to 0.39 hours (simulated) under the old system. This suggests that the improvement made in Jengai Forest Reserve has increased productivity of felling. In skidding, it takes about 0.55 hours to travel one round trip under the new system compared to 0.77 hours (simulated) under the old system. This suggests that the improvement in road construction in Jengai has increased productivity of skidding. In Jengai, it was also found that it is more efficient to transport more than one log as the distance increases to increase production. For a given number of logs, cycle time remained constant irrespective of the volume of logs skidded on every trip as long as the load is within the machine's capabilities on any given terrain. Under average conditions, the cost of felling under the new system (RM 44.49 tree⁻¹) was approximately the same as the old system (simulated) of RM 44.64 tree⁻¹ but productivity under the new system was higher. Simulating the new system in Tembat, the cost of felling under the new system (RM 50.55 tree⁻¹) was approximately the same as the old system (RM 50.41 tree⁻¹), but productivity was slightly lower under the new system. The cost of skidding under the new system (RM 78.12 log⁻¹) is about 14% lower than the cost under the old system (simulated) of RM 90.74 log⁻¹. This shows that under the conditions of distance, diameter and number of logs as in Jengai Forest Reserve, the cost per log was lower using the new system than the old system. The cost of skidding under the new system (simulated) was RM 84.48 log⁻¹ or 3.6% higher than the cost of skidding under the old system of RM 81.56 log⁻¹. Assuming the damage under the new system was 30%, the damage under the old system was estimated at about 40%. Volume of trees damaged in the residual stand in the 30-39 cm dbh and >40 cm dbh is 0.5 m³ ha⁻¹ y⁻¹. The total volume of trees damaged at 30% damage under the new system in the next rotation is 15 m³ ha⁻¹. The total volume of trees damaged at 40% damage under the old system in the next rotation is 20 m³ ha⁻¹. The present value of the cost of damage discounted at 4% discount rate was RM 3.62 m³ compared to RM 5.02 m³ under the old system. Present Net Worth (PNW) of the new system without buffer cost was RM 581.60 m³ or approximately 3% higher compared to PNW of the old system without buffer cost of RM 566.53 m³ based on the yield of 65 m³ ha⁻¹ and revenue of RM 521 m³ as the new system. This shows that the reduction in damage to the residual stand has increased the net future harvests as shown by the higher PNW of the new system. PNW of the new system with buffer cost was RM 577.07 m³ compared to PNW of the old system of RM 566.53 m³ without buffer cost. This shows that PNW of the new system is

approximately 2% higher than PNW of the old system, and the presence of buffer zone has decreased the PNW by 1 % from RM 581.60 m³ to RM 577.07 m³. The reduction in damage to the residual stand and buffer zone has increased the net future harvests as shown by the higher PNW of the new system. PNW of the new system with buffer cost was RM 577.07 m³ compared to PNW of the old system of RM 514.60 m³, with buffer cost. This shows that it is more economical to install the buffer zone in the new system based on the higher PNW of the new system compared with PNW of the old system.

Key words: Productivity - new system - old system - buffer costs - present net worth - damage costs - logging costs - opportunity costs

Introduction

A study was carried out under the Project B7: Malaysia- United Kingdom Program of cooperation on forest management and conservation to evaluate and compare existing and improved harvesting systems in terms of their costs, efficiency and productivity. The objective of the study is to develop an economic model of harvesting costs in order to assess the opportunity costs of timber left in buffer strips and the costs and benefits of directional felling.

Under the new or improved harvesting system, buffer strips are installed and marked on the ground, at least 20 meters width on either side of the streams. There was no buffer strip under the old or existing system. Directional felling is incorporated in the new system while there was no directional felling under the old system. Under the new system, there is improved road location and construction, that is, road construction according to the standards and specifications of forest roads in Peninsular Malaysia, while under the old system, road location and construction did not follow the standards and specifications of forest roads in Peninsular Malaysia.

The Jengai Forest Reserve which is under the new system is located in Compartment 123, Block B, in the district of Dungun, Terengganu, with an area of 197 hectares while the Tembat Forest Reserve which is under the old system is located in Compartment 204, block 12 A, covering an area of 135 hectares. Both study areas were mostly hilly and rocky with elevation between 100 meters to 600 meters and slope ranging from 5° to 22°.

The study areas were managed under the Selective Management System (SMS) with rotation length of 30 years. The cutting limits were 45 cm dbh and above both for the Dipterocarp and Non- Dipterocarp groups for the Jengai Forest Reserve and 50 cm dbh and above both for the Dipterocarp and Non- Dipterocarp groups for the Tembat Forest Reserve, based on the Pre-Felling Inventory (Pre- F Inventory) of the two areas. The Pre- F Inventory was carried out for all trees of diameter-classes of 5 cm and above.

In the Jengai Forest Reserve, there was a total of 48 species and the yield was 65 m³ ha⁻¹ and 3.2 m³ per tree. In the Tembat Forest Reserve, there were 51 species with a yield of 92 m³ ha⁻¹ and 3.3 m³ per tree.

Data was collected using a combination of time-study and survey-questionnaire methods. The study sites were randomly selected from similar forest types, zones

and forest management systems. The forest type selected was the Hill Dipterocarp Forest from the eastern zone of Peninsular Malaysia. Interviews were conducted to obtain information on fixed and operating costs as well as harvesting systems used. The harvesting system used in the Jengai and Tembat Forest Reserves was a combination of chainsaw, crawler tractor and a winch-lorry called San Tai Wong. In the felling site, a chain saw was used to fell the tree and to cross-cut the log immediately at the felling site or at the temporary log-landing. A crawler tractor was used to transport the log from the felling site to the log-landing. The winch lorry was used to transport logs from the temporary log-landing to the permanent log-landing. Production times were recorded from each of the five sub-systems: felling and cross-cutting, skidding or off-road transportation, loading, short distance transportation or short hauling and road construction.

Comparisons of productivity and costs between Jengai and Tembat Forest Reserves were made by using average conditions in each area. Equations developed for the Jengai Forest Reserve were used to represent the new system while equations developed for the Tembat Forest Reserve were used to represent the old system. The same contractor wage rates and equipment costs were used for each area to simulate the new system in Jengai and the old system in Tembat.

For the sensitivity analysis on the damage to the residual stand after logging, comparisons of damage costs between the new and the old systems were made. Comparison of Present Net Worth (PNW) between the new and the old systems without buffer cost was made to evaluate the impacts of future damage on the PNW returns for each of the systems. Comparison of PNW between the new and the old systems with buffer costs was also made to project the impacts of the future damage and buffer zone on the PNW returns for each system. The per cent damage breakeven on the new system was determined for each of the analyses to justify the new system.

Literature review

A cost study on harvesting conducted by Marn *et al.* (1982) included a comparison of a logging system with only one crawler tractor and a system with a crawler tractor combined with the FMC skidder, and a simple model was used. This comparison showed that the system with the combination of crawler tractor and FMC skidder was more economical than using the crawler tractor only when the average skidding distance of the tractor exceeded 0.38 km. Regressions were also made for the loading operation but with a low R^2 value. Loading of the truck was done using a CAT 977L tracked log-loader which travelled from landing to landing. For the hauling, only regression for travel time with volume and with weight could be made as distances were the same for all entries. The correlation was not good (best fit $R^2 = 0.10$).

In another study on logging cost and productivity (Marn *et al.* 1981), the time study was carried out for traditional skidding operations in which three different methods of skidding were studied, namely downhill skidding, uphill skidding and neutral. Regressions were made for time and distance on main, secondary, no trail and opening trail. Generally, good correlations were found.

In the case of loading, no good correlation could be found. Regressions of loading time with volume and weight, hook-on-line time with volume, and winching time with volume and weight were made. However, the correlation coefficient (R^2) was less than 0.1 for every case.

On average, good correlations were found in skidding for time related to volume and distance and there was not much deviation from the straight line.

Regressions were sought between loading time with volume, weight and number of logs respectively. However, none of the regressions gave a satisfactory R^2 (mostly under 0.1) which indicated that there was very little correlation. The best result obtained was between loading time with number of logs loaded.

Comparison of felling time and cost per m^3 between directional felling and traditional felling was studied by Marn (1982). Cost of directional felling was RM 2.29 m^3 compared to RM 2.31 m^3 for traditional felling. Directional felling was thus achieved without any extra cost. In log extraction, two different operations, both using CAT D6C were compared. A carefully planned operation where felling had been done towards already opened main skidtrails and chokers used, was compared with extraction by traditional method. The results showed that increase in production was 36 per cent, with 26 per cent reduction in cost compared to traditional felling.

On the effects of directional felling to the remaining stand, the study showed that number of trees lost was reduced by 33 per cent and volume of felled sound timber left reduced by 48 per cent. The combined effect of the directional felling, the use of chokers and good skidtrail network, planned and opened before the start of the felling contributed mostly to the increase in production and reduction of damage to the remaining stand.

Results and discussion

Productivity

STATGRAPHICS (Windows Version 2) was used to analyse the data from Jengai and Tembat Forest Reserves and then significant independent variables (95% confidence level) were selected that could be used to predict cycle times.

Felling

The model for the Jengai Forest Reserve (new system):

$$\text{Delay-free cycle time} = -241.51 + 0.98 \text{ Distance} + 0.20 \text{ Diameter}^2$$

The model for the Tembat Forest Reserve (old system):

$$\text{Delay-free cycle time} = 47.64 + 5.92 \text{ Distance} + 0.09 \text{ Diameter}^2$$

The above model shows that distance between trees is relatively more important in the Tembat Forest Reserve as illustrated by the greater regression coefficient. It shows that for the same distance, the felling operator takes 5.92 seconds to travel

one meter compared to 0.98 seconds in the Jengai Forest Reserve. Felling time increases with increase in distance between trees and diameter³. In a similar study carried out by FAO, it was found that felling time increased with increase in diameter and number of logs per tree (Anonymous 1974). The improvements made in road construction in Jengai Forest Reserve increased productivity. It took 0.09 s cm² to fell and cross-cut the tree of the same diameter in the Tembat Forest Reserve compared to 0.20 s cm² in the Jengai Forest Reserve. The longer time taken to fell a tree with the same diameter in Jengai Forest Reserve compared to Tembat Forest Reserve may be due to the longer time taken in directional felling in Jengai Forest Reserve.

The results showed that under average conditions, using the new system, it takes 0.31 hours to fell a tree compared to 0.39 hours (simulated) in Tembat Forest Reserve. This suggests that the improvement made in the Jengai Forest Reserve had increased the productivity of felling.

Skidding

The model for the Jengai Forest Reserve (new system):

$$\text{Delay-free cycle time (sec)} = 569.85 + 1.72 \text{ Distance} + 324.15 \log$$

The model for the Tembat Forest Reserve (old system):

$$\text{Delay-free cycle time (sec)} = 119.3 + 3.67 \text{ Distance} + 4.11 \text{ Diameter}$$

This model shows that distance is more significant in the Tembat Forest Reserve compared to the Jengai Forest Reserve as shown by the greater regression coefficient. It shows that for the same distance, the crawler tractor takes 3.67 seconds to travel one round trip compared to 1.72 seconds in Jengai Forest Reserve. The improvement in road construction in the Jengai Forest Reserve had increased skidding productivity compared to the Tembat Forest Reserve. It also shows that the number of logs is significantly related to time in Jengai and diameter in Tembat. In a similar study carried out by FAO between 1966 to 1968 (Anonymous 1974), it was found that skidding time increased with increase in distance, number of logs and diameter.

In skidding, it takes about 0.55 hours to travel one round trip in Jengai compared to 0.77 hours (simulated) in the Tembat Forest Reserve. This suggests that the improvement in road construction in Jengai had increased productivity of skidding. In Jengai, it was also found that to increase production it is more efficient to transport more than one log as the distance increases.

Short hauling

Only one travelling distance was used in the short hauling system, so it is not possible to predict the cycle time using multiple linear regression. The equation for the short hauling system was estimated based on the time taken to travel the hauling distance, excluding the loading and the unloading time as follows:

The model for the Jengai Forest Reserve (new system):

$$\text{Delay-free cycle time (sec)} = 1500 + 0.70 \text{ Distance}$$

The model for the Tembat Forest Reserve (old system):

$$\text{Delay-free cycle time (sec)} = 1338 + 0.62 \text{ Distance}$$

The model shows that distance is more significant in the Jengai Forest Reserve compared to the Tembat Forest Reserve as shown by the greater regression coefficient. It shows that for the same distance, the winch lorry takes 0.70 seconds to travel one round trip compared to 0.62 seconds in the Tembat Forest Reserve.

For the same average distance of 15,200 meters in Jengai Forest Reserve, the time taken for short hauling in Tembat Forest Reserve was 10,762 seconds, which is still lower than the time taken in the Jengai Forest Reserve. However, comparisons of productivity between the two areas was not possible since only one observation for distance was used in the model.

Costs and productivity

Logging costs for the Jengai Forest Reserve using the new system and the Tembat Forest Reserve using the old system are given in Table 1.

Table 1. Logging costs for the Jengai and Tembat Forest Reserves

Activity	Jengai (RM m ³)	Tembat (RM m ³)
Felling and cross-cutting	4.79	6.20
Skidding	10.93	11.03
Loading and unloading	2.49	0.94
Short hauling	8.72	10.60
Supporting costs	23.96	24.14
Total logging cost	50.89	52.91

From Table 1, it can be seen that the cost of logging in the new system was RM 50.89 m³ or 4 per cent lower than the cost of logging under the old system, i.e. RM 52.91 m³, excluding conservation costs, royalty, and premium.

In terms of costs, under average conditions, the cost of felling under the new system is RM 44.49 tree⁻¹ or 0.34 per cent lower than the old system (simulated) of RM 44.64 tree⁻¹. The cost per tree would be approximately the same using the new system or the old system. Simulating the new system in Tembat, the cost of felling in the new system is RM 50.55 tree⁻¹ (simulated) or 0.28 per cent higher than the old system. The cost per tree is approximately the same under the new system as the old system, but the productivity is slightly lower under the new system.

In skidding, the cost under the new system is RM 78.12 log⁻¹ or 14 per cent lower than the old system (simulated) of RM 90.74 log⁻¹. This suggests that under the same conditions of distance, diameter, and number of logs, the cost per log is lower using the new system in Jengai Forest Reserve.

The cost of skidding under the new system (simulated) is RM 84.48 $\log^{-1}$ or 3.6 per cent higher than the cost under the old system of RM 81.56 $\log^{-1}$.

Sensitivity analysis on the damage to the residual stand after logging

Volume of trees damaged in the residual stand in the 30-39 cm dbh and >40 cm dbh is 0.5 $\text{m}^3 \text{ha}^{-1} \text{y}^{-1}$. The total volume of trees damaged at 30 per cent damage under the new system in the next rotation is 15 $\text{m}^3 \text{ha}^{-1}$. Assuming the damage under the new system is about 30 per cent, the damage under the old system is estimated at about 40 per cent (Johnson & Cabarle 1993). The percentage of damaged trees in the next rotation is 18 per cent under the new system and 22.7 per cent under the old system (Forestry Department of Peninsular Malaysia 1991). The total volume of trees damaged at 40 per cent damage under the old system in the next rotation is 20 $\text{m}^3 \text{ha}^{-1}$. The net future volume of harvests for the next rotation after allowing 30 per cent damage under the new system is 50 $\text{m}^3 \text{ha}^{-1}$ and 45 $\text{m}^3 \text{ha}^{-1}$ under the old system at 40 per cent damage. At 30 per cent damage under the new system, the present value of costs of damage discounted at a 4 per cent discount rate was RM 3.62 m^3 , based on yield of 65 $\text{m}^3 \text{ha}^{-1}$ and RM 5.02 m^3 under the old system at 40 per cent damage based on yield of 65 $\text{m}^3 \text{ha}^{-1}$, as shown in Table 2.

When the yield per hectare is 92 $\text{m}^3 \text{ha}^{-1}$ for the old system, the present value of damage cost is RM 3.55 m^3 at 40 per cent damage, as shown in Table 3. This shows that yield other than logging cost plays an important role in influencing the viability of the new system.

Table 2. Comparison of present value of damage costs under the new and old systems (RM m^3), based on yield of 65 $\text{m}^3 \text{ha}^{-1}$ for the new and the old systems

Damage (%)	New system	Old system
0	0.00	0.00
10	1.21	1.25
20	2.41	2.51
30	3.62	3.76
40	4.83	5.02
50	6.03	6.27
60	7.24	7.53

Table 3. Comparison of present value of damage costs between the new and the old systems (RM m^3) based on yield of 65 $\text{m}^3 \text{ha}^{-1}$ (new system) and 92 $\text{m}^3 \text{ha}^{-1}$ (old system)

Damage (%)	New system	Old system
0	0.00	0.00
10	1.21	0.89
20	2.41	1.77
30	3.62	2.65
40	4.83	3.55
50	6.03	4.43
60	7.24	5.32

Under the new system, the cost of buffer zones is RM 19.09 m³. The difference between the PNW of the new system with buffer and the PNW of the new system without buffer is the present value of cost of buffer, which is RM 4.53 m³ or about 7.63 per cent of the present value of logging cost.

PNW of the new system with buffer cost at 30 per cent damage is RM 577.07 m³ compared to PNW of the old system of RM 566.53 m³ at 40 per cent damage without buffer cost, using the same yield of 65 m³ ha⁻¹ and revenue of RM 521 m³ as the new system, as shown by Table 4.

Table 4. Comparison of PNW between the new and the old systems (RM m³)

Damage (%)	New system (with buffer cost)	Old system (without buffer)
0	609.16	612.40
10	598.16	600.93
20	587.77	589.46
30	577.07	577.08
40	566.33	566.53
50	555.68	555.06
60	544.98	543.59

This shows that PNW of the new system is approximately 2 per cent higher than PNW of the old system. Hence the reduction in damage to the residual stand has increased the net future harvests as shown by the higher PNW of the new system with buffer cost.

Without buffer cost, PNW of the new system is RM 581.60 m³ or approximately 3 per cent higher than PNW of the old system of RM 566.53 m³ based on yield of 65 m³ ha⁻¹ and revenue of RM 521 m³ as the new system (Table 5).

Table 5. Comparison of PNW between the new and the old systems without buffer cost (RM m³)

Damage (%)	New system (without buffer cost)	Old system (without buffer)
0	615.04	612.40
10	603.90	600.93
20	592.75	589.46
30	581.60	577.08
40	570.45	566.53
50	559.30	555.06
60	548.15	543.59

This shows that the reduction in damage to the residual stand has increased the net future harvests as shown by the higher PNW of the new system.

Sensitivity analysis was also done on the new system and old system, with and without buffer costs. Table 6 shows comparison of PNW between the new and the old systems.

Table 6. Comparison of PNW between the new and the old systems (RM m³)

Damage(%)	New system (with buffer cost)	Old system (with buffer)
0	609.16	534.19
10	598.46	527.65
20	587.77	521.13
30	577.07	514.60
40	566.38	508.08
50	555.68	501.55
60	544.98	495.02

From Table 6, PNW of the new system with buffer cost was RM 577.07 m³ at 30 per cent damage compared to PNW of the old system of RM 514.60 m³ with buffer. This shows that it is more economical to install the buffer zone in the new system based on the higher PNW of the new system with buffer zone compared to the PNW of the old system with buffer zone.

Conclusions

Productivity

At Jengai Forest Reserve, the new system is more productive than the old system while in Tembat Forest Reserve, the new system is less productive than the old system.

Felling

It was found that distance and diameter² were the two variables that were significantly related to time in both study areas. The time of felling increases as the distance and diameter² increase in both areas. It takes less time to travel between trees in the Jengai Forest Reserve compared to the time taken to travel the same distance in the Tembat Forest Reserve. For the same average distance and diameter, it takes a shorter time to fell a tree in Jengai than in Tembat. This suggests that the improvement made in the Jengai Forest Reserve has contributed to the higher productivity in the Jengai Forest Reserve.

Skidding

It was found that distance and number of logs were significantly related to delay-free time in the Jengai Forest Reserve while distance and diameter were significant in the Tembat Forest Reserve. The time of skidding increases in Jengai as the distance and number of logs increase while in Tembat the time of skidding increases as distance and diameter increases. Productivity in the Jengai Forest Reserve is higher than in the Tembat Forest Reserve based on the same average distance, number of logs and diameter as given by the shorter time taken to skid a log in Jengai than in Tembat.

This suggests that the improvements in road construction in the Jengai Forest Reserve increased productivity of skidding.

From the study, it was also found that number of logs was significantly related to delay-free cycle time in the Jengai Forest Reserve. The delay-free cycle time increases with increase in number of logs skidded. This shows that it is more efficient to transport more than one log as the distance increases in order to increase production.

Short hauling

It was found that on average it took a longer time to haul logs in the Jengai Forest Reserve than in the Tembat Forest Reserve. However, due to the lack of a range of operating conditions for the short hauling system, it is not easy to compare productivity between the two study areas. A more detailed study consisting of more than one hauling distance is needed to arrive at a model of the short hauling system.

Costs

The new system is cheaper in Jengai but more costly in Tembat (and vice versa) because the model for the new system was developed based on the improved conditions with respect to road construction, directional felling and buffer strip.

Felling

Under the same conditions of distance and diameter as in the Jengai Forest Reserve, the cost per tree was RM 44.49 or 0.34 per cent lower using the new system than the old system (RM 44.64). Under the same conditions of distance and diameter as in Tembat Forest Reserve, the cost per tree was RM 50.55 or 0.28 per cent higher using the new system than the old system (RM 50.41).

Skidding

Under the same conditions of distance, diameter and number of logs as in the Jengai Forest Reserve, the cost per log in the Jengai Forest Reserve using the new system was RM 78.12 or 14 per cent lower than the simulated cost of using the old system (RM 90.74). Under the same conditions of distance and diameter and number of logs as in the Tembat Forest Reserve, the cost per log was RM 84.48 or 3.46 per cent higher using the simulated cost of the new system than using the old system (RM 81.56).

Short hauling

On average, the cost of hauling was lower (RM 8.72 m³) in the Jengai Forest Reserve than in the Tembat Forest Reserve (RM 10.60 m³). Because of the lack of a predictive model for the hauling system in each area, it was not possible to compare productivity and costs between the two areas.

Damage costs

Yield other than logging costs plays an important role in influencing the viability of the new system. When yield per hectare is increased from $65 \text{ m}^3 \text{ ha}^{-1}$ to $92 \text{ m}^3 \text{ ha}^{-1}$, breakeven on the new system decreased from 41 per cent to 28 per cent. This shows that the viability of the new system is decreased from 41 per cent to 28 per cent damage.

Present net worth

Compared to PNW of the new system without buffer cost, PNW of the new system is approximately 2.7 per cent higher than the PNW of the old system. This shows that the reduction in damage to the residual stand from 40 per cent to 30 per cent damage had increased the net future harvests as shown by the higher PNW of the new system. The breakeven per cent on the new system has also decreased from greater than 60 per cent to 42 per cent.

PNW of the new system with buffer cost is RM 577.07 m^3 compared to PNW of the old system of RM 566.53 m^3 without buffer cost. This shows that PNW of the new system with buffer cost is approximately 2 per cent higher than PNW of the old system without buffer cost.

It is more economical to install the buffer zone in the new system based on the higher PNW of RM 577.07 m^3 compared to RM 514.60 m^3 in the old system. The breakeven per cent of the new system is higher (37 per cent) than the breakeven per cent of the old system (31 per cent). This shows that the new system with buffer is more viable when damage is increased to 37 per cent from 30 per cent compared to the old system from 30 per cent to 31 per cent damage.

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References

- ANONYMOUS. 1974. *Logging and Log Transport in Tropical High Forest: A Manual on Production and Costs*. FAO Forestry Series No. 5, FAO Forestry Development Paper, No.18.
- FORESTRY DEPARTMENT OF PENINSULAR MALAYSIA. 1991. Current Status of Forestry Sector in Peninsular Malaysia. Forest Planning Unit, Forestry Department Headquarters, Kuala Lumpur.
- JOHNSON, N. & CABARLE, B. 1993. *Surviving the Cut: Natural Forest Management in the Humid Tropics*. World Forest Resources Institute.
- MARN, H.M. 1982. The Planning and Design of the Forest Harvesting and Log Transport Operation in the Mixed Dipterocarp Forest of Sarawak. A Technical Report to the Government of Malaysia.
- MARN, H.M., VEL, E. & CHUA, D.K.H. 1981. Planning and Cost Studies in Harvesting in the Mixed Dipterocarp Forest of Sarawak. A Technical Report to the Government of Malaysia.
- MARN, H.M., VEL, E. & CHUA, D.K.H. 1982. Further Cost Studies in Harvesting the Mixed Dipterocarp Forest of Sarawak including FMC Skidder Operation. A Technical Report to the Government of Malaysia.

MODELLING THE IMPACT OF FOREST CONVERSION ON CLIMATE: A REVIEW

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Large-scale conversion of tropical forests into pastures or crops is likely to change the local microclimate of those regions and may produce regional- or even global-scale impacts. Here, we present a historical review of General Circulation Model (GCM) simulations of the climate effects of tropical deforestation. Our purpose is to compare the different features, perturbations, major developments and results of these experiments. Comparisons reveal that, in the case of Amazon Basin deforestation, there is some agreement in terms of discernible impacts on local and regional climate despite the considerable differences in model dynamical structures, land surface representation, ocean and cloud description, and also the length of the simulations. However, many uncertainties exist with respect to the magnitude and direction of changes depicted in the model results. The impacts simulated in response to tropical deforestation in the Amazon Basin, South East Asia and tropical Africa differed and the changes in response to deforestation in South East Asia and tropical Africa were smaller than those resulting from the Amazonian land cover change region. Recent simulations have shown that alteration of the model surface parameters following deforestation produces significant modifications of both the Hadley and Walker Circulations, resulting in changes distant from the region of deforestation and the possibility of global-scale impacts.

Keywords: Tropical deforestation - general circulation model - climate change

Introduction

The effects of the removal of large areas of tropical forest on local, regional and global climate have received considerable attention from climate analysts and modellers. It is widely recognized that continuing removal of these forests will add carbon to the atmosphere through biomass burning, thereby enhancing the greenhouse effect, as well as disturbing greenhouse gas budgets in other ways. In addition, the clearing of these forests also modifies climatically-important properties of the land surface such as surface albedo, evaporation rate and surface roughness. In this way, deforestation alters the amount of radiation reflected and absorbed at the earth's surface and, therefore, directly affects the radiation budget. The radiation budget is also indirectly affected by the changes in the hydrological cycle over areas of forest clearance.

In terms of greenhouse gas emissions, destruction of the world's forests is releasing, on balance, 1.6 ± 1.0 billion tonnes of carbon per year (Houghton *et al.* 1994, 1995)

and is thus the most important anthropogenic carbon source after the combustion of fossil fuels. It is still very difficult to produce an accurate estimate of the carbon balance due to the complexity of the carbon cycle and the inadequacy of available data. Because of this, none of the climate model studies reported so far has attempted to include effects on the carbon budget and hence the radiation balance in deforestation experiments, focusing instead on the direct and indirect effects of changes in land surface characteristics. Neither has any study attempted to simulate the gradual changes that, in reality, occur as tropical forest is removed and replaced. Instead, modellers have concentrated on comparing the long-term mean situation before and after an imposed deforestation, assessing effects on the radiation budget and the hydrological cycle.

On the basis of previous work, it can be concluded that replacing the tropical forest with grassland leads to three main changes in land surface properties and consequent effects on the local atmosphere:

- (i) the increased surface albedo directly causes a reduction in the surface net radiation balance;
- (ii) the reduction in the leaf area and stem area of the ambient vegetation reduce its water-holding capacity causing decreased interception of precipitation and reduced transpiration; and
- (iii) the relatively short and smooth grasslands have a lower surface roughness than forest and are, therefore, associated with lower surface friction.

The impact that these changes have on the broader climate can be difficult to unravel. For example, there are complex feedback processes involved in relating changes in surface evaporation to changes in total precipitation. These interactions involve increased surface albedo, reduced canopy interception and lower roughness length following deforestation and result in a number of modifications to the energy and moisture budget of the overlying atmospheric column and hence effects on surface temperature and precipitation (Figure 1).

A number of different kinds of climate models has been applied in order to identify the effects of deforestation on local, regional and global climate. Of these models, the most sophisticated form is the General Circulation Model (GCM) which provides a full three-dimensional representation of the climate system. Though they still possess many uncertainties, GCMs represent the best integration of the present level of understanding and development in meteorological science. Coupled with an ocean model, they can now produce realistic simulations of global climate change. In fact, even using the most complex model, quantitative estimation of the effects of large changes in terrestrial ecosystems on climate is a difficult task. The state of the climate system is determined by complex interactions between dynamical processes in the atmosphere and thermodynamic processes at the earth-atmosphere interface. For this reason, some authors have concluded that the earlier, less sophisticated model studies on the effects of deforestation on climate were generally inconclusive, giving, at times, conflicting results (Salati & Nobre 1991, Nobre *et al.* 1991).

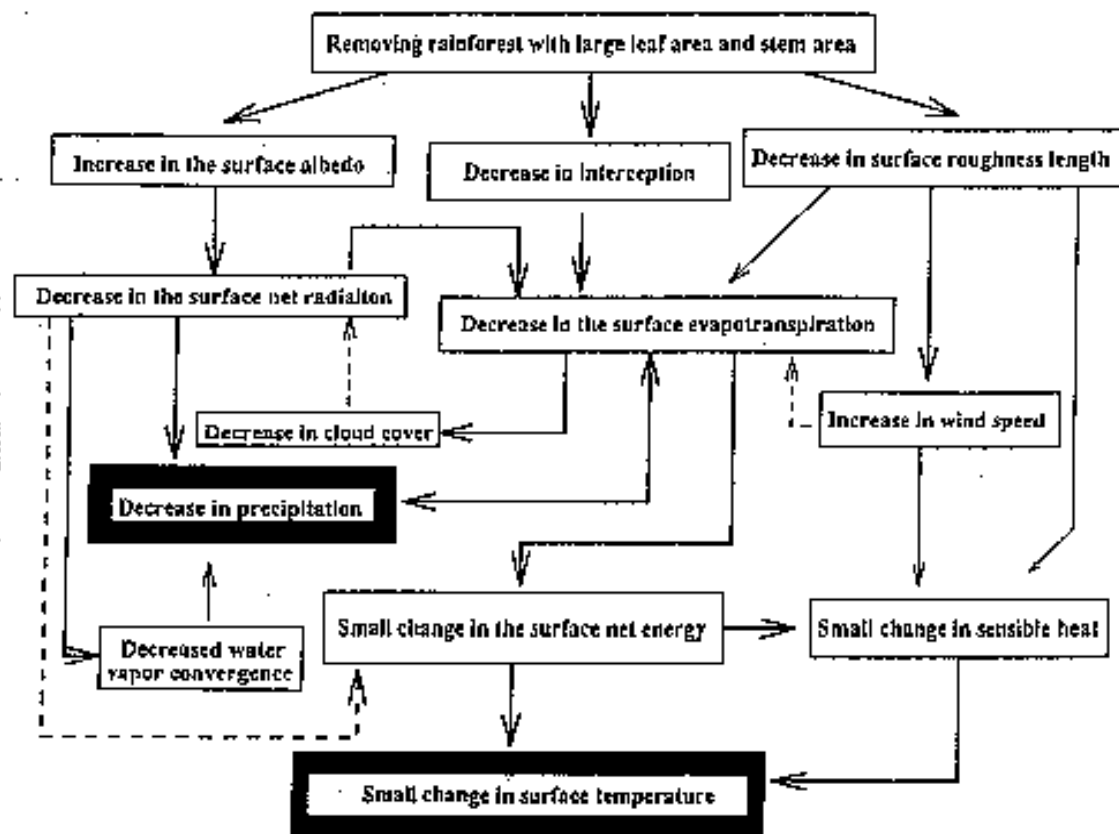


Figure 1. Schematic illustration of processes occurring after deforestation (from Zhang *et al.* 1996b)

Modelling tropical deforestation: overview of the early experiments

As reviewed in Henderson-Sellers (1987), early modelling studies of tropical deforestation were of two types, either simple energy-balance box models, providing only a crude representation of the world's geography, or low-resolution, three-dimensional GCMs. Potter *et al.* (1975), for example, used the Lawrence Livermore global two-dimensional statistical/dynamical zonal energy-balance box model of the atmosphere to investigate the climatic effect of tropical rain forest removal. They found general global cooling and, overall, a net reduction in global precipitation, resulting from a large reduction in tropical precipitation almost balanced by an increase in sub-tropical precipitation. Lettau *et al.* (1979) focussed on the Amazonian region using an energy-balance box model. They used hydrological and mean regional wind data to assess the possible impact of tropical deforestation on regional climate and predicted increases in both local temperature and rainfall. In the first deforestation experiment with a GCM, Henderson-Sellers & Gornitz (1984) used the Goddard Institute for Space Studies (GISS) model and attempted to maximize the possible impact of tropical deforestation by simulating the effects of extensive land cover change in the Amazon region. In the model, a total area of 494 million hectares of tropical moist forest was replaced by grass. The study predicted decreased precipitation with no significant temperature change, results similar to those of Potter *et al.* (1975) for the Amazonian region. The features, perturbation and results for the above experiments are summarised in Table 1.

Henderson-Sellers (1987) identifies some common themes that can be drawn from these early results. First, the results show changes in the surface hydrology are at least as important as changes in the surface albedo. Second, the results are sensitive to the parameterizations (descriptions and formulations of key climate processes) inherent in the models and to the information input to the models regarding land surface characteristics. Finally, while the local meteorological disturbance may be very large, the results of these early experiments are in dispute with regard to whether to expect detectable climatic change in any areas remote from the perturbation region.

Table 1. Early model simulations of tropical deforestation (modified from Henderson-Sellers, 1987)

Model Attributes	Potter <i>et al.</i> 1975	Lettau <i>et al.</i> 1979	Henderson-Sellers & Gornitz 1984
Features:			
Areal coverage	Global two-dimensional statistical dynamical (tropical deforestation)	Amazon Basin	Global (GCM) climate model (deforestation in the Amazonia)
Spatial resolution	10° latitude	5° longitude	8° latitude × 10° longitude
Perturbation:			
Albedo increase	0.18	0.03	0.06
Hydrological change	Dry case had increased runoff and evaporation	Evaporative flux from soil increased	Soil moisture capacity reduced from 200 to 30 cm and from 450 to 200 cm in upper and lower ground layers
Other changes	None	Infrared emissivity changed	Roughness length decreased
Results:			
Atmospheric circulation	Weakened Hadley cell	Assumed regional trade winds unchanged	Walker circulation showed no significant (> 1%) disturbance; No Hadley cell circulation change
Precipitation	Decrease 230 mm y ⁻¹ in 5° N - 5° S zone	Increase 75 mm y ⁻¹ (Amazonia)	Decrease 220 mm y ⁻¹ (Amazonia)
Surface temperature	Decrease 0.4°C in 5° N - 5° S zone	Increase 0.55°C	No significant change

GCM simulations of tropical deforestation

With more detailed land surface parameterization schemes and interacting thermodynamic, hydrodynamic and radiative processes, GCMs can now be used effectively for climate modelling as well as operational numerical weather prediction. The land surface and other parameterization schemes, which were highly simplistic in the early models, have been gradually improved. Currently, climate experiments

with GCMs are normally being run in coupled ocean-atmosphere mode, with at least a mixed-layer slab ocean. Previously, the simulation of ocean processes was crude and this seriously limited the realism and reliability of the early experiments. The new generation of GCMs has the potential for an effective examination of the consequences of the change in land surface boundary conditions following deforestation.

In the past two decades, the number of GCM experiments undertaken to study specifically the climatic effects of tropical deforestation has been limited. Most studies have tried to estimate the impact likely to occur as a result of tropical deforestation by maximizing the changes in surface characteristics (such as the area and the nature of the change) considered important to climate. These early simulations were designed to draw out the local- to regional-scale climate change following deforestation, and simulations of Amazonian deforestation typified modelling of these changes. Some model studies emphasized the importance of surface albedo, and others stressed the role of changes in surface roughness length and soil water capacity (*i.e.* the hydrological cycle) using improved canopy representation. Only recently have deforestation experiments been extended to Southeast Asia and tropical Africa in an attempt to understand the global climate response, with particular emphasis on the role of the large-scale dynamics of the climate system.

Historical review

We now review ten major deforestation experiments using GCMs, comparing features and perturbations, major developments and results. Starting with the first such experiment by Henderson-Seller and Gornitz (1984), we examine the development of model simulation of deforestation impacts by then considering studies by Dickinson and Henderson-Sellers (1988), Lean and Warrilow (1989), Shukla *et al.* (1990), Mylne and Rowntree (1992), Lean and Rowntree (1993), Henderson-Sellers *et al.* (1993), Polcher and Laval (1994a,b), McGuffie *et al.* (1995) and Zhang *et al.* (1996a, b).

Features and perturbations

We first describe the models used and the main features of the experimental design used in these ten studies. Henderson-Sellers and Gornitz (1984) used the Goddard Institute for Space Studies (GISS) finite difference model, with low spatial resolution (80° latitude by 100° longitude), to simulate large-scale clearing of the Brazilian Amazon forest by assuming its replacement with a grass/crop cover. The magnitude of this deforestation was said to be equivalent to 35-50 years of deforestation at the global rate estimated in 1984. A ten-year simulation was undertaken and the results from the last five years was compared with the last five years of a 20-year control run.

Dickinson and Henderson-Sellers (1988) used the CCMOB version of the National Center for Atmospheric Research Community Climate Model (NCAR-CCM), coupled with a biophysically based land-surface parameterization scheme [Biosphere-Atmosphere Transfer Scheme (BATS)]. This spectral model had a rhomboidal truncation at total wavenumber 15, approximately equivalent to a

resolution of 4.5° latitude by 7.5° longitude. (Spectral refers to the manner in which processes in the horizontal are modelled in a 'wave number' rather than latitude/longitude coordinate system, in keeping with the wave-like nature of the large-scale atmospheric circulation.) In their deforestation experiment, all the grid cells with vegetation classified as evergreen broadleaf tree in South America were modified to new vegetation having the characteristics of impoverished scrub-grassland, typical of deforested regions in Amazonia. At each of the modified grid locations, the soil texture was modified to that of finer type and the soil colour to that of a lighter type. A 13-month integration, initialized from the second year of a three-year control simulation, was undertaken giving a one-year simulation of deforestation.

Lean and Warrilow (1989) used the finite grid model of the United Kingdom Meteorological Office (UKMO) with a spatial resolution of 2.5° latitude by 3.75° longitude. They altered the surface characteristics, using the $1^\circ \times 1^\circ$ land-surface points from the Wilson and Henderson-Sellers (1985) data set, by replacing tropical forest or savannah with tropical pasture and integrated for three years for both the control and deforestation experiment.

Shukla *et al.* (1990) [also reported by Nobre *et al.* (1991)] used the Center for Ocean-Land-Atmosphere Interactions GCM (COLA-GCM), a modified version of the National Meteorological Center (NMC) global spectral model (R40), with a resolution of 1.8° latitude by 2.8° longitude. They modelled deforestation by changing a number of physical parameters in the Simple Biosphere (SiB) land-surface scheme [described by Sellers *et al.* (1986)]. Two one-year integrations, for control and deforestation, were carried out for the whole of the Amazon Basin.

Mylne and Rowntree (1992) worked with the same UKMO finite grid GCM used by Lean and Warrilow (1989), but with a simpler land-surface scheme. They used a simple 'bucket hydrology' to predict the soil moisture content of a single soil layer. Their experiments were designed to modify only the land-surface albedo, rather than simulate the effect of a full-scale deforestation. The albedo in two regions was modified; the Amazon and tropical Africa. Their control experiment imposed an albedo of 0.2 over all snow-free land with an eight-year integration time and compared the results with two other experiments with a nine-month integration time. One was a 'forest' experiment that had a snow-free albedo dependant on the vegetation and soil data sets, and the other was a 'woodland' experiment, where snow-free land with a tropical forest albedo was replaced by an albedo appropriate for grassland.

Lean and Rowntree (1993) used the same version of the UKMO finite grid GCM as Lean and Warrilow (1989) and Mylne and Rowntree (1992) to run experiments incorporating an improved representation of micrometeorological processes within the forest. Their three-year control and deforestation experiments provide a comprehensive analysis of simulated climate following the replacement of Amazonian forest by pasture.

Henderson-Sellers *et al.* (1993) used an updated version of CCM1 (CCM1-Oz). This is the NCAR spectral (R15) model at a resolution of 4.5° latitude by 7.5° longitude, coupled with a biophysically-based land-surface parameterization scheme, a modified version of BATS (BATS1E). With a mixed layer slab ocean, Henderson-Sellers *et al.* conducted six-year control and deforestation experiments for

three regions: the northern Amazon Basin, the southern Amazon Basin and Southeast Asia. In the deforestation experiments, the ecotype was changed from tropical moist forest to scrub grassland, the soil texture made finer and the soil colour made lighter. The six-year integration time was designed to accommodate an adequate time scale response to tropical deforestation, so that the climate is at full equilibrium rather than in transient response mode. The authors suggested that previous simulations, particularly those with a complex land-surface scheme, had relatively short integration times that did not allow the climate system to achieve a new equilibrium following a perturbation. Whether or not six years is adequate for equilibrium to be reached is an interesting point which we return to later in this review.

The LMD (Laboratoire de Météorologie Dynamique) grid-point GCM model with a 2.0° latitude by 5.6° longitude resolution coupled with the SECHIBA (Schématisation des Echanges Hydriques à l'Interface entre le Biosphère et l'Atmosphère) parameterization scheme was used by Polcher and Laval (1994a,b) for a global tropical deforestation experiment including South America (Amazonia), South East Asia (Indonesia) and tropical Africa. For the deforested case, the values in a vegetation parameter set associated with tropical rain forests were replaced with those for grassland in the tropical belt. The integration time for the control and deforestation in Polcher and Laval (1994a) was 13.5 months. In their other experiment, Polcher and Laval (1994b) used a longer integration - 11 years - for the control and deforestation to facilitate statistical analysis.

Following a similar approach to Henderson-Sellers *et al.* (1993), another experiment using a modified version of the CCM1 model (CCM1-Oz) at wave number 15 (R15) truncation equivalent to a 4.5° latitude by 7.5° longitude resolution) was carried out by McGuffie *et al.* (1995). This experiment also incorporated BATS1E, a mixed-layer slab ocean and a three-layer sea-ice model. A 14-year control integration was used, followed by a size-year deforestation experiment in which the tropical wet forest throughout the Amazon Basin, Southeast Asia and tropical Africa was replaced by scrub grassland.

Finally, the work by Zhang *et al.* (1996a,b) represents an extension of the experimental design and analysis of McGuffie *et al.* (1995), using the same model (CCM1-Oz) and land-surface parameterization scheme (BATS1E). However, their simulation times were longer, with a 25-year control integration and an 11-year perturbation integration in which the tropical forests in the Amazon Basin, South East Asia, and tropical African region were modified to grassland. Whereas Zhang *et al.* (1996a) focus their report on a detailed process-based analysis of the local changes within the forest region resulting from deforestation, the companion paper reports an evaluation of regional to global-scale changes in climate resulting from deforestation (Zhang *et al.* 1996b).

Table 2 summarizes the major features of the experiments described in this section and Table 3 documents major improvements in model formulation that have occurred, providing an indication of fruitful areas for further improvement.

Table 2. Model features of previous GCM studies of tropical deforestation

Reference	Henderson-Sellers & Gornitz (1984)	Dickinson & Henderson-Sellers (1988)	Lean & Warrilow (1989)	Sankla et al. ^a (1990)	Mylne & Rowntree (1992)	Lean & Rowntree (1993)	Henderson-Sellers et al. (1993)	Polcher & Laval (1994 a, b) ^b	McGuffie et al. (1995)	Zhang et al. (1996 a, b) ^c
Features										
GCM Version	GISS Grid	CCMOB Spectral (R15)	UKMO Grid	NMC Spectral (R40)	UKMO Grid	UKMO Grid	CCMI-O ₂ Spectral (R15)	LMD Grid	CCMI-O ₂ Spectral (R15)	CCMI-O ₂ Spectral (R15)
Resolution (lat × lon)	8° × 10°	4.5° × 7.5°	2.5° × 3.75°	1.8° × 2.8°	2.5° × 3.75°	2.5° × 3.75°	4.5° × 7.5°	2.0° × 5.5°	4.5° × 7.5°	4.5° × 7.5°
Land-surface representation	2-layer soil hydrology	BATS	4-layer soil temperature scheme & canopy interception	SIB	Bucket	4-layer soil temperature model & canopy interception	BATS	SECHIBA	BATS	BATS
Ocean	Computed SST but fixed ocean transport	Fixed SST	Fixed SST	December SST	Fixed SST	Fixed SST	Mixed layer (slab) ocean with 3-layer ice model sub-component & a standard q-flux	Fixed layer	Mixed layer ocean with 3-layer ice model but improved q-flux correction	Similar to McGuffie et al. (1995)
Cloud	(not given)	(not given)	(not given)	Fixed seasonal means	Fixed zonal means	Include cloud-water variable	Include parameterization of liquid water clouds	Include parameterization of liquid water clouds	Include parameterization of liquid water clouds	Similar to McGuffie et al. (1995)
Time of Integration:										
control	20 yr.	3 yr.	3 yr.	1 yr.	3 ^d yr.	3 yr.	6 yr.	11 yr.	14 yr.	25 yr.
deforestation	10 yr.	1 yr.	3 yr.	1 yr.	9 ^d mth.	3 yr.	6 yr.	11 yr.	6 yr.	11 yr.

^aReported in more detail in Nabre et al. (1991).^bBoth '1994a' & '1994b' have the same features but the given time of integration is referred to '1994b' (as '1994a' was integrated for 13.5 months only).^cBoth '1996a' & '1996b' are referred to the same experiments with both having similar features and integration time.^dControl experiment here is the experiment with imposed albedo of 0.2 over all snow-free land and was integrated for 8 years (However, means used for 9 months only) and compared with forest and 'woodland' experiments.^eInitialised from 1 December of the first year of the control run.

Table 3. Major model developments and improvements in previous studies of tropical deforestation

Model	Reference	Development/Improvement
GISS	i. Henderson-Sellers & Gornitz (1984)	Designed specifically to permit long-period climatic integrations and computations of many parameters such as sea-ice, cloud cover and type and also ocean surface temperature. Their ocean sub-model included ocean temperature calculation, fixed ocean transports and simulation of sea ice to allow investigation of the global teleconnections.
NMC	i. Shukla <i>et al.</i> (1990)	The first highest-resolution GCM with deforestation. Included efficient radiation scheme to permit the simulation of diurnal cycle, radiative transfer calculations for the longwave component of terrestrial radiation, and modified convection and large-scale precipitation. Used parameterization for the transfer of shortwave radiation, vertical diffusion of momentum, heat and moisture in the planetary boundary layer.
UKMO	i. Lean & Warrilow (1989)	Improved model with cloud prediction and land-surface schemes. Employed a four-layer soil temperature calculation, a parameterization of canopy interception of precipitation and its reevaporation, and calculation of surface and sub-surface runoff. Included a statistical parameterization of sub-grid-scale variability in precipitation.
	ii. Mynne & Rowntree (1992)	Despite a simple land-surface scheme, this model was specially improved to study the effects of albedo change associated with tropical deforestation. The albedo for any grid square was the weighted average of the albedo appropriate to the average vegetation type and the average soil colour.
	iii. Lean & Rowntree (1993)	Modification of sub-grid scale processes to improve the representation of micrometeorology within the model. Improved the canopy representation particularly on rainfall interception processes, the treatment of surface runoff was more realistically formulated.
LMD	i. Polcher & Laval (1994 a, b)	No report of major change. However, the 11-years integration time first introduced in their experiment [cf. Polcher & Laval (1994b)] can be regarded as a significant improvement that had facilitated an extensive statistical analysis related to modelling experiments of tropical deforestation.
CCM	i. Dickinson & Henderson-Sellers (1988)	The introduction of a coupled atmosphere-biosphere model (CCMOB & BATS). Included a non-linear parameterization of atmospheric vertical diffusion and diurnal as well as annual cycles in solar radiation. Added geographical distribution of vegetation type, soil colour and soil texture. The model's surface-runoff formulation was modified for runoff to decrease less rapidly with drying of the surface layer.
	ii. Henderson-Sellers <i>et al.</i> (1993)	New improved clouds parameterization and radiation updates. Simulations accounted full seasonal and diurnal cycles. The first deforestation simulation that incorporated more detail ocean description with ice model subcomponent and q-flux to correct for ocean advection of energy and the prescription of a fixed mixed layer depth (50 m).
	iii. Mc Guffie <i>et al.</i> (1995)	Improved the formulation for the q-flux correction used in the slab ocean model for ocean advection of energy from the same version used by Henderson-Sellers <i>et al.</i> (1993).
	iv. Zhang <i>et al.</i> (1996 a, b)	Extended the same scenario as that of Mc Guffie <i>et al.</i> (1995) but with the use of longer integration time to cater for evaluation of regional to global-scale changes from deforestation beyond their detailed process-based analysis of the local changes.

Principal findings and discussion

Impact of deforestation on local and regional climate

All ten experiments covered the Amazon Basin and we can, therefore, make a comparison of local to regional climatic changes following deforestation based on these results. The findings are summarized in Table 4. There is some consistency as far as discernible impacts on local and regional climate are concerned despite the considerable differences in the GCM dynamical structures, land surface representation, ocean and cloud description and the length of the simulations. With some exceptions, most of the impacts on climate are outside the range of natural variability. Nevertheless, there are many uncertainties with respect to the magnitude and direction of changes. The simulations, especially those employing different land-surface schemes, give different results for the effect of tropical deforestation on local climate.

The experiments of Henderson-Sellers and Gornitz (1984) and Mylne and Rowntree (1993) did not find an overall significant change in temperature over Amazonia. The experiment reported by Mylne and Rowntree (1993) found an annual average change in temperature of -0.11°C , but this value is probably too small to be significantly different from the natural variability. Both Henderson-Sellers and Gornitz (1984) and Mylne and Rowntree (1993) did identify considerable decreases in annual average precipitation, evaporation and moisture flux convergence on a local to regional scale, similar to most of the other experiments. In general, moisture flux convergence decreases in the Amazon, where the reduction in evaporation is less than the reduction in precipitation. Only the Dickinson and Henderson-Sellers (1988) and Polcher and Laval (1994a) results were somewhat inconsistent with those from other experiments.

All the simulations that covered Southeast Asia (Henderson-Sellers *et al.* 1993, Polcher and Laval 1994b, McGuffie *et al.* 1995, Zhang *et al.* 1996a) showed only minor impacts on local and regional climate resulting from deforestation in this region. Overall, the regional climatic impacts of deforestation were smaller over South East Asia than over the Amazon. In some cases, the responses were reversed. Because of the monsoon circulation over South East Asia and the warm ocean temperatures, especially in the western Pacific Ocean, the impacts of deforestation in South East Asia differ from those in the Amazon. The results of Zhang *et al.* (1996a) show that the Southeast Asia monsoon is much less sensitive to deforestation than to low-level flow over South America. McGuffie *et al.* (1995) do, though, describe a possible impact on the monsoon system over Southeast Asia. For South East Asia, all results showed that total precipitation and evaporation are very little affected by the imposed deforestation. In terms of temperature, the change was different from that over the Amazon Basin, with South East Asia exhibiting discernible decreases in ground surface temperature following deforestation (Henderson-Sellers *et al.* 1993, McGuffie *et al.* 1995, Zhang *et al.* 1996a).

Table 4. Comparison of annually averaged climatic changes for the Amazon region from previous GCM simulations of tropical deforestation

Reference:	Henderson-Sellers & Connitt (1984)	Dickinson & Henderson-Sellers (1988)	Lean & Warrilow (1989)	Shukla <i>et al.</i> ^a (1990)	Myles & Rowntree (1992)	Lean & Rowntree (1993)	Henderson-Sellers <i>et al.</i> (1993)	Polcher & Laval (1994 <i>a, b</i>) ^b	McGuffie <i>et al.</i> (1995)	Zhang <i>et al.</i> (1996 <i>a, b</i>) ^c
Version of GCM	GISS Grid 8° × 10°	CCMOB Spectral (R15) 4.5° × 7.5°	UKMO Grid 2.5° × 3.75°	NMC Spectral (R40) 1.8° × 2.8°	UKMO Grid 2.5° × 3.75°	UKMO Grid 2.5° × 3.75°	CCML-Oz Spectral (R15) 4.5° × 7.5°	LMD Grid 2.0° × 5.6°	CCML-Oz Spectral (R15) 4.5° × 7.5°	CCML-Oz Spectral (R15) 4.5° × 7.5°
Annual average change in temperature [ΔT in °C]	0	+3	+2.4	+2	-0.11	+2	+0.6	+3.8	+0.3	+0.3
Annual average change in precipitation [ΔP in mm]	-220	0	-490	-640	-335	-295	-588	+394	-437	-402 ^d -300 ^e -96 ^f
Annual average change in evaporation [ΔE in mm]	-164	-200	-310	-500	-176	-200	-232	-985	-231	-222
Annual average change in moisture flux convergence [(ΔP-ΔE) in mm]	-56	+200	-180	-140	-159	-95	-356	+1380	-206	-180

^aNobre *et al.* (1991) reports in more detail^bfrom total annual precipitation^cfrom annual convective precipitation^dfrom annual large-scale precipitation

As indicated by Henderson-Sellers *et al.* (1993), and supported by subsequent studies (*e.g.* Polcher & Laval, 1994*b*; McGuffie *et al.* 1995, Zhang *et al.* 1996*a*), investigation of precipitation is difficult in the context of deforestation in Southeast Asia due to the very high annual rainfall. This is particularly a problem in the wet season. There is strong forcing of rainfall by orographic uplift and a ready supply of moisture from the adjacent tropical ocean. The tropical forest plays a lesser role in producing the high rainfall over the South East Asia region than in the Amazon region, rendering identification of deforestation-induced change difficult. Although the experiments show that some point values of precipitation over South East Asia alter in the deforested case, there was no clear change to the basic spatial pattern of rainfall as only a few of the point deviations are statistically significant. Similarly, reductions in total precipitation exist almost throughout the year but, with only a few statistically significant, there is no significant seasonal impact following deforestation (Henderson-Sellers *et al.* 1993, McGuffie *et al.* 1995, Zhang *et al.* 1996*a*). For example, Henderson-Sellers *et al.* (1993) found a significant decrease in precipitation in only two of the wet season months (June and July).

In most experiments, deforestation in tropical Africa also led to only minor effects on local and regional climate in this region compared with the effect over the Amazon (Polcher & Laval 1994*b*, McGuffie *et al.* 1995, Zhang *et al.* 1996*a*). On the other hand, Mylne and Rowntree (1992) found that percentage climate changes over tropical Africa were even greater than over the Amazon Basin. Zhang *et al.* (1996*a*) showed that deforestation in Africa results in cooling of the land surface, similar to the simulations in South East Asia where the ground surface temperature decreased slightly.

The nature of the changes in albedo, roughness length and surface hydrological characteristics used in defining the deforestation process are very important in determining the local to regional effects of tropical deforestation. These model experiments show that the impacts simulated in response to tropical deforestation in the Amazon Basin, South East Asia and tropical Africa are regionally dependent. This occurs because the response to deforestation is determined by the nature of the local climate system and atmospheric circulation.

Impact of deforestation on global climate

The first GCM experiment of Henderson-Sellers and Cornitz (1984), designed specifically to investigate global teleconnections, did not suggest any discernible modification of global climate despite the exaggerated nature of the input perturbation (*cf.* Table 1). It appears that any model with a land surface that neglects the canopy hydrology, such as this, cannot successfully represent changes in regional and global circulation. Some of the later GCM simulations (*e.g.* Shukla *et al.* 1990, Henderson-Sellers *et al.* 1993) hinted that climatic disturbances distant from the areas of tropical deforestation may occur following. Impacts on the general circulation of the atmosphere can be detected in the longitudinal Walker and latitudinal Hadley circulations of lower latitudes. These conclusions are supported by the very latest model experiments which do suggest that tropical deforestation may excite large-scale or global-scale

atmospheric impacts. With a coupled atmosphere and biosphere to give a more realistic canopy hydrology, and improved experimental design such as longer integration times, the more recent model simulations have a credibility perhaps lacking in some of the earlier experiments.

The results of McGuffie *et al.* (1995) and Zhang *et al.* (1996a, b), encompassing deforestation of all three regions (Amazonia, tropical Africa and Southeast Asia), are particularly interesting in the context of global climate. McGuffie *et al.* (1995), as well as describing impacts on the monsoon system over Southeast Asia following deforestation, find small but statistically significant changes in climate in middle and high latitudes. Modification of the model surface parameters to simulate tropical deforestation produces significant modifications of both the Hadley and Walker circulations (Figure 2), which are associated with changes distant from the region of deforestation. Zhang *et al.* (1996b) proposed a mechanism for the spread of

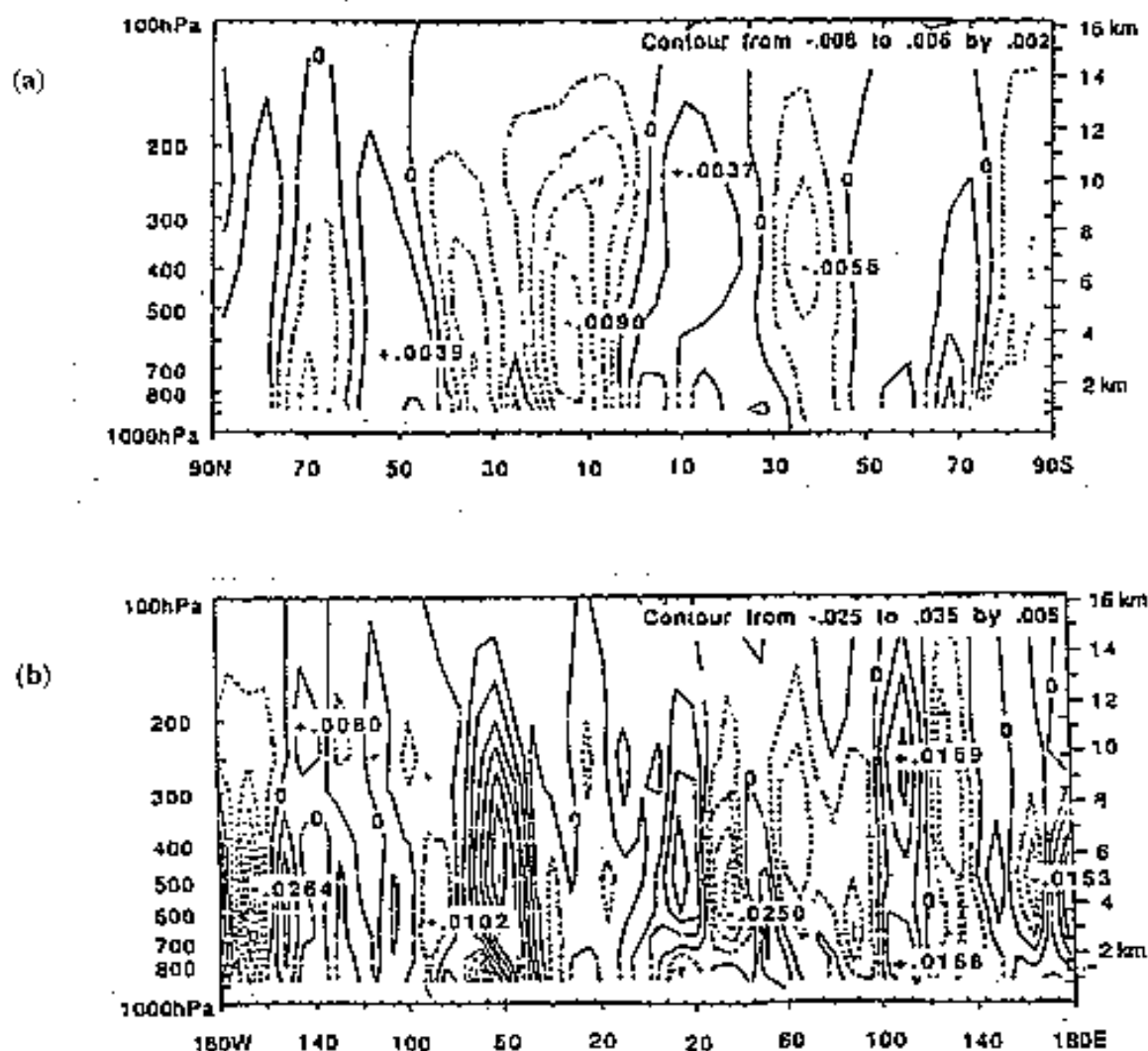


Figure 2. Changes (*i.e.* difference between deforestation and control experiment) of (a) Hadley Circulation [zonal average of vertical velocity from 180° W to 80° W (Pa s^{-1})] and (b) Walker Circulation [meridional average of vertical velocity from 9° S to 9° N (Pa s^{-1})] in October (from McGuffie *et al.* 1995)

disturbances arising from tropical deforestation to middle and high latitudes based on Rossby wave propagation. This is similar to the mechanisms associated with the extratropical influence of ENSO events which facilitate the dispersion of the tropical disturbances to high latitudes. Hence, Zhang *et al.* (1996b) not only suggest that it is possible for tropical deforestation to produce global-scale impacts, but offer a mechanism to explain how this might occur.

Improving model simulations of the effects of tropical deforestation

In assessing the results discussed above it must be remembered that there are inherent uncertainties in these simulations which may affect both the magnitude and the direction of the predicted consequences of tropical deforestation. These shortcomings need to be addressed through the refinement of both models and experimental designs. The need to improve modelling of the effects of tropical deforestation has received much attention from modellers. For example, as stated by McGuffie and Henderson-Sellers (1997), future challenges include the simulation of the dynamic processes associated with vegetation destruction and (potential) regeneration.

One major criticism of previous studies is that they are all unrealistic in terms of the change in land cover used to force the model. Despite the word 'simulation' used here and in the original publications in describing previous model experiments, all of these experiments were strictly 'sensitivity' rather than true simulation experiments. This is because all of the studies tried to generate an unequivocal model response, or estimate the maximum impact likely to occur as a result of tropical deforestation, by maximizing the perturbation to land surface boundary condition (*i.e.* surface vegetation, soil moisture, albedo, etc.). These perturbations were, in fact, much larger than the observed changes. Simulation experiments should be conducted by imposing a known and realistic, *i.e.* observable, perturbation on the model.

Considering this same point from a different perspective, it is fair to say that the GCM experiments undertaken to date reveal a great deal about the sensitivity of each model to changes in its particular land-surface boundary conditions following deforestation. Yet the models are probably not yet suited to climate prediction per se and, without much further development, cannot provide information at a resolution appropriate to environmental monitoring and management.

Prominent amongst the many challenges facing modellers wanting to use GCMs as a more reliable tool to study the impacts of tropical deforestation are the development of improved biophysical models and new techniques for regional climate assessment. For example, the next generation of land-surface parameterizations should include more comprehensive models of microclimate. In the longer-term, complete interactive links to biogeochemistry and terrestrial ecology could be usefully incorporated into such models, permitting simulation of time-dependent deforestation and regeneration as well as the analysis of trace gas contributions to the change in the radiation balance.

Finally, there are critical issues of scale to be considered. The limited integration time of many previous experiments is a shortcoming that is only slowly being addressed and does render many results open to doubt. Longer integration times are essential in climate-oriented studies. Given technical constraints, this requirement may cut across a parallel need to improve the spatial resolution of the model experiments. The limited spatial resolution of even the most sophisticated GCM is a serious deficiency when the key concern lies in analysing deforestation-related processes which, at the outset, have a characteristic spatial scale well below that of the models and have to be parameterized. The application of high resolution general circulation models in limited area mode (regional down to mesoscale) appears likely to prove a productive way forward.

The current project

The aim of the current project is to define the potential effect of deforestation in Malaysia on local, regional and global climate, both in the present-day and under global warming conditions. Site studies in Malaysia indicate that immediately after forest clearance, the local microclimate changes though the magnitude of the change decreases through time as vegetation regrows in the humid, tropical environment. However, the results from these studies cannot be generalized because they are site-specific and understanding of the effects on regional and global climate resulting from deforestation in Malaysia is virtually non-existent.

As apparent in the preceding review, regional studies of the large-scale impact of deforestation have considered land-cover change over Southeast Asia as a whole and the results have been somewhat equivocal. There is a clear need to meaningfully and accurately quantify the effects of changing land-use in the tropical forests of the region on local, regional and global climate. There is also no doubt that the best way to address the problem is to use the most sophisticated general circulation models. A major weakness of any general circulation model, though, in addressing regional or local problems is that the spatial resolution is very coarse. In order to meaningfully simulate the effect of deforestation in Malaysia and neighbouring areas, the most practical approach is to make use of a limited area model (LAM) which covers a restricted domain (geographical area) but at a relatively high spatial resolution.

This project uses the Unified Model, a well-established GCM developed by the United Kingdom Meteorological Office, implemented as a limited area model centred on Malaysia. The limited area model will be run to derive an unperturbed climate of the region and then in a series of perturbation experiments in which the land cover of the region is changed. The project is on-going and is expected to be completed by the end of 1999.

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References

- DICKINSON, R. E. & HENDERSON-SELLERS, A. 1988. Modelling tropical deforestation: a study of GCM land-surface parameterisations. *Quart. J. Roy. Meteor. Soc.* **114**: 439-62.
- HENDERSON-SELLERS, A. & GORNTZ, V. 1984. Possible climatic impacts of land cover transformations, with particular emphasis on tropical deforestation. *Climatic Change* **6**: 231-257.
- HENDERSON-SELLERS, A. 1987. Effect of change in land use on climate in the humid tropics. Pp 463-493, in Dickinson, R.E. (Ed.) *The Geophysics of Amazonia*, John Wiley and Sons, Chichester.
- HENDERSON-SELLERS, A., DICKINSON, R. E., DURBINCE, T. B., KENNEDY, P. J., MCGUFFIE, K. & PITMAN, A. J. 1993. Tropical deforestation: modeling local- to regional-scale climate change. *J. Geophys. Res.* **98**: 7289-7315.
- HOUGHTON, J. T., MEIRA FILHO, L. G., BRUCE, J., HOESUNG LEE, CALLANDER, B. A., HAITES, U., HARRIS, N. & MASSELL, K. (eds.) 1994. *Climate Change 1994: Radiative Forcing of Climate Change and an Evaluation of the IPCC IS92 Emission Scenarios*. 339 pp. Cambridge University Press, Cambridge.
- HOUGHTON, J. T., MEIRA FILHO, L. G., CALLANDER, B. A., HARRIS, N., KATTENBERG, A. & MASSELL, K. (eds.) 1995. *Climate Change 1995: The Science of Climate Change*. 572 pp. Cambridge University Press, Cambridge.
- LEAN, J. & WARRILLOW, D. A. 1989. Simulation of the regional climatic impact of Amazon deforestation. *Nature* **342**: 411-13.
- LEAN, J. & ROWNTREE, P. R. 1993. A GCM simulation of the impact of Amazonian deforestation on climate using an improved canopy representation. *Quart. J. Roy. Meteor. Soc.* **119**: 509-530.
- LETTAU, H., LETTAU, K. & MOLION, L. C. B. 1979. Amazonia's hydrologic cycle and the role of atmospheric recycling in assessing deforestation effects. *Mon. Wea. Rev.* **107**: 227-238.
- MCGUFFIE, K., HENDERSON-SELLERS, A., ZILANG, H., DURBINCE, T. B. & PITMAN, A. J. 1995. Global Climate sensitivity to tropical deforestation. *Global Planet. Change* **10**: 97-128.
- MCGUFFIE, K. & HENDERSON-SELLERS, A. 1997. *A Climate Modelling Primer* (2nd Edition). 253 pp. John Wiley and Sons, Chichester.
- MYNNE, M. F. & ROWNTREE, P. R. 1992. Modelling the effects of albedo change associated with tropical deforestation. *Climatic Change* **21**: 317-43.
- NOBRE, C. A., SELLERS, P. J. & SHUKLA, J. 1991. Amazonian deforestation and regional climate change. *J. Climate* **4**: 957-988.
- POLCHER, J. & LAVAL, K. 1994a. The impact of African and Amazonian deforestation on tropical climate. *J. Hydrol* **155**: 389-405.
- POLCHER, J. & LAVAL, K. 1994b. A statistical study of the regional impact of deforestation on climate in the LMD GCM. *Climate Dynamics* **10**: 205-219.
- POTTER, G. J., ILLISAESSER, H. W., MACCRACKEN, M. G. & LUTHER, F. M. 1975. Possible climatic impact of tropical deforestation. *Nature* **258**: 697-698.
- SALATI, E. & NOBRE, C. A. 1991. Possible climatic impacts of tropical deforestation. *Climatic Change* **19**: 177-196.
- SELLERS, P. J., MINTZ, Y., SUD, Y. C. & DALCHER, A. 1986. A simple biosphere model (SiB) for use with general circulation models. *J. Atmos. Sci.* **43**: 505-531.
- SHUKLA, J., NOBRE, C. & SELLERS, P. 1990. Amazon deforestation and climate change. *Science* **247**: 1322-1325.

- WILSON, M. F. & HENDERSON-SELLERS, A. 1985. A global archive of land cover and soils data for use in general circulation climate models. *J. Climatol* 5: 119-143.
- ZHANG, H., HENDERSON-SELLERS, A. & MCGUFFEE, K. 1996a. Impacts of tropical deforestation. Part I: Process analysis of local climatic change. *J. Climate* 9: 1497-1517.
- ZHANG, H., MCGUFFEE, K. & HENDERSON-SELLERS, A. 1996b. Impacts of tropical deforestation. Part II: The role of large-scale dynamics. *J. Climate* 9: 2498-2521.

THE STATUS AND BENEFITS OF EX-SITU BIODIVERSITY CONSERVATION AREAS IN MALAYSIA

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Ex-situ conservation is an important effort towards maintaining biological diversity given the ever increasing rate of development Malaysia is currently undergoing. The unknown potentials of genes and species are difficult to estimate but they can be of high value. The many benefits of biological diversity and its importance for development indicate why ex-situ conservation is undertaken. It is a proactive effort which seeks to meet peoples' needs from biological resources while simultaneously ensuring the long-term sustainability of Malaysia's biotic wealth. Collections at ex-situ sites in Malaysia are made with the intention of safeguarding the genetic and species diversity of the cultivated and domesticated species and their wild relatives. There is already a large collection of fruit, orchid, medicinal plant and timber species at the respective sites. These were obtained either directly from the wild or from farmers' farms. The number of collected species at each site reflects the level of genetic and species variations that exist within and between the populations of the commodities. Findings from the study showed that orchids have greater species diversity followed by timber, fruit and finally, medicinal plant species. Apart from collection, research and development (R&D) activities are also undertaken. However, these activities are limited only to a few institutions and so far the results of these efforts, in terms of releases of new varieties and hybrids, are still very low.

Key words: Ex-situ - conservation - biodiversity and benefits

Introduction

Biological diversity or biodiversity is used to describe the number, variety and variability of living organisms. It can also be described as the totality of genes, species and ecosystems in a region (Anonymous 1992). While it is universally agreed that the most effective and efficient mechanism for the conservation of biodiversity is habitat protection, it is also acknowledged that off-site or ex-situ facilities can be critical components of a comprehensive conservation programme (Conway 1988, Ashton 1988).

Ex-situ conservation maintains species outside their original habitats in facilities such as zoos, rehabilitation centres, captive breeding centres, botanical gardens, seed genebanks, in-vitro genebanks and field genebanks. It provides long term storage, analysis, testing, propagation of threatened rare species of plants and animals and their propagules, and is a major repository of genetic material for future breeding programmes of domestic species.

Research efforts on the collections have contributed towards the improvement and sustainable development of agriculture. There are several activities undertaken before naturally occurring plant genetic resources are converted into economically valuable plant improvements. Firstly, collection activities are required to place plant genetic resources in accessible form *i.e.* ex-situ collection. Then evaluation activities are required to classify and identify potentially valuable plant genetic resources. These activities range from phenotype evaluation and progeny evaluation to DNA and marker analysis. Pre-breeding activities are required to systematically incorporate original genetic resources (land-races and wild species) into advanced lines suited for breeding. Breeding activities are then required to produce new varieties of crops. These new varieties are the ultimate objective of the breeding activities.

The most extensive efforts in ex-situ conservation have been applied during the past 20 years to crop species (mainly food plants), to some trees, and to pasture plants by the Food and Agriculture Organisation of the United Nations (FAO), the Consultative Group on International Agricultural Research (CGIAR) including the International Board on Plant Genetic Resources (IBPGR), 12 other international agricultural research centres throughout the world, 150 genebanks around the world and other crop genetic resource centres (McNeely *et al.* 1990). According to Nijar (1994), global holdings of crop germplasm in ex-situ collections (including wild relatives) amount to a massive 4.2 million accessions, of which over two million accessions are cereals and about half a million, food legumes. About 53 per cent of the accessions are located in developed countries and another 12 per cent in international centres which are controlled by countries of the North. The remaining 35 per cent are located in developing countries.

Malaysia signed the Convention on Biological Diversity in June 1992 (Ayad in Krattiger *et al.* 1994). Article 9 of the Convention stresses the importance of ex-situ conservation, predominantly for the purpose of complementing in-situ measures. Malaysia already has 26 ex-situ areas and their establishment has enabled the direct handling of the two important aspects of biodiversity conservation *i.e.* genetic and species diversity.

Objectives

The general objective of this study is to determine the current status and to identify the values generated by the ex-situ biodiversity conservation areas in Malaysia.

The specific objectives of this paper are:

- i) to determine the status of fruits, orchids, medicinal plants and timber species diversity in ex-situ areas, and
- ii) to identify the benefits generated by the ex-situ biodiversity conservation areas.

Methodology

Pearce (1993) mentioned that the conservation benefits of biodiversity are measured by Total Economic Value (TEV). This can be represented as follows:

$$\begin{aligned} \text{TEV} &= \text{UV} + \text{NUV} \\ \text{where } \text{UV} &= \text{DUV} + \text{IUV} + \text{OV} \text{ and} \\ \text{NUV} &= \text{EV} + \text{BV} \end{aligned}$$

TEV comprises of Use Value (UV) and Non-Use Value (NUV). UV can be divided into three *i.e.* Direct Use Value (DUV), Indirect Use Value (IUV) and Option Value (OV), while NUV refers to the Existence Value (EV) and Bequest Value (BV). DUV refers to the harvested products such as timber and non-timber products, medicinal plants, plant genetic resources for scientific research, and also non-consumptive use such as recreation, education and tourism. IUV corresponds to the ecologist's concept of 'ecological functions', where watersheds are protected, carbon dioxide produced during power generation is absorbed and stored, and also gains from television and other media coverage of aspects of biodiversity. OV relates to the amount that individuals would be willing to pay to conserve biodiversity for future use *i.e.* the potential value of biodiversity in the future. EV refers to the intrinsic value unassociated with actual or potential use or the vicarious value attached by individuals to the continued existence of species such as the African elephant or the Blue whale. BV measures the benefit accruing to any individual from the knowledge that others might benefit from a resource in the future.

The more relevant value for ex-situ conservation would be UV, particularly DUV, where large collection of plant genetic resources can be utilised for scientific research, as well as for recreation, education and tourism. Agriculture research has proven that by increasing crop yields on existing land, it reduces the pressure to expand production into the wild ecosystems, thus indirectly protecting the ecosystems' diversity (IUV). Another relevant value which is difficult to measure would be OV which may include new bio-types of pest and pathogens (now unforeseen) to be addressed through genetic host plant resistance (HPR) breeding programmes, resulting in genetic resources not currently valued to take on value.

Results and discussion

Quantitatively, very little is known about the results of the investment in ex-situ conservation efforts. This study presents a first step towards answering this question. Species diversity represents the diversity among the species in collection. The development and operating costs are included where they are available to indicate the costs incurred in setting up and maintaining ex-situ areas. The number of visitors to these sites reflects the demand for the products of ex-situ conservation efforts. The number of publications, releases of new varieties/hybrids and the discovery of new species can be used as measures of the benefits of ex-situ conservation efforts. The

results of the survey on 21 ex-situ areas conducted between August and November 1995 are presented below.

Status

The status of plant species diversity in various ex-situ areas are presented by commodity groupings, namely, fruits, orchids, medicinal plants and timber in Tables 1 to 4 respectively. The number of species, accessions and wild species are presented according to data supplied by respondents.

Fruits

Table 1 displays the fruit species diversity in 17 ex-situ areas. The Malaysian Agricultural Research and Development Institute's (MARDI) fruit division in Serdang, Selangor, has the highest number of fruit species in collection among the institutions surveyed. Of these species, numbering 153, all originated from the wild. About 95 per cent of the collections are maintained in the field genebank and the remainder in seed genebank (papaya). Almost all the collections are from within Malaysia. The land area allocated strictly for fruits is 160.5 acres.

The Botanical Garden in Pulau Pinang, formed in 1884 during British rule, is the oldest ex-situ conservation area in this country. While it collects all kinds of plant species, only 20 per cent of its collection are fruit species. There are 142 fruit species with a large number of accessions (619) but only 11 species are wild. About 90 per cent of the collections are from Malaysia, obtained through exploration at in-situ areas, and 10 per cent are gifts from abroad. The land area allocated to the Botanical Garden is 20 acres, but it has an adjoining forest area of about 52 acres. The development cost for 1995 alone amounted to RM581,814.

The Agricultural Park in Tenom, Sabah, formed in 1971 also collects all kinds of plant species. Almost all the collections are in the field genebank. About 60 per cent of the collections are from within Malaysia and 40 per cent are foreign, obtained via exchanges with international agencies. There are 88 fruit species (67 wild) in collection with 241 accessions. The total land area for the collection is 300 acres. The park does not conduct R & D but the agriculture research station adjacent to it, uses the collections for R&D. The total project cost over a five year period (1993-1997) was RM65 million.

The Agriculture Research Centre (ARC) in Semonggok, is the main research centre in Sarawak for a wide range of perennial and short-term crops. It has a total land area of about 500 acres within the gazetted Semonggok Forest Reserve. However, the area reserved for plant and fruit collections is about 47 acres. It has 75 different species in collection, where 22 are wild with 337 accessions. About 80 per cent of the collection are from Malaysia and 20 per cent are from overseas. The development cost in 1995 was RM60,000.

Table 1. Fruit species diversity

Respondents	No. of species	No. of accessions	No. of wild species
Malaysian Agricultural Research and Development Institute (MARDI), Fruits Division, Serdang	153	159	153
Botanical Garden Pulau Pinang	142	619	11
Agriculture Park, Tenom, Sabah	88	241	67
Agriculture Research Centre (ARC), Semonggok, Sarawak	75	387	22
Forest Research Institute of Malaysia (FRIM), Kepong	56	241	43
Layar Integrated Agri. Station, Betong, Sri Aman, Sarawak	54	1518	53
Department of Agriculture, Kuala Terengganu	54	230	0
Department of Agriculture, Ulu Dusun, Sandakan	37	912	37
Forest Research Centre (FRC), Sandakan, Sabah	35	35	34
Kinabalu Mountain Garden, Taman Sabah	30	56	14
Univ. Putra Malaysia (UPM), Serdang, Selangor	15	292	0
Department of Agriculture, Serdang, Selangor	8	197	0
Department of Agriculture, Teluk Chengai, Kedah	7	49	0
Univ. Kebangsaan Malaysia (UKM), Bangi, Selangor	4	140	0
Department of Agriculture, Pulau Gadong, Melaka	1	25	0
Department of Agriculture, Kota Bharu, Kelantan	1	2	0
Department of Agriculture, Seremban, N. Sembilan	1	2	0

The Forest Research Institute of Malaysia (FRIM) in Kepong covers an area that includes the natural lowland and hill dipterocarp forest, plantations and arboreta. The plant collection area of about 58 acres includes the dipterocarp arboretum (16 ac), the main non-dipterocarp arboretum (27 ac), a special area for gamopetalous dicotyledonous families (3.7 ac), an indigenous fruit tree collection (1.5 ac), a monocotyledon garden (3.7 ac) and a gymnosperm arboretum (6.2 ac). About 85 per cent of the collections are from in-situ areas in Malaysia. It currently has about 56 fruit species, 43 being wild with 241 accessions.

The Integrated Agricultural Research Station in Laya, Sarawak emphasizes an integrated approach to crop, livestock and fisheries development. The facilities at the station are developed to cater mainly for training and production, with limited research work. The station has a total area of 716 acres and about 69 acres are allocated for the fruit collection. Even though the station was recently established (1992), it has 54 fruit species (153 wild) with 1,518 accessions. About 90 per cent of the collections are from in-situ areas in Malaysia.

The Department of Agriculture Station in Kuala Terengganu has about 62.5 acres reserved for the fruit collection. It currently has 54 species collected from farmers (56%), in-situ areas (32%) and gifts from other domestic agencies (12%). The station started the collections in 1990 with a development expenditure of RM130,725.

The Department of Agriculture in Ulu Dusun, Sabah has about 50 acres reserved for its fruit germplasm collection out of a total area of 3,340 acres. The number of species collected amounts to 37 with 912 accessions. All the species in the collection are wild. The development expenditure for fruits alone in 1994 amounted to RM33,000.

The Forest Research Centre (FRC) at Sepilok, Sabah, which has a land area of 264 acres, has allocated about 173 acres for an arboretum to cater for the naturally occurring forest species and other indigenous species. There are 35 species of fruit trees in the collection where 34 are wild species.

The Kinabalu Mountain Garden of Taman Sabah situated at an altitude of 1,560 metres above sea level, has an area of 5 acres reserved for endemic and endangered species found around the Mount Kinabalu area. It has a total of 30 species, with 14 wild species and 56 accessions.

The plant germplasm unit of Universiti Putra Malaysia (UPM) was formed in 1991. The total area allocated for this unit is 100 acres. To date it has 15 species in collection with about 292 accessions. The development cost in 1995 was about RM720,000.

The remaining six ex-situ areas do not have much diversity in fruit species collection. The number of collections in each area varies from one to eight species. The number of accessions among the six areas varies from two to 140, and there are no wild species in their collections.

Orchids

Table 2 displays the orchid species diversity in seven ex-situ areas. Among the seven, three of them, namely, the Poring Orchid Centre in Sabah, the Orchid Garden under City Hall in Kuala Lumpur and the horticulture division of MARDI in Serdaang, specialise in orchid collections.

The Poring Orchid Centre which was formed in 1987 has the largest collection of wild species (600). It also has the largest number of accessions at 4,774. All the collections are from in-situ areas of Sabah. The initial cost of setting up six orchid houses in 1987 within the 6 acres land area was RM30,000.

Table 2. Orchid species diversity

Respondents	No. of species	No. of accessions	No. of wild species
Poring Orchid Centre, Taman Sabah	600	4774	600
Agriculture Park Tenom, Sabah	500	3000	400
Orchid Garden, Dept. of Landscape and Recreation, City Hall, K. Lumpur	300	2000	280
MARDI			
Horticulture Division, Serdang	155	701	155
Botanical Garden Pulau Pinang	124	372	71
Kinabalu Mountain Garden, Taman Sabah	91	186	91
Univ. Kebangsaan Malaysia (UKM), Bangi, Selangor	43	85	42

The Agriculture Park in Tenom, Sabah has allocated about 10 acres for orchid collections. It is the second largest collector of orchid species with about 500 species, of which about 400 are estimated to be wild species. It has the second largest number of accessions at 3,000. All the wild orchids collected are from Sabah.

The orchid garden under the Department of Landscape and Recreation of City Hall, Kuala Lumpur, has 5.4 acres of land for its orchid collection. It started the collection in 1984 and has now accumulated about 300 species of orchids with about 280 from the wild with 2,000 accessions. About 80 per cent of the collections were obtained from the in-situ areas in Malaysia, five per cent were exchanges with international agencies, 12 per cent were bought from local commercial nurseries and about three per cent were gifts from other domestic agencies. The development cost incurred between 1985 and 1995 was about RM3 million.

The Horticulture Division of MARDI in Serdang began its orchid collection in 1976. Almost 10 acres of land are allocated for the orchid collection. About 85 per cent of the collections are from in-situ areas of Malaysia, five per cent gifts from other domestic agencies and ten per cent purchases from Thailand and Indonesia. There are about 155 species in collection where all are from the wild with 701 accessions. The development cost in 1976/77 was about RM1.02 million.

The Botanical Garden in Pulau Pinang collects orchids and other ornamentals. The number of orchids in collection amounts to 124 species where 71 are wild species with 372 accessions.

The Kinabalu Mountain Garden has 91 species in collection where all are wild species and there are about 186 accessions. The Taman Pantun of Universiti Kebangsaan Malaysia (UKM) has about 43 species where 42 are wild species with about 85 accessions.

Medicinal plants

Table 3 displays the medicinal plant species diversity in seven ex-situ areas. These areas generally have other plant germplasm besides medicinal plants.

Table 3. Medicinal plant species diversity

Respondents	No. of species	No. of accessions	No. of wild species
Botanical Garden Pulau Pinang	110	348	8
Agriculture Park Tenom, Sabah	89	227	65
Kinabalu Mountain Garden, Taman Sabah	49	119	25
Univ. Putra Malaysia (UPM), Serdang, Selangor	28	427	0
Forest Research Institute Malaysia (FRIM), Kepong	20	51	9
Forest Research Centre (FRC), Sandakan, Sabah	8	8	8
Univ. Kebangsaan Malaysia (UKM), Bangi, Selangor	1	21	0

The Botanical Garden in Pulau Pinang has the highest number of species (110) for medicinal purposes with 348 accessions and 8 wild species. The Agriculture Park in Tenom, Sabah has about 89 species in collection with 227 accessions and it has the highest number of wild species (65). The Kinabalu Mountain Garden has 49 species with about 25 wild species and 119 accessions. UPM in Serdang has 28 species in collection with 427 accessions. FRIM has 20 species with nine of them wild and 51 accessions. FRC in Sandakan, Sabah has eight species and all are wild. UKM has one species and 21 accessions.

Timber

Table 4 displays the timber species diversity for six ex-situ areas. Four of these areas have adjoining forest reserve areas.

FRIM in Kepong, is the leading institute with the highest number of timber species (287), where about 124 are wild species, and with 991 accessions. FRC in Sandakan, Sabah has 153 species and almost all the species are wild. The Agriculture Park in Tenom, Sabah has 77 species with 62 wild species and 219 accessions. The Kinabalu Mountain Garden has about 34 species with 22 wild species and 64 accessions. UPM has 23 species in collection, no wild species and 148 accessions. The Botanical Garden in Pulau Pinang has 17 species with four wild species and 39 accessions.

Table 4. Timber species diversity

Respondents	No. of species	No. of accessions	No. of wild species
Forest Research Institute Malaysia (FRIM), Kepong	287	991	124
Forest Research Centre (FRC), Sandakan, Sabah	153	153	152
Agriculture Park Tenom, Sabah	77	219	62
Kinabalu Mountain Garden, Taman Sabah	34	64	22
Univ. Putra Malaysia (UPM), Serdang, Selangor	23	148	0
Botanical Garden Pulau Pinang	17	39	4

Biodiversity benefits

The calculation of TEV using the method that has been described in the methodology section of this paper, has not been possible. This is due to the unavailability of adequate data required for such an evaluation method. The data gathered from the survey have only allowed for the quantification of direct use benefits, which are benefits that are derived from variables such as number of visitors, number of publications, number of new varieties and hybrids released and number of new species discovered. The biodiversity benefits for each selected ex-situ area are presented in Table 5.

Number of visitors

The number of visitors refers to the number of tourists, teachers and students that visit the area annually. This gives direct use benefits because the plant germplasm collection area provides educational and recreational facilities as well as a tourist destination.

Of the 21 sites surveyed, 17 reported visitors. The Kinabalu Mountain Garden of Taman Sabah reported the highest number of annual visitors at 200,000. This is not surprising since the Mountain Garden is situated at the entrance to the main attraction, which is the Kinabalu mountain. Kuala Lumpur City Hall's orchid garden attracted about 120,000 people annually. The Botanical Garden in Pulau Pinang reported 7,500 visitors, FRIM about 5,500 visitors and the Agricultural Park in Tenom, Sabah, 5,000 visitors, annually. The Planting Material Production centre in Tarat, Sarawak, the ARC in Semonggok, Sarawak, the plant germplasm unit of UPM in Serdang, the Poring Orchid Centre in Sabah and the Layar Integrated Agricultural Station in Sri Aman, Sarawak have 600, 400, 240, 200 and 150 visitors, respectively, annually. The remaining seven ex-situ areas have between 20 to 120 visitors annually.

Table 5. Biodiversity values of ex-situ areas

Respondent	Year started	Area (acre)	Annual operating cost (RM)	No. of visitors	Direct use benefits		No. of new species
					No. of publications	No. of new varieties/hybrids	
Botanical Garden Jalan Kebun Bunga, Pulau Pinang	1885	20	1,255,330	7,500	-	-	70
Forest Research Institute of Malaysia (FRIM), Kepong	1929	58	na	5,500	7	na	na
Department of Agriculture, Serdang, Selangor	1932	100	na	na	2	na	na
Planting Material Production Centre Department of Agriculture, Tarat, Sarawak	1950	618	1,700,000	500	na	-	-
Forest Research Centre (FRC), Sandakan, Sabah	1971	173	300,000	30	2	na	1
Agriculture Park, Tenom, Sabah	1972	300	900,000	5,000	3	na	na
Malaysian Agricultural Research & Development Institute (MARDI), Fruit Division, Serdang	1974	161	na	60	15	11	-
Malaysian Agricultural Research & Development Institute (MARDI), Horticultural Division, Serdang	1976	10	216,732	30	10	5	-
Universiti Kebangsaan Malaysia (UKM), Bangi, Selangor	1977	580	78,300	120	na	na	-
Agricultural Research Centre (ARC), Semonggok, Sarawak	1979	47	160,000	400	na	na	-
Kinabalu Mountain Garden, Taman Sabah	1981	5	na	200,000	na	na	na
Orchid Garden, Department of Landscape and Recreation, City Hall, K. Lumpur	1984	8	396,000	120,000	-	-	-
Poring Orchid Centre, Taman Sabah	1987	6	58,400	200	-	-	2
Department of Agriculture, Teluk Chengai, Kedah	1987	10	na	20	na	-	-
Department of Agriculture, Ulu Dusun, Sandakan, Sabah	1989	60	210,000	120	na	-	-
Layar Integrated Agri. Station, Betong, Sri Aman, Sarawak	1990	69	na	150	na	-	-
Department of Agriculture, Kuala Terengganu	1990	63	90,694	50	na	-	-
Universiti Pertanian Malaysia (UPM), Serdang, Selangor	1991	100	na	240	4	na	na
Department of Agriculture, Seremban, Negeri Sembilan	1994	2	950	na	na	-	-
Department of Agriculture, Kota Bharu, Kelantan	1994	2	na	na	na	-	-
Department of Agriculture, Pulau Gadong, Melaka	1994	3	na	na	na	-	-

na = not available

Number of publications

The number of publications refers to the number of articles published based on research findings on these collections. These can be in the form of books, newsletters, reports or journal articles. The publications provide direct use benefits because not only are they educational to the readers but they also provide new knowledge or new technology from research findings.

Only seven institutions out of 21 reported any publications. MARDI's fruit and horticulture divisions recorded the most number of publications at 15 and 10, respectively. They are in various MARDI publications namely MARDI's Research Journal, MARDI Report and Commodity Bulletins. FRIM, UPM, the Agriculture Park in Tenom, Sabah, FRC in Sabah and the Department of Agriculture in Serdang, Selangor are the other institutions involved in generating publications from the collections.

Number of new varieties/hybrids

The number of varieties/hybrids refers to the research products brought about through selections and breeding work. These are in the form of new varieties or hybrids released over the years. These research products provide direct use benefits to both farmers and consumers.

Generally, the benefits derived from R&D were not reported by many respondents. Out of the 21 ex-situ areas, only two generated new varieties or hybrids. MARDI's fruit division is the leading institution in producing new varieties and hybrids. The R&D efforts at this division have produced five new varieties (one for durian, two for guava and two for duku langsung) and six hybrids (three for durian, one for pineapple and two for papaya). The varieties and hybrids are multiplied and offered for sale to the public. MARDI's horticulture division has so far produced five new hybrids of orchids and their planting materials are offered for sale. Other respondents did not report R&D results because they did not undertake this activity and/or other departments make use of their facilities to conduct R&D work.

Number of new species

The number of new species refers to the number of new records and descriptions of the species discovered through collection efforts and established in these ex-situ areas. This also provides direct use benefits because the discoveries add to the stock of knowledge and information.

However, the benefits derived from new discoveries are not reported by many respondents. Out of the 21 ex-situ areas, only three recorded new species. The Botanical Garden in Pulau Pinang recorded the largest number of new species for orchids (70). The Poring Orchid Centre recorded only two and FRC recorded one for timber species. The information in the other ex-situ areas are not available.

Conclusion

The study concludes that among the four commodity groupings, orchids have greater species diversity in ex-situ conservation areas, ranging from 43 in UKM in Bangi, Selangor to 600 in Poring Orchid Centre. Timber species diversity is next, ranging from 17 in the Botanical Garden in Pulau Pinang to 287 in FRIM, Kepong. Third is fruit species diversity ranging from four in UKM, Bangi, to 153 in MARDI's arboretum in Serdang. Medicinal plants species diversity range from eight in FRC, Sabah, to 110 in the Botanical Garden of Pulau Pinang.

In terms of benefits, most of these areas are contributing towards education, recreation and as tourist destinations. Next in ranking is publications in terms of providing educational value as well as new knowledge or new technology. The contribution from research efforts such as selection of suitable variety, breeding for new hybrids or new species is limited to very few institutions. This can be attributed to the inadequate number of skilled researchers at many of these institutions and also the lack of linkages with the industry.

One of the solutions to the above problem is perhaps to address the Intellectual Property Rights (IPR) issue. This needs to be formulated and enforced to ensure that breeders/researchers rights are protected. Such protection will go a long way towards harnessing the vast biodiversity that this country has.

The limitation of this study is its inability to quantify the benefits generated by these ex-situ areas into values. This is due to the inadequate data kept by the institutions surveyed, especially cost data. In terms of valuation methods, there are many. Previous studies such as the value of a mangrove area in Sarawak, have used the Contingent Valuation Method (CVM) and the valuation of *Parkia speciosa* Hassk. in Peninsular Malaysia used the Market Price approach.

Future work in this area should focus on specific commodities. Durian being a popular fruit, and orchids which have the greatest diversity in the collections should be the target commodities. In terms of the valuation methods, the economic surplus method is one of the most popular approaches for assessing the effects of investment in agricultural research. Specifically, it looks at the impact that research has on the level of production, consumer prices and producer prices. A primary survey of the growers and consumers will have to be carried out to gather as much relevant data and information as possible.

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References

- ANONYMOUS. 1992. *Global Biodiversity Strategy. Policy-makers' Guide*. World Resources Institute (WRI), The World Conservation Union (IUCN), United Nations Environment Programme (UNEP) in consultation with Food and Agriculture Organisation (FAO) and United Nations Education, Scientific and Cultural Organisation (UNESCO).
- ASHTON, P. S. 1988. Conservation of biological diversity in botanical garden. Pp. 39-48 in Wilson, E.O. & Peter, F.M. (Eds.) *Biodiversity*. National Academy Press, Washington, D.C. 521 pp.
- CONWAY, W. 1988. Can technology aid species preservation? Pp. 263-268 in Wilson, E.O. & Peter, F.M. (Eds.) *Biodiversity*. National Academy Press, Washington, D.C. 521 pp.
- KRATTIGER, A.F., MCNEELY, J.A., LESSER, W.H., MILLER, K.R., HILL, Y.S. & SENANAYAKE, E. (Eds.) 1994. *Widening perspectives on biodiversity*. IUCN-The World Conservation Union, Gland, Switzerland and Cambridge, UK, and International Academy of the Environment, Geneva, Switzerland.
- MCNEELY, J.A., MILLER, K.R., REID, W.V., MITTERMEIER, R.A. & WERNER, T.B. 1990. *Conserving the world's biological diversity*. IUCN, WRI, Conservation International, WWF-USA and World Bank. Gland, Switzerland and Washington D.C.
- NGAR, G.S. 1994. Why the ex-situ collections are so crucial. *Third World Resurgence* 48: 11-12.
- PEARCE, D.W. 1993. *Economic Values and the Natural World*. Earthscan Publications Ltd., London. 1993

DISCUSSION AND RECOMMENDATIONS OF THE WORKING GROUPS

Participants of the Workshop were divided into four working groups and each group was assigned a theme for discussion guided by a list of questions and drawing upon the results of the various studies presented during the Workshop. The results of the discussions of the four Working Groups are presented in the following sections.

Group 1: Integrated Forest Management and the Environment

The following seven questions were posed to members of Group 1 as the basis for their discussion on Integrated Forest Management and the Environment:

1. What are the most critical environmental and socio-economic issues in forest management in Malaysia?
2. How could forest management systems better integrate both environmental and socio-economic issues and what practical steps are required to achieve these changes?
3. What recommendations can be made with respect to pre-felling operations, site planning, timber harvesting, post-felling operations, user permits and concessions?
4. How should forest lands be classified into different zones to support integrated forest management (for example, what should be the types of zones)?
5. Can the existing system be improved? What criteria and indicators should be the basis of the classification system?
6. What changes can be recommended immediately based on current knowledge, in particular the results of the programme?
7. What issues require further investigation, by formulating specific research questions for follow-up studies?

Before tackling the questions posed, the group first defined forest management. According to Lushener, forest management is defined as "the integration of all the biological, social, economic and other factors that affect management decisions about the forest". As such the management decision will inevitably be based on the desired objectives and these always refer to the goods and services that the forest produces.

Forest management objectives are usually determined by the forest owner, *i.e.* Government in the case of Malaysia, and land owners. Since the forest provides a multitude of goods and services, management objectives are usually a composite of such objectives. Guided by the working papers on forest resources and their economics discussed on the first day of the Workshop, the group divided the papers into the following categories:

- Biological/ecological aspects of forestry
- Economic aspects (valuation)
- Social aspects (non-wood products, recreation).

The question facing Workshop Group 1 then, is to how to integrate and manage these diverse interests while taking cognisance of the needs and objectives of society. As a background to the discussion, examples were drawn from the Malaysian experience with regard to the evolution of the forest management system. The first system used was the Regeneration Improvement Felling System (RIF) which evolved into the Malayan Uniform System (MUS) which subsequently gave rise to the currently used Selective Management System (SMS).

Taking cognisance of the substantial contributions of the timber and wood based sectors to the Malaysian economy, timber production will be one of the main elements of integrated forest management. Tempering this with the changing values and priorities of society as highlighted in the Keynote Address by the Director-General of Forestry, Peninsular Malaysia, a paradigm shift in forest management is inevitable - "The traditional system of sustained yield forest management which is based on the concept of equilibrium, a balance between growth and harvest which can be sustained in perpetuity, is deemed to be inappropriate in a society where forest is appreciated for provision of an array of commodities and amenity values". Perhaps this will provide a move towards integrated forest resources management.

On the question of critical environmental and socio-economic issues in Malaysian forest management, the group identified the following issues for consideration:

- Ensure biodiversity
- Conserve soil and water in forests
- Demonstrate sustainability of forests
- Maintain sustainable resource flow
- Maintain amenity values
- Involvement of people.

In efforts to determine how forest management systems could better integrate environmental and socio-economic issues, the following steps were identified as necessary:

- Prepare integrated forest management plan
- Conduct multi-resource inventories
- Provide a bridge between national and operations inventories
- Habitat classification
- Identify gaps in information (*i.e.* inventorising values of biodiversity, fragile ecological habitats, forest fragmentation, non-timber forest produce [NTFP])
- Forest stand level management
- Use multi-resource accounting/valuation system
- Identify zones, wildlife corridors
- Identify standards and guidelines, timing of harvest operations, buffer strip width
- Integrated plans should consider all lands within ecological planning unit
- State lands should be managed by the same regulations as production forests if immediate conversion plans do not exist

- Involve government, environment and industry groups and rural people in determining values and benefits.

Recommendations on pre-felling operations, site planning, timber harvesting, post-felling, user permits and concessions are as follows:

- Pre-felling operations
 - Improved harvest planning (including marking buffer strips, habitat corridors, reserve areas, site classification for harvest systems, road and harvest system planning)
 - Consult with wildlife and watershed specialists
 - Identify mother trees
 - Mark retention trees
 - Identify timing of operations
 - Prepare clear instructions for field foresters
 - Climber cutting when appropriate.
- Site planning
 - Improve road location and minimize road density
 - Field check harvest system suitability.
- Timber harvesting
 - Directional felling
 - Improve harvest equipment selection
 - Improve communication with loggers
 - Improve enforcement
 - Evaluate and demonstrate reduced impact logging systems (skyline, helicopter, etc.).
- Post-felling operations
 - Improve road maintenance
 - Consult colleagues about multi-resource post-harvesting inventories for follow-up silvicultural planning.
- User permits and concessions
 - Limit number of layers of sub-contracting.

The group was of the opinion that in addition to the legal zoning of the forest into 11 zones, namely, timber production forest, soil protection forest, soil reclamation forest, flood control forest, water catchment forest, wildlife sanctuary, virgin jungle reserve (VJR), amenity forest, education forest, research forest and forest for federal purposes, specific guidelines need to be proposed with emphasis on the following:

- Watershed zones (riparian and upland)
- Wildlife habitats
- Habitats of unique flora
- Landslide potential areas (geomorphology/slope stability)
- Soil zones (erosion potential)
- Scenic zones.

Based on current knowledge, in particular, the results of the programme, the group proposed the following changes for integrated forest resource management:

- Timber production be carried out as part of integrated resource management using best management practices
- NTFP licences be reassessed with regards to sustainability and distribution of benefits
- Integrated resource plans should consider increased recreation demand
- Improve harvest planning procedures
- Reduce stand damage and increase skidding productivity through directional felling.

The group identified the following issues for further investigation and follow-up studies:

- Research studies should be extended to the hill forest where conditions are different
- The potential of using forest pricing policy to reach integrated forestry goals should be examined
- The methodology for biodiversity inventory needs to be determined
- Fragile ecological habitats need to be identified
- Means of preventing forest fragmentation need to be formulated
- The best means of managing NTFP (*e.g.* creation of plantations) need to be identified
- Reduced impact logging technologies need to be tested.

Group 2: Economic Implications of Non-timber Benefits in Forest Management

Five questions were posed to Working Group 2 for their discussion on Economic Implications of Non-timber Forest Benefits (NTFBs) in Forest Management. These were:

1. What is the role of economic assessment of NTFBs in forest management? How should such information be used?
2. What information systems are required to integrate NTFPs in forest management? Issues to be addressed include:
 - What should be the product classification system for NTFPs?
 - How can a statistical database for NTFPs be designed to ensure their regular recognition (for example in the national accounts)?
3. How can forest lands be evaluated to account for monetary and non-monetary benefits in a practical and efficient manner? (For example, how can different forest areas be scored or ranked without having to undertake a comprehensive valuation study? To what extent can the results of valuation be transferred from one forest site to another?)

4. What changes can be recommended immediately based on current knowledge, in particular the results of the programme?
5. What issues require further investigation, by formulating specific research questions and follow-up studies?

The group identified three major roles of economic assessment of NTFBs in forest management. These were:

1. To assist in operationalising existing policies for forest management by providing information that can be integrated into decisions taken by the Forestry Department personnel (*i.e.* as an added decision tool).
2. As an input to future policy making, by providing a general indication to policy-makers of the relative worth of the non-timber products and services under a range of different land-use scenarios, as well as different forest management regimes.
3. To provide general information on important development and conservation issues to the general public as well as detailed information in specific cases, to governmental and relevant stakeholders.

While recognising that a broad overview of economic valuation is provided by these three roles, the group also realises that these roles are not necessarily comprehensive.

Several issues were tackled in response to the second group of questions. There was general consensus that there is a need to further clarify what is meant by NTFBs. The changing perception of users has resulted in some products previously classified as 'minor forest products' becoming 'major forest products'. To make the point explicit, a quick listing of some of the main products and services currently deemed important was drawn up (Table 1). The group understands that the situation with regard to NTFBs is dynamic, but recognises also the need for a definition to reflect the current/contemporary situation. This would then be the guiding 'definition' for the forest managers.

The group understood that although the Forestry Department's management and operational work had concentrated largely on timber production, it had for some time now also included a limited range of NTFBs in its programmes. In fact, several NTFBs, such as rattan, ecotourism (recreation) and medicinal plants have been endorsed at the highest level. There is recognition, however, that there is a need for more information to allow for these to be better incorporated into the management process.

Table 1. A list of the main products and services from the forest which are currently deemed important

Products	Services
Rattan	Recreation
Bamboo	Tourism
Fruits	Soil and water protection
Herbs	Carbon sink
Medicinal plants	Microclimate
Wildlife	Gene pool
Ornamental plants	Biodiversity
Resins	Aesthetics
Germplasm	Research and education
	Security (economic, option value)

Note: this is an illustrative, not exhaustive list and can be reflected in alternative ways, such as using valuation taxonomy (*i.e.* use value, indirect user, existence value, etc.)

There was consensus on the need for more inventory work to be undertaken with regard to NTFBs. In this context, there were some practical suggestions. At present, the Forestry Department conducts two levels of inventory: at the planning (national) level and the operational (*i.e.* the pre-felling and post-felling inventories for logging compartments) level. The inclusion of a wider range of NTFBs into the pre-felling and post-felling inventory process would represent a cost effective way of meeting this need. The inclusion of some 'indicator' species which reflect 'ecosystem stability' would also be a useful inclusion. There would, however, be a need to provide the necessary training to staff, to undertake these additional tasks.

Apart from the 'stocking' information, economic valuation requires data collection on the ecological and biophysical relationships, production and marketing information, and local community utilisation of products. The downstream effects on industry and demand also need to be addressed.

In response to the question of how forest lands could be evaluated to account for monetary and non-monetary benefits in a practical and efficient manner, two main points emerged. The results of the studies undertaken on economic valuation in Sub-programme B have produced interesting and meaningful results, but there is still a need for further research in this area. Benefits transfer is a difficult issue, and work elsewhere too suggests that caution should be exercised in scaling up the results, and/or extrapolating the results to other sites. A practical approach towards incorporating NTFBs, and subsequent valuation into the process of forest management would be to use the 'functional categories' provided for under Section 10(1) of the National Forestry Act (1984, amended 1993). This section provides for multiple-use management through its 11 functional categories. A comprehensive identification of the functional categories as identified under the Act could be used to guide 'valuation' of the forest for its NTFBs. These functional categories may, however, need to be revised or re-classed to include some which are not directly reflected in the Act (*e.g.* non-timber forest products such as rattan, medicinal plants, etc.).

The group agreed that the studies undertaken in the two sub-programmes had produced some interesting and startling results, for example, the high percentage of ectomycorrhizal fungi on the forest floor of Pasoh. In terms of management and operation, however, the Forestry Department personnel need sufficient information, time and direction prior to incorporating these on the ground. The group also felt that there was an urgent need for research results to be presented in a practicable and applicable manner (*i.e.* must go beyond the 'research' focus) so that they could be put into operation by forest managers.

While the group did not have time to fully address the question of issues in need of further investigation, two examples of NTFBs were highlighted. In the case of rattans, the key questions are:

- Is rattan production a complement or substitute to logging?
- How best to manage rattan harvesting?
- Does the Forestry Department have the manpower to enforce proper harvesting?
- What is the potential for including local populations in the management of rattans?

The second example was recreation. Whilst some key information has been collected in the recreation study undertaken in Sub-programme B and in a separate study by Universiti Putra Malaysia (UPM), there was a need to incorporate some of these findings into management. For example, what decisions have to be made on the pricing policy? Other questions that need to be addressed include the effect of high levels of visitation on the forest environment and the identification of potential sites for future recreational areas.

Group 3: Management, Utilisation and Marketing of Non-timber Forest Products

The following six questions were posed to members of Working Group 3 who addressed the topic Management, Utilisation and Marketing of Non-timber Forest Products:

1. How can potential markets and demands for NTFPs be identified and encouraged?
2. What steps should be taken to promote the development of NTFP-based enterprises, particularly those that involved increased added value through local processing?
3. What should be the system for:
 - the development of standards, grading rules and testing methods?
 - the identification of R&D needs in product development?
4. Do existing rules and regulations relating to NTFP harvesting, utilisation and distribution require any modification to support both conservation and economic objectives? If so, how? Possible issues include:

- economic incentives (e.g. NTFP licence fees, concessions, etc.)
 - involvement of different groups in designing new systems
 - monitoring and enforcement
5. What changes can be recommended immediately based on current knowledge, in particular the results of the programme?
 6. What issues require further investigation, by formulating specific research questions for follow-up studies?

For the purposes of this discussion, the group defined NTFPs as rattan, bamboo, medicinal plants, fruits such as engkabang, keranji, berangan and salak. Petai and durians were excluded as the group felt that petai had already been well discussed in one of the papers while durian had now become a cultivated fruit.

Several areas for improvement in the management of NTFPs were identified, in particular the feasibility and practicality of improving inventories of NTFPs, and illegal and damaging extraction created by difficulty of monitoring and enforcement of rules on license holders. The group pointed out that licenses to harvest rattan could lead to harvesting outside the permitted area and extraction of other produce. However, presently there is no official management system for NTFPs.

On the issue of utilisation, each of the four NTFPs was considered in turn:

- Rattan
 - mainly processed into polished poles and furniture
 - design, quality and upgrading of products need to be encouraged.
- Bamboo
 - mainly utilised locally and there was a question mark about its export
 - several difficulties are encountered in bamboo utilization, these being, the varieties of bamboo involved, the quantity and quality, consistency of supply and treatment against borers and fungi.
- Medicinal plants
 - presently only used locally
 - attract the low end of the market
 - need to upgrade the utilization of local medicinal plants.
- Fruits
 - insufficient information available
 - need for more research
 - presently the fruits are mainly utilised locally in the fresh form with limited prospects for processing due to limited volume and seasonality.

As with the issue of utilisation, marketing of the four NTFPs were considered separately:

- Rattan
 - the domestic market for rattan is limited with most being concentrated on exports
 - efforts are needed in product development, especially in
 - a) improving quality and design,

- b) upgrading of links with buyers,
- c) private initiatives in design and multi-material furniture,
- d) market repositioning for better quality, better design and higher unit prices.
- **Bamboo**
 - incentives from Malaysian Industrial Development Authority (MIDA) and state governments for joss paper
 - need to sustain local demand for present product range.
- **Medicinal plants**
 - contacts with local traders and manufacturers needed
 - direct selling to end users should be encouraged.
- **Fruits (for the domestic market)**
 - market testing needs to be conducted
 - consumer taste panels should be set up to achieve wider local distribution.

Several issues were identified for follow-up activities:

- **Rattan:** the group recommended that a study be conducted on the rattan supply position and that the contractor/supplier, rattan miller and state Forestry Department be considered. The group also recommended that the next national forest inventory not only include rattan and bamboo but also fruit trees.
- **Bamboo:** a review needs to be carried out on the suitability of Malaysian genera for economic processing. Information on the technical characteristics and volume available is also lacking.
- **Medicinal plants:** the group had several recommendations. An experimental farm/plantation should be established in the logged over forest to provide experimental plots for the most important medicinal plants. Studies should also be conducted on the fruiting season and the silvicultural regime suited to selected medicinal plants. A cost analysis of agricultural practices for medicinal plants should be carried out and a monograph on herbal, spice and medicinal plants be prepared.
- **Fruits:** a wider group of marketable fruits should be identified for further research.

Group 4. Biodiversity Conservation in Forest Management

The following six questions were posed to Working Group 4 in their discussion on Biodiversity Conservation in Forest Management:

1. What are the major components of biodiversity that need to be conserved?
2. How do current forest management practices incorporate biodiversity conservation?
3. Which aspects of pre- and post-felling operations have the greatest impact on biodiversity conservation?

4. What actions can be taken to ensure conservation of biodiversity in production forests (e.g. pre-felling operations, logging systems, access systems, buffer strips, wildlife corridors, log landing and silvicultural treatments, etc.)?
5. What changes can be recommended immediately based on current knowledge, in particular the results of the programme?
6. What issues require further investigation, by formulation of specific research questions for follow-up studies?

In answering the first question, the Working Group recognised that in the Malaysian context biodiversity conservation needs to be addressed at its three distinct levels:

1. Ecosystem level
2. Species level
3. Genetic level.

The following main points were highlighted in relation to each level:

- Ecosystem level
 - Conserving biodiversity at the highest level, i.e. at the ecosystem level, has the advantage of encompassing the conservation of biodiversity at both species and genetic levels.
 - Ecosystem level conservation is the easiest and most practical level of conservation for policy makers and management authorities to handle.
 - Conservation at the level of ecosystem, however, needs to take into consideration other factors relating to species level and genetic level biodiversity conservation.
- Species level
 - Conservation of biodiversity at the species level has the added benefit that if the larger species are targeted, other smaller species will likewise be conserved. For example, although fungi are an exceptionally diverse group, it is difficult to argue a case for their conservation. However, should larger species of plants, for example, be targeted for conservation, this will take care of smaller/more diverse/abundant or dependent biota, which are equally important because of their relationship with larger biota.
 - When conserving biodiversity at the species level, the geographical distribution of species needs to be taken into account as there can be substantial variation throughout the country between similar ecosystems. Likewise variations in geology, soils and climate need to be addressed. It was noted that insects tend to follow the biogeographical and geological patterns of plants more closely than mammals.
 - In Malaysia, there is considerable documentation of many species and their habitat requirements. The endangered or rare status of many plant and animal species is known. Information on many other taxa is rather rudimentary. There is also an increasing awareness of areas of high species

diversity, endemism and/or rarity ('hot spots') and these could and should be mapped and targeted for protection as relatively small units of forest. For example, some areas that merit particular attention include compartments in Forest Reserves (FRs) in south-east Johore, Terengganu, Maxwell/Bubu Mountains, Langkawi, north of the Kedah river, etc., which have distinctive faunistic and floristic characteristics.

- Genetic level

- The conservation of biodiversity at a genetic level, though a critical area, is poorly understood, as this discipline is in its infancy.
- The question of genetic erosion was raised. It was recommended that current forestry practices be studied to ascertain their impact upon the gene pool. A fear was voiced that current logging practices may be causing an impoverishment of the genetic base, leaving less desirable genes. It was noted that this is an important issue with long-term economic implications for the forestry sector.

Recommendations to emerge from addressing the first question were as follows:

- Identification of forest areas that need to be targeted for conservation

- The following question was posed and addressed: are there any components of biodiversity that do not need to be conserved? - No! No one goes out to make a species extinct. Extinction is a by-product of human activity. The object is to conserve as much biodiversity as possible, while focusing on which areas need to be conserved. In order to do this, it is necessary to know what has already been reasonably conserved and then establish what needs to be further conserved.

- Expansion of protected forest areas within the PFE

- The different levels of protection within the Productive Forests of the Permanent Forest Estate (PFE) were discussed. These included forestry practices that reduce the negative impacts of logging and also ensuring protection of areas such as VJRs. The benefits of the VJR system, in particular, were enumerated including the fact that the system is extremely flexible and adaptable. The system practically covers the whole of the country and has the ability to contribute to the protection of a considerable amount of biodiversity. Recommendations made include an active policy to encourage the expansion of the VJR system or similar protected areas within the PFE by the Forestry Department. Such protected units should be sited to minimise the risks of disturbance and to maximise their potential to conserve biodiversity, for example, by locating such units centrally within a FR as opposed to on the edge of the FR (where 63% of all VJRs have been located). In addition, it was suggested that every major productive forest area could have at least one protected unit, such as a VJR, as such protected units are integral to sustainable management. Currently, only 22 per cent of FRs contain VJRs.

- Centre for Biodiversity

- It was noted that a Centre for Biodiversity would be a useful facility and an appropriate home for it could be found within the existing Government structure.

The group noted and applauded the fact that current forest management policies incorporate biodiversity conservation. This is achieved in two main ways:

1. By ascribing to forests different levels and categories of protection

- Large areas of forest have been reserved in the PFE which is comprised of FRs
- Forest Reserves or parts of Forest Reserves are classified under a number of different categories including:
 - Flood control and/or water catchment forest (for the management of watersheds)
 - Forest sanctuaries for wildlife (e.g. the serow in Jengka)
 - VJRs (as undisturbed areas of natural vegetation for non-destructive scientific research, as particular silviculture control sites for forestry; and also as protected examples of the country's national heritage as nature reserves)
 - Amenity forests
 - Education forests
 - Research forests.
- It was noted that certain vegetation types, for example montane vegetation, are under-represented by the VJR network as a whole. It was recommended that representation be a major consideration in the expansion of the VJR system.

2. Specific management practices

- A number of specific management practices which have a positive impact on biodiversity conservation were enumerated including:
 - maintenance of mother trees. For superior trees, 1 tree/ha; for 20-30 cm dbh trees, 2 trees/ha. In open areas more mother trees are left
 - The practice of tree girdling has been largely eliminated
 - Fig trees (which have been shown to be important for certain birds and primates in particular) are deliberately retained in recognition of their value as 'keystone' food species
 - There are elevation and gradient limits for logging
 - Directional felling, which reduces site impact.

In addressing the question as to which aspects of (pre- and post-) felling operations have the greatest impact on biodiversity conservation, the group emphasised that any form of logging alters the age structure of the forest and also the species composition. Some changes are permanent in the sense that the next logging cycle eventuates before full succession can take place. The protection of some forest within the PFE/FRs was considered to be essential and recommended. The following aspects were highlighted as having the greatest impact on biodiversity conservation:

- Logging roads and log landings
 - The possibility of reducing the large percentage of forest that is denuded (a figure of 35% was mentioned) by the construction and use of logging roads and log landings was discussed.
- Physical removal of trees
 - The possibility of reducing the damage caused by the felling and skidding of trees was discussed. The question of whether or not there is an overall impoverishment of the ecosystem was also commented upon. An example from Scandinavia was given, in that removal of large diameter trunks resulted in decreased fungal activity and this had a negative effect on regeneration. In Malaysia, however, such effects have not been demonstrated so far.
- Post-felling climber cutting
 - Climber cutting is thought to have a negative impact on the forest fauna as certain animal species have been shown to include a considerable proportion of climbers in their diet. It was noted that the effects of post-felling climber cutting were negative with respect to faunal conservation and needed to be re-evaluated.
- Microclimatic changes (relative humidity, ultra-violet radiation and temperature)
 - Logging generated changes in microclimate can result in the loss of some plant/animal species, in particular smaller and more specialised forms.

The following subjects were discussed and recommendations made in relation to actions that could be taken to minimise biodiversity loss in productive forest:

- Forest fragmentation: Fragmentation of the PFE can have a serious negative impact on biodiversity, particularly the megafauna. Forest fragmentation was considered to be a very serious threat to biodiversity conservation in comparison to timber extraction. A recommendation was made that planners and land managers be sensitised to the consequences of forest fragmentation. In addition it was recommended that wherever possible, forest corridors be planned for and maintained between areas of natural forests. It was suggested that the Department of Wildlife and National Parks could be involved in developing appropriate recommendations and disseminating these to relevant institutions involved in land management.
- Building on existing protected areas of forest within the PFE: To build on existing protected areas, such as wildlife sanctuaries, amenity forests and VJRs within the PFE/FRs, taking into account the relevant recommendations made in relation to previous questions regarding siting and the biogeographical distribution of such units, as the number, size and location of such areas are considered to be of critical importance. It was recognised that the Forestry Department was in the best position to decide the appropriate designation for any area that was being considered for such protection.
- Developing a special unit/function within the Forestry Department for consideration of biodiversity conservation issues within the PFE: A mechanism for providing the Forestry Department with results and focused

recommendations relating to the protection of areas within the FRs was discussed. It was recommended that a special unit/function be set up within the Forestry Department to which specific recommendations regarding biodiversity conservation within the PFE could be made. In addition, a formalised way of presenting information relating to endangered species/indicator species and their location to the Forestry Department was discussed, for example, a standard form, map and recommendations being channeled on an institution to institution basis.

In relation to the question of what changes could be recommended immediately based on current knowledge, in particular, the results of the Programme, the group noted that although there is comparatively good recovery in the logged areas surveyed, the results from a number of disciplines clearly indicate detectable differences between logged and unlogged forest. The recommendations made endorsed those made in relation to the other questions. In particular, the importance of maintaining and establishing a network of protected units, such as VJRs, within the PFE was re-emphasised. In addition, it was also noted that it was too early to make more detailed recommendations based on the results of the Programme, especially as some of the studies were currently on-going.

Subjects discussed and recommended for further investigation included:

- Identification of priority areas for biodiversity conservation within the PFE/FRs, taking into account 'hot spots' and the geographical distribution of species.
- Research on biodiversity conservation in hill dipterocarp forests, in addition to lowland dipterocarp forests, as this is where current forestry practices are most active. It was suggested that disciplines involved should include studies on lichens, fungi ('unfortunately, sporome appearance does not reflect what is growing below ground and this is an area which must be addressed in the future'), understorey plants, herpetofauna, avifauna and insects other than ants.
- Coastal ecosystems (including peat swamps and mangroves) were not included in the present programme, but it was suggested that biodiversity conservation recommendations should equally be applied to these and other ecosystems.
- Research on biodiversity conservation in plantation forests to see if there is any way of maintaining a degree of biodiversity within them. It was noted that while intensive monoculture plantations were biodiversity poor, a mosaic of varying species was much richer in species diversity.
- The following research areas were highlighted as requiring more local involvement and a longer period of time in order to produce results relating to biodiversity conservation in managed forests:
 - Canopy and understorey cryptogams and fungi (in particular, to enlarge on lichens as indicator species) - 'Studies over no less than five and ideally as long as ten years are essential if a balanced view of the mycota is to be obtained'
 - Microclimate work.

- The effects of logging on water quality and consequently aquatic life had not been sufficiently addressed.
- The size of the protected unit required to conserve biodiversity (e.g. VJRs within the PFE/FR) was discussed at length. The following points were made:
 - Although VJRs are small, the strength of the VJR network is that VJRs are, on the whole, contained within existing FRs and are, therefore an integral part of a much larger area of forest/FR.
 - Viable breeding populations were discussed and it was noted that the requirements are different for different species and much of this information is still unknown. However, some questions can be answered based on existing information. It was suggested that the Forestry Department could look at the problem relating to the size of VJRs (and indeed suggest adequate sizes for VJRs) from the point of view of certain tree species, because they have the expertise. In addition, it was mentioned that this could be done for palms if the relevant professionals were consulted. There is a need for policy-makers to address these questions to relevant institutions/academics/professionals.
 - There is a need to know the species composition of VJRs and only then can certain species be focused on for biodiversity conservation within that FR.
 - Communities evolve together and play an important part in the integrity of the overall ecosystem. There may be duplication and redundancy within ecosystems, but we do not really know and therefore we do not know whether we can afford any losses. However, VJRs buffer against such losses.
 - The question was asked as to what extent buffer strips and the conservation of steep slopes adequately take care of biodiversity conservation needs. The response was that these areas contain niche specific flora and fauna and therefore the needs of biodiversity conservation would not be met.
 - A suggestion was made that recommendations for biodiversity conservation should also take account of low-impact logging and timber extraction techniques.
 - The question was raised as to whether the category of Research Forest had any practical value. It was pointed out that an immense amount of valuable scientific information had accrued from Pasoh and Sungai Menyala and other research plots.
 - With respect to the required size of VJRs for the preservation of biodiversity, it was noted that there was an inadequate response from both biologists and economists. It was pointed out that VJRs existed within larger FRs, thereby acting as 'mother communities' for the overall forest. Such VJRs should not be sited on the edge of FRs because edge communities differ from what is generally found within an area of forest.
 - It would appear that due to the widely varying requirements of different biological taxa, the question of the size of VJRs should ultimately be answered by an administrator.

Education and extension activities were discussed including workshops for specialist groups. Research restrictions discussed included:

- Lack of taxonomic facilities (literature and specimens)
- Time
- Workshops
- Manpower
- Equipment
- Funding.

CLOSING REMARKS

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Mr. Chairman, distinguished guests, ladies and gentlemen, its been a long haul and here we are in the closing minutes for our Workshop. But, first Mr. Chairman, my Bio-Data! I am not a Scientist; I am not an Economist; and I have certainly never ever worked in the Asian rain forest.

So, you can see Mr. Chairman just how well suited I am to wind up this Workshop. It is just as well that the Workshop evaluation is already completed.

I happen to think that this has been a most exciting, if not exhilarating experience, to have witnessed combined presentations as at this Workshop. This is a benefit beyond quantification even by this Programme's Economists. And the work has been diverse – just how diverse can be seen in the first day's concentration of papers.

It is not coincidence, Mr. Chairman, that this Programme was sited in Malaysia. Not only does Malaysia lead the world in certain aspects of applied research in tropical forestry but it also has the virtue of space in relation to population – few people per square kilometre. As the millennium approaches, it is evident that the two unavoidable but conflicting economic challenges in the 21st Century will be alleviating global poverty and sustaining the global environment. These will not be easy tasks. But Malaysia, with relatively high incomes per head and only limited pressures on the environment, will be secure from much of this conflict and, consequently, should be able to continue to grapple with many of the challenges that have formed the mainstream of this Workshop.

Perhaps, in passing, I might just dip my toes into technical conflict. Two of the papers on Monday, those for Projects B5 and A6 touched on the matter of site location – the issue as to whether results from one location are applicable in others. As a soils man I was interested in the conclusion that palm distribution is a function of soil type. It made me wonder how many aspects are also a function of other environmental variables. In any event it is certainly the time to move beyond Pasoh and to lift up our eyes to the hills.

On another matter, I was surprised by the general acceptance of a forest classification which was brought into effect I understand in 1984, an apt date indeed. I understand moreover that the categorisation is based solely on slope and on elevation. Surely the time has come to question the merits of a forest policy based on such elementary criteria? Although the National Forestry Act has been mentioned several times today, nobody has pointed to the dichotomy between the bases for the Act and the recommendations now being formulated.

Nor do I think that the Malaysian National Forestry Act would necessarily serve the long-term interests of the Elegant Trogon of Costa Rica which, Ian Gauld in the

very first presentation, indicated was at risk owing to its dual habitat and its gastronomic propensities.

In many countries the area of conflict is already drawn between the Land Use Planner on the one hand and Land Use Implementer on the other. These people rarely talk to one another. In many lands the Land Use Implementer is a species that enjoys almost a free hand. They tend to be large, rather hairy, non-endemic mammals who act to transform the landscape. They may take the form of Provincial Administrators, ruthless capitalistic developers, or even innocent small farmers making their way with ritualistic slash and burn agriculture. However, I deem it possible that few of these will read the outputs of this Workshop. This thought leads on naturally to the question as to where we go from here. Certainly we must publish the results of this Workshop and publish them as soon as possible. ODA will provide the funding for this and I would hope that this will be sufficient to allow us to compile a Book with, I propose, an editorial committee comprising our four Technical Coordinators.

But we need to do more than just produce a Book. In discussion, Kanta Kumari suggested the establishment of several government Task Forces to look more deeply into a number of the issues that you have defined in outline. That would ensure continuation of momentum and also the prospect for introducing necessary change into the System.

We in the UK will I fear be retiring before we have all of the answers. But our position now, as against that when we set out together in 1993, is surely that we have at least generated some of the right questions even if we are still a long way from discerning all of the answers.

We, Ladies and Gentlemen, are attempting to navigate across a wide, a complex and an uncharted sea. But do not be dismayed. The entire World Community is involved in these issues. This involvement will not evaporate in the years to come; rather it will intensify. Following three years hard labour, we have gained some worthwhile results, and Malaysia has added to its wealth of experience and expertise. There are many perceptive donors who will be prepared to carry this global work forward and who will carry it forward with verve, conviction and understanding.

Finally, it remains to me to convey to the Government of Malaysia our grateful thanks for your indulgence in permitting us to ship vast tonnages of ants and other produce to the UK for identification, and for allowing us to tramp willy-nilly all over your countryside – and in the case of Eric Gardette's Orang Asli, also through the air.

Turning specifically to the Workshop, we must first convey our deep and humble thanks to all of the participants. Without you, there would have been no Workshop. But the Workshop also would not have functioned without an array of Chairmen and Rapporteurs. We are grateful to the D-G of Forestry and to Mr. Narayanan Kanan, our Chairman, for setting us on our way. Nor too should we forget the organisers of the two splendid field visits.

But, above all, I should express a particular vote of thanks to the indefatigable Workshop Organising Committee, chaired by the ever active Mr. Thang Hooi Chiew, among whose members two names stand out in particular, those of the ever perceptive Dr. Lee Su See, and the Chairman of the Secretariat, the untiring Mrs. Dan Yit May.

Our grateful thanks are to all of them.

SUMMARY AND SYNTHESIS

On 21-24 October 1996, a workshop was held at the Forest Research Institute Malaysia (FRIM) in Kepong, Malaysia for all researchers involved under the Malaysia-UK Conservation, Management and Development of Forest Resources Programme. The workshop was jointly organised by FRIM, the Forestry Department Peninsular Malaysia (FDPM) and the International Institute for Environment and Development (IIED). In addition, officials representing a number of institutions took part, including representatives from several State Forestry Departments. The objectives of the workshop were:

- to provide a forum for scientists and policy makers involved in the Programme to present and discuss the results of joint Malaysia-UK projects;
- to assess the implications of research to-date under the Programme for the sustainable management of tropical forests and the conservation of its biological diversity; and
- to identify priorities for further research and development.

During the four-day workshop, scientists and policy makers discussed research findings of the Programme, their implications, and future research and development needed to ensure long-term sustainable management of tropical forests, including conservation of its biological diversity.

The workshop devoted its first day to brief presentations from each of the projects under the Programme. Projects under Sub-programme A have concentrated generally on assessing the differences in biological diversity, particularly species diversity, between unlogged and logged or regenerated forests. Of course, a major difficulty in determining the effects of timber harvesting on biological diversity is that little is often known of the interactions between species within ecological systems as complex as tropical forests. A further uncertainty concerns the potential uses of many of these species which are often regarded as economically insignificant today.

Projects under Sub-programme B have concentrated on estimating many of the non-timber benefits which are less plagued by uncertainty but often regarded, nevertheless, as negligible. The key economic question concerning the sustainable management of tropical forests is to assess how much conservation is necessary, taking into account the fact that many non-timber benefits are increasing in economic importance, particularly as economic growth proceeds.

The workshop further increased the awareness that forests play multiple roles in sustaining ecosystems which are relevant to species survival, including human, in the long run. Hence, a paradigm shift in forest management is inevitable. There is a need to change from sustained-yield management to that of multiple-use forest management. This shift in emphasis will provide a move towards integrated forest resources management.

Since forests provide a multitude of goods and services, management objectives must balance the provision of these various benefits. The findings and recommenda-

tions of the workshop should be useful for forest managers and planners who are working to achieve integrated forest management.

Four separate working groups each produced a set of written findings on the following four topics:

- Integrated forest management and the environment;
- Economic implications of non-timber forest benefits in forest management;
- Management, utilisation and marketing of non-timber forest products; and
- Biodiversity conservation in forest management.

This summary synthesises the findings of the workshop in the following five areas:

- Functional classification of forests
- Forest management systems
- Timber harvesting activities and procedures
- Management and utilisation of non-timber forest benefits
- Other issues.

Functional Classification of Forests

The workshop examined the functional classification of forests in detail. Currently, it was felt that inadequate attention is given to the multiple functions of the forests as the emphasis is 'biased' towards timber production even though non-timber values are generally recognised. With respect to the 11 current classifications, specific guidelines need to be proposed within the following areas:

- watershed zones
- wildlife habitats
- habitats of unique flora and fauna
- landslide potential (geomorphology/slope stability)
- soil zones (erosion potential)
- scenic zones.

Implementing multiple-use forest management implies the need to revise or reclassify functional categories of forests under the National Forestry Act 1984 (revised 1993) to directly include some of the major non-timber forest benefits such as rattan and medicinal plants. This revision is necessary to reflect the economic importance of non-timber forest benefits in forest planning and management at the state and district levels. Although forest recreation areas have been identified, as with many NTFBs¹, their economic contribution has generally been neglected. Increased demand for this type of benefit should be taken into account in the classification of forests. In addition, Virgin Jungle Reserves (VJR; National Forestry Act 1984, Section 10(1)) which were intended primarily as silvicultural control sites could be quite

¹Non-timber forest benefits (NTFBs) include both products (NTFPs) and services

important in multiple-use forest management as they serve both silvicultural and conservation needs.

Enhancing efforts in conservation continues to be an important area of concern. Further research is needed to identify priority forest areas for conservation taking into account Hot Spots and the geographical distribution of species. For the present, the Forestry Department should build on the range of existing protected units, including Sanctuaries for Wildlife, Amenity Forests and VJRs to establish and maintain a co-ordinated network of protected areas within the Permanent Forest Estate. The VJR system, which is extremely flexible and adaptable, covers almost the whole country and can therefore contribute considerably to the protection of a considerable amount of biological diversity. These protected areas should be sited to minimise the risks of disturbance and to maximise their potential for conserving biological diversity, for example, by locating such units centrally within a Forest Reserve (FR) as opposed to on the edge (where 63 per cent of all VJRs have been located). It was also recommended that every major productive forest area should have at least one protected unit or area, such as a VJR, as these are integral to sustainable management. (Currently, only 22 per cent of FRs contain VJRs.) The workshop noted that biogeographic representation should be a major consideration in the expansion of the VJR system since certain vegetation types are under-represented in the existing network as a whole (for example, montane, mangrove, peat swamp, fresh water swamp, limestone, heath and strand vegetation types are all under-represented in the current VJR network). Wherever possible, continuous areas of natural forest should be retained in preference to permitting fragmentation of areas of natural forest to occur. Failing this, fragmented areas of natural forest should be joined by corridors of natural forest to improve biological diversity conservation.

Forest Management Systems

The workshop discussed forest management systems in Malaysia and recognised the efforts being made to achieve sustainable forest management. To promote further the achievement of this objective, the workshop suggested a number of possible improvements to forest management systems. In general, assessment of proposed management regimes should reflect the relative economic importance of non-timber, as well as timber, benefits. The Programme has estimated some of the values involved but more work is required on the extent to which estimates from one site can be extrapolated to another area (sometimes called 'benefits transfer').

The workshop also recognised that the first step towards integrated forest management is generating necessary and sufficient baseline data. Specific gaps in information (*i.e.* inventorying values of biological diversity, fragile ecological habitats, forest fragmentation, NTFPs) need to be identified. Filling these gaps will involve the use of multiple-resource accounting or valuation systems to assess tangible and intangible values of the forests. Multi-resource inventories (such as the inclusion of a wider range of NTFPs into the pre-felling and post-felling inventories) are essential for gathering this data. In particular, there is a need to identify gaps in information such as values

of biological diversity. However, it is also important to provide a bridge between national and operations inventories. Further research to fill information gaps could include areas such as the values associated with biological diversity.

Integrated management of forest lands should be undertaken using an ecological planning unit. This should also incorporate wildlife corridors and special conservation areas. With respect to operations there is a need to improve harvest planning procedures. In addition, standards or guidelines are required for issues such as buffer strip width and the timing of harvest operations.

Recognising the potential role of Stateland forest in providing various benefits, it was suggested that these forests be managed with the same regulations as production forests provided immediate conversion plans do not exist. Finally, integrated forest management should not be a 'top-down' process but should involve government, environmental groups, rural people and industry. In particular, this whole range of actors should be involved in determining the values and benefits of forests. As direct users or clients, groups such as industry, rural people and non-governmental organisations can provide important inputs to improve forest management.

Timber Harvesting Activities and Procedures

In general, timber production should be carried out according to best management practices. The workshop noted a number of existing management practices which have a positive impact on biological diversity conservation:

- A minimum number of mother trees are maintained;
- The practice of tree girdling has been largely eliminated;
- Fig trees (which have been shown to be important for certain birds and primates in particular) are deliberately retained in recognition of their value as 'keystone' food species;
- There are elevation and gradient limits for logging; and
- Directional felling is required, reducing site impact.

Any form of logging alters the age structure of the forest as well as the species composition. Some of these changes are permanent, particularly in production forest since the next felling cycle will occur before full succession can take place. Participants reviewed the aspects of forest operations that have the greatest impact on biological diversity, including the construction of roads, and the felling and skidding of trees. These activities not only lead to the greatest loss of trees (largely through incidental damage) but they are the cause of subsequent micro-climatic changes which also alter the species composition of the forest.

Nonetheless, to assist forest managers, the workshop made a number of specific recommendations in the areas of pre-felling operations, site planning, timber harvesting and post-felling operations, as follows:

Pre-felling Operations

- Improved harvest planning (including marking buffer strips, habitat corridors, reserve areas, site classification for harvest systems, road and harvest system planning)
- Consultation with wildlife and watershed specialists
- Identify mother trees for natural regeneration and seeding
- Mark retention trees
- Identify timing of operations
- Prepare clear instructions for field foresters
- Climber cutting when appropriate.

Site Planning

- Improve road location and minimise road density
- Field check harvest system suitability.

Timber Harvesting

- Directional felling (across contour)
- Improve harvest equipment selection (to better match individual sites)
- Improve communication with loggers
- Improve enforcement.

Evaluate and demonstrate reduced impact logging systems (*e.g.* skyline, helicopter, etc.).

Post-Felling

- Improve road maintenance.

User permits and concessions

- Reduce or limit the number of layers of sub-contracting.

For example, participants in the workshop were given first-hand experience of how stand damage from timber harvesting could be decreased and skidding productivity increased through improved directional felling during the field trip. The trip was also a chance to discuss how, in some cases, enforcement of harvesting procedures with contractors requires improvement.

Management and Utilisation of NTFBs

The Programme has generated much information on the economic importance of NTFBs. This information has a number of uses. It can be reflected in decisions taken by Forestry Departments (at both federal and state levels) within the framework of existing management guidelines and policies. The economic assessment of NTFBs can also provide an input into the development of future policies.

Several NTFBs, such as rattan, recreation and medicinal plants have been considered at the highest levels of the Forestry Department. Nevertheless, there remains a need for more information in order for NTFBs to be better incorporated into the forest management process. First, it is necessary to further clarify what is covered under NTFBs. While any such categorisation or definitions will have to reflect circumstances as they continue to change, forest managers need a guiding definition. Very little systematic information covering the production, harvesting and use of many non-timber forest products and services are available. As mentioned above, NTFBs should be incorporated into various forest inventory procedures.

One area requiring further clarification is the relationship between the production of NTFPs and timber. In some cases, such as petai, logging and fruit production appear to be complementary. In others, such as palms (including rattan), forest disturbance through timber harvesting seems to have a negative effect. Thus, forest management plans should incorporate both types of products and reflect the relationships between them. However, for other products, such as medicinal plants, little is known about how their supply is related to timber harvesting. In the case of a non-timber service, such as recreation, the effects of high numbers of visitors on the forest environment remains unclear; where tourists are not confined to certain areas or paths, they are certainly likely to have a negative impact on seedling regeneration.

Many questions also remain on the management of NTFP harvesting. How should harvesting a resource such as rattan be managed? Is adequate capacity, for example in terms of manpower, available to enforce systems? Harvesting of some NTFPs, including bamboo, rattan, petai and durian is currently regulated in many states with a licensing approach. Such systems should be assessed with regards to sustainability and distribution of benefits. Indeed, on-going work under the Programme plans to address these issues in the case of petai but work is needed for other NTFPs. As with timber, the use of economic incentives to ensure management objectives concerning NTFPs should be explored.

In the case of many NTFPs, little information exists on the current trends in their use and the associated causes. For example, the workshop highlighted that a number of factors have been identified that might play a role in the decreasing supply of rattan to the Malaysian furniture industry, such as lower biological production or smuggling of rattan outside Malaysia. However, without being able to pinpoint which factors are most important, it is not possible to promote the further development of the sector into the higher quality segment of the market. Similarly, in the case of medicinal plants, surveys of users and processors are necessary to assess which domestic species are used and where possibilities might lie for substituting imports with domestically

harvested varieties. With respect to forest fruits, taste sampling tests are required to determine which species could be encouraged for distribution and consumption on a wider scale.

Other Issues

The workshop also concentrated on the important issue of incorporating information generated by this Programme, as well as other efforts, into operations and management. Specific mechanisms are required to ensure that information on non-timber forest benefits reaches forest managers and those involved in operations who will need sufficient information, time and direction prior to incorporating these on the ground. There is also a need for the research results to be presented in a practical and applicable manner in order for them to meet the needs of forest managers. Furthermore, training in various aspects of NTFBs, such as multi-resource inventorying, may be required.

Finally the workshop stressed that the type of research undertaken under the Programme should be extended from lowland forest, such as that found at Pasoh, to upland forest where much of the current production forest is located. From a biological perspective, a number of areas need to be studied, including lichens, fungi, understorey plants, herpetofauna, avifauna, insects (aside from ants) and aquatic flora and fauna. In terms of biological diversity conservation, it is also important to look at other types of ecosystems, such as peat swamp and mangrove forests. Participants also noted the importance of assessing biological diversity conservation in plantation forests to see if there is any way of maintaining a degree of biological diversity within them. It may also be useful to assess the possibility of multi-species plantations which are richer in biological diversity.

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