CONSERVATION, UTILIZATION AND MANAGEMENT OF FOREST GENETIC RESOURCES IN MALAYSIA

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Introduction

Forest genetic resources can be defined as the economic, scientific or social values of the heritable materials contained within and between species. They are associated with different levels of natural diversity from ecosystems to species, populations, individuals and genes. Conservation of forest genetic resources means managing forest genetic resources for human use to yield the greatest sustainable benefits for present generations, while maintaining their potential to meet the needs and aspirations of future generations (FAO 1993).

Malaysia is fortunate in having extensive areas of valuable natural tropical forests, richer in plant species diversity than other similar areas in Africa and South America. They are, in fact, the most species-rich communities known anywhere in the world (Whitmore 1975). This paper assesses the status of conservation, management and use of forest genetic resources in Malaysia. Information for this paper was collected through a review of the available literature and through consultations with government departments and non-governmental organizations.

Physiography

Malaysia consists of two large landmasses situated between 0º 50' and 7º 25' N and separated by the South China Sea. Peninsular Malaysia, an extension of the Asian continent, is a narrow land mass bordered by Thailand to the north and Singapore to the south. East Malaysia, comprising the states of Sabah, Sarawak and the Federal Territory of Labuan, is situated on the island of Borneo and is bordered by Brunei and Kalimantan, Indonesia. Peninsular Malaysia accounts for two-fifths of Malaysia's land area of 330,000km^2 and East Malaysia for the remainder.

Malaysia has a hot and humid tropical climate influenced by the northeast and southwest monsoons, and characterized by seasonal variations in rainfall. Annual rainfall in Peninsular Malaysia averages 2540mm, peaking during the southwest monsoon of September to December. East Malaysia receives most of its rainfall during the northeast monsoon of October to February. Average annual rainfall in Sabah is 2630mm and in Sarawak 3850mm. Temperatures average 27ºC with a diurnal range of 9 C. Relative humidity is high (85–95%), particularly in coastal areas (Anon 1997).

Forest resources

In 1998, Malaysia had an estimated forest area of 18.64 million hectares, or 56.7% of the country's land area (Table 1). About 15 million hectares of this area consists of inland forests, including lowland dipterocarp forests, hill dipterocarp forests and upper hill or montane forests. The remainder includes peat swamp and freshwater swamp forests (1.46 million

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hectares), mangrove forests (0.53 million hectares) and other types such as beach, heath and plantation forests (1.33 million hectares).

Table 1. *Total forested land and distribution of forest cover by major forest types in Malaysia, 1998 (in millions of hectares). Source: Anon (1999a).*

Region	Land area	Inland forest	Swamp forest	Mangrove forest	Others	Total forested area	% forested area
Peninsular Malaysia	13.15	4.40	0.17	0.09	1.18	5.84	44.4
Sabah	7.37	3.79	0.19	0.34	0.15	4.47	60.7
Sarawak	12.33	7.13	1.10	0.10	–	8.33	67.6
Total	**32.86**	**15.32**	**1.46**	**0.53**	**1.33**	**18.64**	**56.7**

Taxonomy

The tropical forests of Malaysia are a unique, highly diverse natural heritage that has evolved over many millions of years. The exact number of plant species in Malaysian forests is not known. According to a recent assessment of biological diversity, the number of recorded plant species is about 15,000 (Anon 1997). Some plant groups are better known than others. The Tree Flora of Malaya (Whitmore 1972; Whitmore 1973; Ng 1978; Ng 1989) covers every tree species of Peninsular Malaysia except the dipterocarps, which were covered by Symington (1943). The four volumes of the Tree Flora describe nearly 2830 species of woody plants, of which 746 are endemic and 511 endangered because they are rare, hyper-endemic or their habitats are threatened (Ng 1991). Work on the tree flora of Sabah and Sarawak is currently underway and three volumes have so far been published (Soepadmo & Wong 1995; Soepadmo *et al*. 1996; Soepadmo & Saw 2000).

Most lowland rainforests in Malaysia are dominated by the Dipterocarpaceae family. Sixty-seven percent of the total growing stock in Sabah and Sarawak is estimated to consist of *Shorea*, a common dipterocarp genus. In Peninsular Malaysia, dipterocarps constitute 50–60% of the total growing stock over 30cm in diameter, and account for three-quarters of the commercial volume (Soerianegara & Lemmens 1994).

In Peninsular Malaysia, rattans and bamboos have been documented respectively by Dransfield (1979) and Wong (1995). Herbaceous plants, however, have been neglected in taxonomic and ecological studies. About 2600 species of herbaceous plants have been recorded in Peninsular Malaysia. Of these, 850 species belong to the orchid family and 650 to the ferns and their allies. In addition, at least 2500 herbaceous species are thought to occur in Sabah and Sarawak (Anon 1997). No figures have been published for fungi, lichens or mosses.

Forest types

The forest ecosystems of Malaysia are classified into several schemes which vary according to substrate (i.e. dry or wet soil types), floristic composition, altitude and other features. Examples of widely used forest classification systems applicable to Peninsular Malaysia are given by Symington (1943), Wyatt-Smith (1963) and Whitmore (1990). Ashton (1995) compares forest profiles in Sabah and Sarawak to those in Peninsular Malaysia. The eight major forest types recognized in Malaysia are as follows:

Lowland dipterocarp forest: This occurs up to an elevation of 300m. Together with hill dipterocarp forest, it constitutes the main forest type in Malaysia. Primary lowland dipterocarp

forest consists of dominant and co-dominant strata reaching 45m in height with emergent trees reaching 60m in height. An intermediate stratum of trees forms a canopy between 23m and 30m, below which grows suppressed vegetation. Where emergent trees are rare, the forest forms a three-layered stand. Ground vegetation is of moderate density. About half of the upper-story trees belong to the Dipterocarpaceae family. In Sarawak, no distinction is made between lowland and hill dipterocarp forests. They are generally referred to as mixed dipterocarp forest, and occupy an area from the inland limit of the freshwater peat swamps to the lower limit of the montane forests. In Sabah, lowland dipterocarp forest is further divided into sub-types based on species dominance, such as *Parashorea malaanonan* forest and *Shorea/Eusideroxylon zwageri* forest.

Hill dipterocarp forest: This occurs between elevations of 300m and 1300m. Many of the lowland dipterocarp forest genera are represented but species composition varies. Ridges, for example, are often dominated by *Shorea curtisii* (Seraya forest), and non-dipterocarp species such as *Swintonia spicifera* occur frequently. Hill forests are found on ultisols, oxisols and podzols with low agricultural potential. They currently form the bulk of the productive permanent forest estate. In Sabah, two sub-types of hill dipterocarp forest are distinguished: i) *Shorea* forest (Selangan Batu forest) found on steeper and higher hills; and ii) *Dipterocarpus/Shorea* forest on sandstone escarpments along the east and north coast.

Upper hill/montane forest: This occurs above 1300m on brown earth and podzol soils. In Peninsular Malaysia this forest type contains few dipterocarp species. Commonly found species belong to the Fagaceae (*Quercus, Lithocarpus* and *Castanopsis* spp.) and Lauraceae families. Other species include *Agathis alba*, *Engelhardtia* spp. and *Podocarpus* spp. Ericaceous ('mossy') forests with few oaks occur above 1600m in the cloud belt. *Pteris ovalifolia, Rhododendron* spp. and *Vaccinium* spp. are common on acid peaty gley soils. In Sabah, montane dipterocarp forests occur above the zone of hill dipterocarp forests in the Crocker Range and the central uplands. The main species here are *Shorea platyclados, Shorea venulosa* (on ultra basic rocks), *Shorea monticola*, *Shorea laevis*, *Hopea montana*, *Hopea dyeri, Dipterocarpus ochraceus, Vatica dulitentis*, and *Vatica umbonata.* At higher elevations these forests become oak-chestnut forests and, at elevations over 2000m, they are replaced by mossy forests rich in conifers and Ericaceae.

Heath forest: This is generally grouped with hill forests, and is also known as kerangas forest. Heath forest trees are small and poorly formed. Heath forest has a limited distribution and occurs on white sandy soils and beach terraces at all elevations. The main species and genera are *Casuarina, Agathis alba, Dacrydium, Tristania* and, infrequently, *Shorea albida.*

Beach forest: This is restricted to sandy coastal soils where it occupies strips seldom more than 100 metres wide. The main species is *Casuarina equisetifolia.*

Peat swamp forest: In Peninsular Malaysia, peat swamp forests once occupied extensive areas of the central and southern coastal plain. Many species not typically found in dipterocarp forests occur in peat swamp forests (with the notable exception of *Koompassia malaccensis* and some dipterocarp species). In Sabah, these forests are found on the west and east coast, principally on the Klias Peninsula. The main species on the west coast are ramin (*Gonystylus bancanus*), jongkong (*Dactylocladus stenostachya*), *Dryobalanops rappa*, *Shorea platycarpa*, *Shorea scabrida*, *Shorea teysmanniana* and *Hopea pentanervia.* On the eastern coast the main species are *S. scabrida* and *H. pentanervia*. *D. rappa* is often replaced by *Dryobalanops beccarii*. The most extensive peat swamp forests occur in Sarawak. These are commercially important and since 1946 have made a major contribution to the state's economy. The main

commercial species occur in two of the six sub-types of peat swamp forest: i) mixed swamp forest with ramin (*G. bancanus*), jongkong (*D. stenostachys*), swamp merantis (*Shorea uliginosa*, *S. teysmanniana*, *S. platycarpa* and *S. scabrida*), jelutone pacsa (*Dyera lowii*), sepetir (*Copaifera palustris*), and swamp kapur (*D. rappa*); and ii) alan (*S. albida*) forests.

Freshwater swamp forest: This occurs with peat swamp forest at low elevations that are only temporarily submerged by mineral-rich, less acidic fresh water during the rainy season. Floristic composition varies but the forest is often richer in dipterocarp species than true swamp (peat) forest. *Dipterocarpus coriaceus*, *Dipterocarpus costulatus*, *Dryobalanops oblongifolia*, *Hopea mengarawan* and *Shorea* and *Vatica* spp. represent the dipterocarps. *Hopea* spp. and *Vatica* spp. are also common, interspersed with non-dipterocarps such as *Intsia palembanica*, *K. malaccensis*, *Melanorrhoea*, *Palaquium*, *Pometia* and *Sindora* spp. Soils are partly drained levee soils or backswamp soils that are being widely reclaimed for agriculture. In Sabah, these forests are usually rich in *Dipterocarpus warburgii*, *Shorea gysbertsiana* and *Dipterocarpus exalatus* on alluvial soils near rivers. *Dipterocarpus oblongifolius* is common along streams in hilly areas.

Mangrove forest: This is found mainly on marine alluvial soils (tropaquents and saprists) along sheltered coasts and estuaries. Mangrove forest has a simple structure with *Rhizophora*, *Avicennia*, *Bruguiera*, *Sonneratia* and *Xylocarpus* spp. distributed in species-specific belts that follow soil and inundation patterns. Trees range in height from 7m to 25m. Mangroves are highly productive ecosystems and important spawning, nursery and feeding habitats for many marine fish and invertebrates. Mangrove wood is used for buildings, fish traps and for firewood and charcoal. Two types of swamp palms are also included in the mangrove forest type, namely, nipah (*Nypa fruticans*) and nibong (*Oncosperma horridum*). Nipah is a multiple-use species that provides housing thatch, cigarette paper, sugar, alcohol, vinegar, salt and other products. This species frequently grows in pure stands. Nibong occurs in the drier zone of the mangrove forest.

Utilization of forest genetic resources

Historically, Malaysia's forests have been seen as a source of timber and wood for charcoal or fuelwood. In recent years, more attention has been paid to the importance of non-timber forest products, including plants for food and medicinal purposes, rattan, bamboo, dyes, gums, resins and honey, as well as services such as water conservation and recreation. As a natural renewable resource, forests have contributed significantly to socio-economic development. In 1998, the state forestry departments of Peninsular Malaysia collected revenues of US$74.21 million from log production totalling 5.5 million m^3 (Anon 1999b). The total value of exports in 1998 was US$2,457.63 million, based on exports of logs, sawn timber, plywood, veneer and mouldings totalling 13 million m^3 (Anon 1999a).

In 1998, the forestry sector provided employment for 10,064 people in public sector services and agencies, which are responsible for forestry administration and for managing and developing the forest resource. Another 223,574 people were employed in the private forest industry (Anon 1999a). Employment opportunities in the sector are expected to increase substantially as the forest resource base expands through more intensive management, the creation of fast-growing tree plantations and the modernization of the forest industry to increase value-added processing. Most forestry workers are either semi-skilled or skilled, and so tend to earn higher wages than those employed in other sectors. Because most forestry jobs are in rural areas, expansion of the forest sector will not only contribute to rural development but also transfer skills and expertise to rural areas.

Institutional framework

The Forest Research Institute Malaysia (FRIM), the Forestry Department of Peninsular Malaysia, the Forestry Departments of Sabah and Sarawak, the Malaysian Timber Industry Board (MTIB) and the Malaysian Timber Council (MTC) are directly involved in administration, management, research and development in the forest sector. All of these agencies are under the Ministry of Primary Industries. In addition, a number of other centres of excellence conduct complementary research and development. These include the Forest Research Centre at Sandakan in Sabah, the Timber Research and Technical Centre and the Forestry Research Division of the Sarawak Forestry Department, the Sarawak Timber Industry Development Corporation and the Faculty of Forestry at the University of Putra, Malaysia.

Forest Research Institute Malaysia: FRIM was established as a statutory body in 1985 and is Malaysia's primary forest research organization. Before 1985, FRIM was a research institute within the Forestry Department of Peninsular Malaysia. FRIM is entrusted with responsibility for carrying out research and development activities in forestry and forest-based industries at the national level. In addition, FRIM provides technical support in research and development to government agencies and the private sector. FRIM's main objectives are:

- To generate knowledge and develop appropriate technology for the conservation, management, development and use of forest resources;
- To provide research-based services to meet the need of clients;
- To commercialize research and development results;
- To acquire and disseminate information;
- To create awareness of the environmental and conservation roles of forestry; and
- To pursue excellence and attain leadership in tropical forestry research.

FRIM's activities are organized under a number of divisions: natural forest management, plantation forest management, conservation of biological diversity, forest product technology, wood chemistry, techno-economics and utilization of medicinal plants. Monitoring and evaluation of research and technology transfer are important subsidiary activities. Several methods of technology transfer are used, including two international refereed journals and other in-house publications, and technical services such as fire-door testing, furniture testing, wood and plant identification, and consultancy services. Much of the research that FRIM does is enhanced by collaboration with the private sector and with other national and international organizations.

Forestry Department, Peninsular Malaysia: This institution has long been entrusted with the task of sustainably managing and developing forests to maximize their contribution to national socio-economic development. Among its objectives are:

- To manage forest resources sustainably for the continuous production of forest goods and services, and their optimum use, consistent with environmental requirements;
- To increase the supply of forest goods and services through appropriate forestry activities that enhance the quality, productivity and use of forest resources;
- To further develop appropriate and environmentally sound technologies for the conservation, management and use of forest resources;
- To conserve, protect and use sustainably forest biological diversity, water and soil resources;

- To increase the quality and efficiency of forest-based processing mills and enhance value-added downstream activities; and
- To improve public awareness of the environmental role of forests through education and dissemination of information.

Forestry Department, Sabah: Like its counterpart in Peninsular Malaysia, Sabah's Forestry Department is entrusted with managing the state's forest resources sustainably and protecting the forest environment. The objectives of the department are:

- To ensure that the management and development of Sabah's forest resources are in accordance with sustainable forestry principles;
- To optimize the use of forest resources in order to sustain socio-economic benefits to the state;
- To enhance the efficiency of the forestry industry in forest resource utilization, while ensuring that the processing capacity of the industry corresponds to the long-term production capacity of the forest resource;
- To intensify efforts in research and education towards sustainable forest management; and
- To conserve sufficient natural forest areas for the protection and maintenance of the environment, water resources, soils, and biodiversity.

Forestry Department, Sarawak: This institution was established to implement the state's forest policy. The objectives of this policy are:

- To ensure the sound climatic and physical condition of the state, safeguarding soil fertility and water supplies for domestic and industrial use, irrigation and general agricultural purpose, and the prevention of damage by flooding and erosion to rivers and agriculture land;
- To ensure the supply in perpetuity and at moderate prices of all forms of forest produce that can be economically produced within the state, and that are required by the people for agricultural, domestic and industrial purposes under a fully developed economy;
- To manage the productive forests of the permanent forest estate with the objective of obtaining the highest possible revenue compatible with the principle of sustained yield and other objectives;
- To promote, as far as possible, the thorough and economic utilization of forest products on land not included in the permanent forest estate, before the alienation of such land;
- To foster by education and publicity the value of forests among the public, and to provide training in the field of forestry and forest industry; and
- To ensure a regular and uninterrupted source of funds for the advancement of forestry in the state.

Forestry Faculty, University of Putra, Serdang: The Faculty was established in 1971 to train professional foresters. It also aims to enhance wood-based industries and ecotourism in Malaysia, and specializes in subjects such as forest management and production, wood industries, and park and recreation management. The Faculty currently has more than 11 research groups with strong local and international linkages.

Constitution, policy and legal provisions

Malaysia has a federal system of government. There are 13 states in the Federation, all except two of which are in Peninsular Malaysia. The Constitution defines land (including forested land) as a state responsibility. Each state can enact laws and formulate land policy independently, and each has its own forest department which is responsible for implementing forest laws. The Forestry Department headquarters in Kuala Lumpur, under the supervision of the federal Ministry of Primary Industries, is responsible for training, research and providing technical assistance to the states.

The National Forestry Council (NFC), established in 1971 by the National Land Council (NLC), provides a forum for federal and state governments to discuss forest-related issues such as planning, management and development of forest resources. It also plays a major role in encouraging the adoption of federal acts at state level. All of the Council's decisions must be endorsed by the NLC. Responsibility for implementing these decisions, however, lies with state governments, unless the issue comes under the authority of the federal government.

Malaysia's national forest policy was formally adopted in 1978. The purpose of the policy is to ensure uniformity in the implementation of all forest management, conservation and development strategies that address common aims. The policy promotes the maintenance of a permanent forest estate (PFE), managed in accordance with the principles of sound forest management. It also provides for the thorough and efficient use of state forests outside the PFE that are earmarked for conversion. The policy was revised in 1993 to acknowledge the importance of biodiversity conservation and sustainable use of forest genetic resources, as well as the role of local communities in forest development.

The 1984 National Forestry Act provides a legal framework for implementing the national forest policy in Peninsular Malaysia. The amended 1993 National Forestry Act introduced fines of up to US$200,000 or a prison sentence of up to 20 years for illegal logging. It also enables forest rangers to arrest violators with the assistance of the police and armed forces. Forest management in Sabah and Sarawak is controlled respectively by state forest acts of 1968 and 1954. All acts have subsequently been amended to conform with the national policy.

In 1994, Malaysia established a national committee on sustainable forest management to implement the International Tropical Timber Organization's (ITTO) criteria for sustainable tropical forest management. In support of the committee's task, a working group on sustainable natural forest management in Peninsular Malaysia was established in 1994. The national committee has defined 92 activities, based on 5 criteria and 27 indicators, to implement ITTO's criteria at the national level, and 84 activities, based on 6 criteria and 23 indicators, to implement the criteria at the forest management unit level. Management specifications for assessing forest management at both national and forest management unit levels have been developed to facilitate timber certification efforts (Thang 1997a).

In 1998, Malaysia launched a national biodiversity policy, which aims to enhance the conservation of the country's plant and animal species, and to create a safe, healthy and productive environment (Anon 1998a). It is the first policy with documented multi-sectoral involvement, including the Ministry of Primary Industries, the Ministry of Agriculture, and the Departments of Wildlife and National Parks, and Fisheries. The policy includes strategies and outlines action programmes to conserve biological diversity and use biological resources sustainably. The policy underscores the importance of managing Malaysia's natural resources to provide long-term economic benefits, food security and environmental stability.

Forest management

Management of forested land falls under three broad categories in Malaysia: i) totally protected areas (TPAs) under the control of the federal government (Department of Wildlife and National Parks); ii) PFEs comprising forest reserves under the control of forestry departments; and iii) state land, which is owned by state governments and used essentially as a land reserve for development. The term permanent forest estate is misleading because state governments can claim any part of the PFE for infrastructure development, agriculture, housing or other purposes. Nevertheless, compared with state land, PFEs are better protected against unnecessary interference and threats. And, although they are subject to logging, their diversity and indigenous wildlife are broadly maintained.

Under the national forest policy, PFEs are classified and managed as four main functional types: i) protected forests for conservation of ecological diversity, flood mitigation, and amelioration of soil erosion and river siltation; ii) production forests for economic exploitation of forest resources; iii) amenity forests for conservation of adequate forest areas for recreation, ecotourism and enhancing public awareness of forestry; and iv) education and research forests. Under the National Forestry Act of 1984, provisions have been made to define the end uses of the PFEs. Peninsular Malaysia, Sabah and Sarawak have separate classifications for their PFEs; these include 11 categories in the Peninsula, 7 in Sabah and 3 in Sarawak (Table 2). Most of the states are still in the process of defining their PFEs according to these classifications and have yet to determine appropriate legal or management guidelines.

Table 2. *Classification of permanent forest estates in Malaysia*

Peninsular Malaysia	Sabah	Sarawak
1. Timber Production Forest under Sustained Yield	1. Protection Forest Reserve	1. Forest Reserve
2. Soil Protection Forest	2. Commercial Forest Reserve	2. Protected Forest
3. Soil Reclamation Forest	3. Domestic Forest Reserve	3. Communal Forest
4. Flood Control Forest	4. Amenity Forest Reserve	
5. Water Catchment Forest	5. Mangrove Forest Reserve	
6. Forest Sanctuary for Wildlife	6. Virgin Jungle Reserve	
7. Virgin Jungle Reserve	7. Wildlife Reserve	
8. Amenity Forest		
9. Education Forest		
10. Research Forest		
11. Forest for Federal Purpose		

In Peninsular Malaysia, the production forests of the PFE are managed under two management systems, the Malayan Uniform System or MUS (based on a 55-year cutting cycle), and the Selective Management System or SMS (based on a 30-year cutting cycle). Under the MUS, all mature commercial trees above 45cm diameter at breast height (dbh) are harvested in one operation in the area being logged (Wyatt-Smith 1963; Thang 1988). Under the SMS, management (felling) regimes are determined using pre-felling inventory data (Thang 1987, 1988).

Following logging under the MUS, all remaining large trees of non-commercial species are removed by poison girdling. The next tree crop develops from seedlings and consequently is of uniform age. According to Wyatt-Smith (1988), the MUS is not environmentally degrading, although it is not oriented towards gene conservation.

As the MUS relies primarily on seedlings and saplings to establish succeeding crops, silvicultural treatments are designed to favour these groups, often at the expense of larger trees. This bias tends to encourage more poison girdling than is necessary and, in some cases, excessive opening of the canopy. Over time, however, the emphasis of management has moved from seedlings and saplings to the remaining large trees. This has reduced the incidence of poison girdling and has promoted a more conservation-oriented approach to silvicultural treatments (Hashim 1997).

After modification, the MUS has been applied successfully in lowland dipterocarp forests. It is unsuitable for hill dipterocarp forests, however, owing to the more difficult terrain, uneven stocking, a lack of natural regeneration, erosion risks on steep slopes and the secondary growth promoted by canopy opening. Consequently, in 1978, the SMS was introduced for hill forests. This system is based on the selective removal of the mature crop in a single operation, an approach that allows flexibility in harvesting regimes because it emphasizes the recruitment of trees with a diameter between 15cm and 45 cm for the next crop. It also discourages poison girdling of non-commercial species and so better conserves forest genetic resources. The cutting limit for selective felling is not less than 50cm dbh for dipterocarp species and 45cm dbh for non-dipterocarp species. The cutting limit for the dipterocarp *Neobalanocarpus heimii,* however, is set above 60cm. The difference in the cutting limits between dipterocarps and non-dipterocarps is kept at no less than 5cm in order to preserve a higher proportion of dipterocarp species for the next crop (Thang 1988).

Views differ on the suitability of the SMS for managing dipterocarp forests. Whereas Cheah (1978), Thang (1987) and FAO (1989) all viewed the SMS as most suitable for hill dipterocarp forests, Wyatt-Smith (1987, 1988) and Chin (1989) thought that selective logging under a short cutting cycle was not suitable for managing dipterocarp forests, especially the hill forests. Nevertheless, the SMS is the principal management system for hill dipterocarp forests in Peninsular Malaysia, although some lowland dipterocarp forests are still managed under the MUS.

In pursuit of sustainable management objectives, forest harvesting in Sabah is carried out according to prescribed silvicultural practices to promote natural regeneration. To this end, the dipterocarp forests of Sabah are selectively harvested on a 50-year cutting cycle and only trees of 60cm dbh or above are removed. In Sarawak, the cutting cycle for dipterocarp forests is 25 years, and the prescribed cutting limits for dipterocarps and non-dipterocarps are respectively 60cm and 45cm (Thang 1997b).

The peat swamp forests of Peninsular Malaysia are currently managed under a modified form of the SMS which, owing to less abundant natural regeneration, applies higher cutting limits. Research and development efforts are underway to formulate more effective management systems for this forest type. The cutting cycle adopted for the peat swamp forests of Sarawak is 45 years, with the cutting limit for ramin (*G. bancanus*) and other species set at 40cm dbh (Thang 1997a).

Malaysia's mangrove forests are managed under cutting cycles varying from 20 to 30 years. Currently, however, no mangrove forests are being harvested in Sabah or Sarawak. In Peninsular Malaysia, mature mangrove trees are clear felled, but seven mother (seed) trees are retained in each hectare of forest. A three-metre-wide river bank and coastal strip is also retained to ensure adequate natural regeneration and protect the forest environment (Thang 1997a).

In situ conservation

In situ conservation means maintaining natural plant habitats. In many cases, this is a much cheaper and easier method of conserving genetic diversity than *ex situ* conservation. Malaysia has adopted several measures to protect and conserve forest diversity. These include the creation of a network of totally protected areas including national and state parks, wildlife and bird sanctuaries, and the PFEs. Malaysia currently has 2.12 million hectares in legally protected conservation areas. Of this, 1.79 million hectares are located outside the PFEs and the rest within.

In Peninsular Malaysia, Taman Negara is the only officially designated national park. It represents the flora of central Peninsular Malaysia together with the Krau, Sungkai and Sungai Dusun Wildlife Reserves. Endau-Rompin (Johor) National Park and Endau-Rompin (Pahang) Wildlife Reserve represent the southern flora while the Perlis and proposed Belum State Parks form a continuous link with the monsoon forests of Thailand and Myanmar (Table 3).

Table 3. *Totally protected areas in Malaysia. Source: Anon (1997, 1999c); Abang Morshidi and Gumal (1995).*

Totally Protected Areas	Size (ha)	State/Division
Peninsular Malaysia		
Park		
Endau-Rompin (Johor)	48,905	Johor
Perlis	5,075	Perlis
Taman Negara	431,453	Pahang, Kelantan, Terengganu
Belum (proposed)	–	Perak
Wildlife Reserve		
Endau-Rompin (Pahang)	40,197	Pahang
Krau	62,395	Pahang
Sungai Dusun	4,330	Selangor
Sungkai	2,468	Perak
Tioman Island	9,455	Pahang
Sarawak		
Park		
Bako	2,727	Kuching
Batang Ai	24,040	Sri Aman
Gunung Gading	4,106	Kuching
Gunung Mulu	52,865	Miri
Kubah	2,230	Kuching
Lambir Hills	6,949	Miri
Loagan Bunut	10,736	Miri
Niah	3,139	Miri
Similajau	7,064	Bintulu
Tanjung Datu	1,379	Kuching
Bako Extension (proposed)	870	Kuching
Batang Ai Extension (proposed)	8,630	Sri Aman
Bruit (proposed)	1,776	Sarikei
Buan (proposed)	17,935	Bintulu
Bukit Mersing (proposed)	1,460	Bintulu
Bukit Tiban (proposed)	8,000	Bintulu/Miri
Dulit Range (proposed)	11,110	Kapit/Miri
Gunung Buda (proposed)	6,235	Miri/Limbang
Hose Mountain (proposed)	284,700	Kapit
Kalambuku (proposed)	32,000	Limbang

Table 3. (continued)

Totally Protected Areas	Size (ha)	State/Division
Sarawak		
Kubah Extension (proposed)	1,700	Kuching
Maludam (proposed)	43,147	Sri Aman
Mulu Extension (proposed)	7,108	Miri
Pelagus (proposed)	2,041	Kapit
Pulong Tau (proposed)	63,700	Miri/Limbang
Santubong (proposed)	1,641	Kuching
Sarawak Mangrove (proposed)	6,858	Kuching
Similajau Extension (proposed)	30,713	Bintulu
Talang Satang (proposed)	19,414	Kuching
Ulu Sebuyau (proposed)	16,169	Samarahan & Sri Aman
Usun Apau (proposed)	49,760	Miri/Kapit
Lanjak-Entimau	168,758	Sri Aman, Sibu, Sarikei, Kapit
Pulau Tukong Ara Banum	1.4	Kuching
Samunsam	6,092	Kuching
Batu Laga (proposed)	200,000	Kapit
Lanjak Entimau Extension (proposed)	18,414	Sibu/Kapit
Limbang Mangrove (proposed)	4,500	Limbang
Samunsam Extension I (proposed)	10,897	Kuching
Samunsam Extension II (proposed)	1,101	Kuching
Sibuti (proposed)	1,213	Miri
Sabah		
Park		
Crocker Range	139,919	n.a.
Kinabalu	73,370	n.a.
Pulau Tiga	607	n.a.
Tawau Hills	27,972	n.a.
Tunku Abdul Rahman	1,289	n.a.
Turtle Island	15	n.a.
Wildlife Reserve		
Kulamba	20,682	n.a.
Tabin	120,521	n.a.
Conservation Area		
Maliau Basin (Gunung Lotung)	39,000	n.a.

Although Malaysia's network of protected areas covers a diversity of forest ecosystems, some natural habitats and flora are poorly represented. This problem is mitigated by the presence of PFEs. These represent all of the habitats found in Malaysia, from mangrove forests to sub-alpine forests. As already mentioned, forest reserves in the PFEs are classified as productive forests and licensed for timber harvesting. Within the boundaries of these forests, however, there are often protection forests and virgin jungle reserves (VJRs). Although the PFEs are less effective at conserving forest genetic resources than national and state parks and wildlife reserves, protection forests and VJRs often support a diverse flora, including threatened, endangered and endemic species.

Virgin jungle reserves were established to serve as permanent nature reserves and natural arboreta, as a control for comparing harvested and silviculturally treated forests, and as undisturbed natural forests for general ecological and botanical studies (Wyatt-Smith 1950). Since their introduction in the 1950s, 72 VJRs covering 21,284ha have been established throughout Peninsular Malaysia. These preserve virgin samples of many of the different forest types found in the country. Various studies have recognized the importance of a VJR network,

including FAO (1984) and Laidlaw (1994). Research efforts are underway to document the species and habitats represented in the VJR network, and to assess the optimal distribution of the network to maximize its conservation value.

Sarawak currently has ten national parks and three wildlife sanctuaries. Some forest and vegetation types are under-represented in the present system, which covers only 2.36% of the state's land area. The state government is keen to expand its conservation network by establishing new parks and wildlife sanctuaries. If all of the new areas currently under consideration are established, the protected area network will cover 8% of the state's land area. At the same time, the state government is determined to enlarge the PFE to cover 70% of the state's forests. In Sabah, the second-largest state of Malaysia, forests cover just over 60% of the total land area. There, the protected area network consists of six natural parks, two wildlife reserves and one conservation area.

Ex situ conservation

Ex situ conservation means maintaining species outside their original habitats in botanical gardens, arboreta, seed genebanks, *in vitro* genebanks or field genebanks. It is an important technique for long-term storage of genetic material for breeding programmes or for reintroducing species to the wild. Article 9 of the Convention on Biological Diversity stresses the importance of *ex situ* conservation as a complement to *in situ* measures.

At present, Malaysia has 26 *ex situ* conservation areas. Collections are conserved mainly in arboreta and field genebanks of research institutions, universities and government agencies. The universities include Universiti Malaya, Universiti Putra Malaysia and Universiti Kebangsaan Malaysia, and the government-funded research centres include those at Semenggok in Sarawak and at Sepilok and Poring in Sabah. Of the research institutions, FRIM, the Malaysia Palm Oil Board, the Malaysia Rubber Board and the Malaysian Agricultural Research and Development Institute have arboreta for various groups of wild species. Seed genebanks for forest species are not appropriate as most of tropical trees produce recalcitrant seeds, which cannot be stored for long periods (see below). Various institutes in the country are carrying out research to explore the possibilities of using cryogenic and *in vitro* techniques for long-term gene conservation of tree species.

Malaysia lost its most valuable botanical garden when Singapore left the Federation in 1965. The Singapore Botanical Garden was a centre of botanical research and had large plant collections. It also played an important role in describing and documenting Malayan flora. The Penang Botanical Garden, established under British rule, is currently the oldest *ex situ* conservation area in Malaysia. This garden, however, has carried out little research or collecting in recent years. Its major functions are education, recreation and tourism. For these reasons, FRIM has begun to develop a national botanical garden with support from the federal government. This garden is still at an early stage of development and will not be completed for another decade. Planning for two other botanical gardens at Putrajaya and Sungai Buluh is also underway.

Ex situ conservation areas have been established to safeguard the genetic diversity of cultivated and domesticated plant species and their wild relatives (Table 4). Most research efforts have concentrated on the improvement and sustainable development of agricultural crop species. Little work has been carried out on conserving the genetic diversity of forest species. The largest groups of forest species under *ex situ* conservation are orchids (1639 species), followed by fruit trees (434 species), timber trees (364 species) and medicinal plants (115 species). Saw and Raja Barizan (1991) give detailed lists of *ex situ* conserved species.

Table 4. *Examples of ex situ plant gene conservation in Malaysia*

Arboreta	Medicinal plants Fruit trees Timber species Ornamentals
Field genebanks	Rubber Oil palm Cocoa Fruit trees Coconut Orchid Sweet potato
In vitro genebanks	Cassava Timber species
Seed genebanks	Rice Vegetables

Seed demand and supply for reforestation programmes

The ITTO criteria for sustainable forest management include replenishing forest resources through planting of indigenous species. Most tropical timber species, however, have erratic fruiting behaviour which restricts the continuous supply of seed. In general, mass fruiting happens every 3–8 years in most tropical timber species. Dipterocarps fruit every 1–5 years, although some species flower annually but at a low intensity (Marzalina & Abdul Rahman 2000). Furthermore, an estimated 94% of dipterocarp species and 72% of other tree species produce recalcitrant seed (Tompsett 1994). Recalcitrant seeds are large tropical seeds that can last no more than ten days before losing viability. Stem cuttings, however, have been reported to produce rooting rates of between 28% and 95% (Aminah 1996), and provide some assurance of a future supply of planting material.

A working group under the Malaysian-German Forest Planting Material Procurement Programme (MGFPMPP) conducted a survey in 1996 to estimate the amount of planting material required in Malaysia (Table 5). With this information, it is hoped that a continuous supply of planting material can be established to meet demand. Species are selected for plantations on the basis of current trends and societal demand, whereas those for enrichment planting are determined by site-specific conditions, silviculture and economic factors. Tree planting for biodiversity conservation is carried out by the Forest Department with help from FRIM and local universities. Such planting, however, is carried out on an *ad hoc* basis and covers only small areas.

The participation of large private companies (e.g. Boh Plantation, Sime Darby, Maju Aik and IOI Corporation) in establishing forest plantations is still at an early stage. Planting of fast-growing timber trees focuses on a small group of species to determine growth rates and financial performance. Private nurseries, which mostly concentrate on producing planting material for landscaping and horticulture, also need seed of forest tree species. Their demand is normally limited and the species required vary according to need. The Forest Department, with assistance from FRIM, is setting up two seed centres in Malaysia (in Pahang and Sarawak), which should start operations by mid-2001. It is hoped that such centralized plant procurement centres will be able to supply enough seed to meet the demands of each state.

Table 5. *Total planting stock required by forestry departments in Malaysia for forest development programmes. Source: Anon (1998b).*

State	Forest plantation[a)]	Enrichment planting[b)]	Special project[c)]	Landscape[d)]
Negeri Sembilan	645,666	895,000	–	–
Perlis	299,630	–	40,750	42,000
Pulau Pinang	–	15,452	–	50,000
Kedah	n.a.	n.a.	n.a.	n.a.
Perak	1,250,000	14,383,325	100,000	–
Selangor	–	493,140	–	–
Johor	–	888,255	–	–
Pahang	n.a.	n.a.	n.a.	n.a.
Terengganu	725,522	4,479,058	25,000	67,710
Kelantan	6,436,170	5,679,431	77,775	–
Sabah	100,000	–	–	–
Sarawak	278,100	2,383,605	–	–
Total	**9,735,088**	**29,217,266**	**243,525**	**159,710**

a) Multi-storied forest, agroforestry, community forest and replanting of grazing areas.
b) Gap or open-space planting, planting of mangrove areas, rattan planting, bamboo planting, etc.
c) Planting of medicinal plants, biodiversity conservation, and people's insurance scheme.
d) Urban forestry, road-side planting and coastal planting.

Genetic diversity and mating systems

In order to establish guidelines for conserving and using the genetic resources of a given species, adequate information must be available on population biology, reproductive systems and genetic diversity. A lack of information on these topics limits our ability to manage deliberately the genetic resources of most tree species. Until adequate data are available, the safest option is to maintain a broad genetic base of target species by conserving a wide range of provenances. To date, genetic studies and characterizations of mating system parameters using molecular markers have been completed for the following tree species: *Hopea odorata* (Wickneswari *et al*. 1994); *Dyera costulata* (Norwati 1994); *Shorea leprosula* (Lee *et al*. 2000a, 2000b); *Dryobalanops aromatica* (Lee 2000; Lee *et al*. 2000); *Aquilaria malaccensis* (Norwati 2000); and *N. heimii* (Konuma *et al*. 2000). Studies on *S. parvifolia*, *S. lumutensis*, *S. ovalis*, *S. macroptera*, *S. acuminata*, *S. curtisii*, *I. palembanica*, and *K. malaccensis* are continuing.

Identification of priority species

The 100 priority species for Malaysia are listed in Table 6. Species selection was based primarily on the references given in the table. The list consists mainly of commercially valuable timber species (e.g. *N. heimii*, *I. palembanica* and *E. zwageri*), fast-growing timber species for plantations (e.g. *Azadirachta excelsa*, *D. costulata* and *Endospermum diadenum*) and non-wood species (e.g. *Eurycoma longifolia*, *Labisia pumila* and *Calophyllum lanigerum*).

Table 6. *Value and use of target, important species in Malaysia. Source: Burkill (1966); Kiew and Pearce (1991); Appanah and Weinland (1993); Dransfield and Manokaran (1993); Soerianegara and Lemmens (1993); Dransfield and Widjaja (1995); Abdul Latiff (1998a, 1998b); Kiew (1998a); Saw (1998); Soepadmo (1998); Teo (1998); Wong (1998); Anon (1999c); de Padua et al. (1999).*

Species name (Family)	Value code[a)]	Present, future or potential use[b)]											
		ti	po	wo	nw	pu	fo	fd	sh	ag	co	am	xx
1. *Acalypha hispada* (Euphorbiaceae)	2				✓								
2. *Acorus calamus* (Araceae)	2				✓								
3. *Agathis borneensis* (Coniferae)	1	✓			✓								
4. *Alangium serraca* (Alangiaceae)	2				✓								
5. *Alstonia scholaris* (Apocynaceae)	2				✓								
6. *Andrographis paniculata* (Acanthaceae)	2				✓								
7. *Anisoptera costata* (Dipterocarpaceae)	1	✓											
8. *Anisoptera curtisii* (Dipterocarpaceae)	1	✓	✓										
9. *Antiaris toxicaria* (Moraceae)[c)]	1	✓			✓								
10. *Aquilaria malaccensis* (Thymelaeaceae)[c)]	1	✓			✓								
11. *Artocarpus elastica* (Moraceaae)	1	✓											
12. *Artocarpus lanceaefolia* (Moraceae)	1	✓											
13. *Avicennia alba* (Verbanaceae)[c)]	1		✓	✓									
14. *Azadirachta excelsa* (Meliaceae)	1	✓			✓				✓	✓			
15. *Brucea javanica* (Simaroubaceae)	2				✓								
16. *Calamus manan* (Palmae)	1									✓			✓
17. *Calamus subinermis* (Palmae)	1									✓			✓
18. *Calophyllum lanigerum* var. *austrocoriaceum* (Guttiferae)	1	✓			✓								
19. *Casuarina equisetifolia* (Casuarinaceae)[c)]	1										✓		
20. *Centella asiatica* (Umbelliferae)	1				✓								
21. *Chukrasia tabularis* (Meliaceae)	1	✓											
22. *Cotylelobium lanceolatum* (Dipterocarpaceae)	1	✓			✓								
23. *Cycas* sp. (Cycadaceae)	2										✓	✓	
24. *Dillenia grandifolia* (Dilleniaceae)	1	✓	✓										
25. *Dipterocarpus baudii* (Dipterocarpaceae)	1	✓			✓								
26. *Dipterocarpus cornutus* (Dipterocarpaceae)	1	✓											
27. *Dipterocarpus costulatus* (Dipterocarpaceae)	1	✓											
28. *Dipterocarpus crinitus* (Dipterocarpaceae)	1	✓			✓	✓							
29. *Dipterocarpus grandiflorus* (Dipterocarpaceae)	1	✓			✓	✓							

Table 6. *(continued)*

Species name (Family)	Value code[a)]	Present, future or potential use[b)]											
		ti	po	wo	nw	pu	fo	fd	sh	ag	co	am	xx
30. *Dipterocarpus oblongifolius* (Dipterocarpaceae)[d)]	1	✓			✓								
31. *Dryobalanops aromatica* (Dipterocarpaceae)	1	✓			✓								
32. *Dryobalanops oblongifolia* (Dipterocarpaceae)	1	✓											
33. *Durio* sp. (Bombacaceae)	1	✓					✓						
34. *Dyera costulata* (Apocynaceae)	1	✓			✓		✓		✓			✓	
35. *Endospermum diadenum* (Euphorbiaceae)	1	✓											
36. *Eurycoma longifolia* (Simaroubaceae)[c)]	1				✓								
37. *Eusideroxylon zwageri* (Lauraceae)	1	✓	✓										
38. *Fagraea fragrans* (Loganiaceae)	1	✓							✓			✓	
39. *Ficus deltoidea* (Moraceae)	2				✓								
40. *Garcinia* sp. (Guttiferae)	1	✓					✓						
41. *Gigantochloa scortechinii* (Gramineae)	1						✓			✓			✓
42. *Goniothalamus velutinus* (Anonaceae)[c)]	1				✓								
43. *Gonystylus bancanus* (Thymelaeaceae)	1	✓											
44. *Heritiera javanica* (Sterculiaceae)	1	✓	✓										
45. *Hopea nervosa* (Dipterocarpaceae)	1	✓											
46. *Hopea nutans* (Dipterocarpaceae)	1	✓			✓								
47. *Hopea odorata* (Dipterocarpaceae)	1	✓							✓				
48. *Intsia palembanica* (Leguminosae)	1	✓	✓		✓								
49. *Johannesteijsmannia* sp. (Palmae)	1											✓	
50. *Koompassia malaccensis* (Leguminosae)[c)]	1	✓	✓										
51. *Labisia pumila* (Myrsinaceae)	1				✓								
52. *Metroxylon rumphii* (Palmae)	1						✓						
53. *Metroxylon sagu* (Palmae)	1						✓						
54. *Neobalanocarpus heimii* (Dipterocarpaceae)	1	✓	✓		✓								
55. *Nepenthes* sp. (Nepenthaceae)[c)]	1											✓	
56. *Nephelium* sp. (Sapindaceae)	1	✓					✓						
57. *Oncosperma tigillaria* (Palmae)	1		✓										
58. *Orthosiphon grandiflorus* (Labiatae)	2				✓								

Table 6. *(continued)*

Species name (Family)	Value code[a)]	Present, future or potential use[b)]											
		ti	po	wo	nw	pu	fo	fd	sh	ag	co	am	xx
59. *Palaquium maingayi* (Sapotaceae)	1	✓											
60. *Palaquium rostratum* (Sapotaceae)	1	✓											
61. *Paphiopedilum* sp. (Orchidaceae)[c)]	1											✓	
62. *Parashorea lucida* (Dipterocarpaceae)	1	✓											
63. *Parashorea stellata* (Dipterocarpaceae)	1	✓											
64. *Parkia javanica* (Leguminosae)	1	✓											
65. *Parkia speciosa* (Leguminosae)	1	✓					✓						
66. *Phalaenopsis* sp. (Orchidaceae)	1											✓	
67. *Pterocarpus indicus* ((Leguminosae)	1	✓							✓			✓	
68. *Rafflesia* sp. (Rafflesiaceae)[d)]	1				✓							✓	
69. *Santiria laevigata* (Burseraceae)	1	✓											
70. *Schima wallichii* (Theaceae)	1	✓											
71. *Senna alata* (Leguminosae)	2				✓								
72. *Shorea acuminata* (Dipterocarpaceae)	1	✓											
73. *Shorea bracteolata* (Dipterocarpaceae)	1	✓											
74. *Shorea curtisii* (Dipterocarpaceae)	1	✓			✓								
75. *Shorea glauca* (Dipterocarpaceae)	1	✓											
76. *Shorea hemsleyana* (Dipterocarpaceae)[c)]	1	✓											
77. *Shorea kunstleri* (Dipterocarpaceae)	1	✓											
78. *Shorea laevis* (Dipterocarpaceae)	1	✓											
79. *Shorea lepidota* (Dipterocarpaceae)	1	✓											
80. *Shorea leprosula* (Dipterocarpaceae)	1	✓											
81. *Shorea longisperma* (Dipterocarpaceae)	1	✓			✓								
82. *Shorea macrophylla* (Dipterocarpaceae)[c)]	1	✓			✓								
83. *Shorea macroptera* (Dipterocarpaceae)	1	✓											
84. *Shorea maxwelliana* (Dipterocarpaceae)	1	✓											
85. *Shorea multiflora* (Dipterocarpaceae)	1	✓											
86. *Shorea ovalis* (Dipterocarpaceae)	1	✓											
87. *Shorea parvifolia* (Dipterocarpaceae)	1	✓											

Table 6. *(continued)*

Species name (Family)	Value code[a)]	Present, future or potential use[b)]											
		ti	po	wo	nw	pu	fo	fd	sh	ag	co	am	xx
88. *Shorea pauciflora* (Dipterocarpaceae)	1	✓											
89. *Shorea platyclados* (Dipterocarpaceae)	1	✓											
90. *Shorea resinosa* (Dipterocarpaceae)	1	✓											
91. *Shorea roxburghii* (Dipterocarpaceae)	1	✓											
92. *Shorea splendida* (Dipterocarpaceae)[c)]	1	✓			✓								
93. *Shorea stenoptera* (Dipterocarpaceae)[c)]	1	✓			✓								
94. *Sindora coriacea* (Leguminosae)	1	✓											
95. *Sonneratia alba* (Sonneratiaceae)[c)]	1		✓	✓									
96. *Tinospora crispa* (Menispermaceae)	2				✓								
97. *Toona sinensis* (Meliaceae)	1	✓											
98. *Toona sureni* (Meliaceae)	1	✓											
99. *Vatica maingayi* (Dipterocarpaceae)	1	✓											
100. *Vatica pauciflora* (Dipterocarpaceae)	1	✓											

a) 1 = Species of current socio-economic importance; 2 = Species with clear potential or future value; 3 = Species of unknown value given present knowledge and technology.

b) ti = timber production; po = posts, poles, roundwood; wo = fuelwood, charcoal; nw = non-wood products (gums, resins, oils, tannins, medicines, dyes); pu = pulp and paper; fo = food; fd = fodder; sh = shade, shelter; ag = agroforestry; co = soil and water conservation; am = amenity, aesthetic, ethical values; xx = other.

c) Protected species by law in Sarawak.

d) Totally protected species by law in Sarawak.

The priority list also includes species for agroforestry (e.g. *A. excelsa* and *Calamus* spp.), ornamental plants (e.g. *Cycas* spp., *Nepenthes* spp. and *Johannesteijsmannia* spp.) and fruit trees (e.g. *Nephelium* spp. and *Durio* spp.). The following species are protected in Sarawak: *Antiaris toxicaria*, *Aquilaria malaccensis*, *Avicennia alba*, *C. equisetifolia*, *Dipterocarpus oblongifolius*, *Eurycoma longifolia*, *Goniothalamus velutinus*, *K. malaccensis*, *Nepenthes* spp., *Paphiopedilum* spp., *Rafflesia* spp., *Shorea hemsleyana*, *Shorea macrophylla*, *Shorea splendida*, *Shorea stenoptera* and *Sonneratia alba* (Anon 1999c).

Location and management of priority species

The location and management of the 100 priority species are given in Table 7. A thorough review of these data is not currently possible and the information presented relies heavily on published records. In addition, information on forest genetic resources in national parks, VJRs and managed forests is inadequate. *In situ* conservation stands have been established for *Agathis borneensis*, *A. malaccensis*, *Calamus manan*, *D. aromatica*, *N. heimii*, *Rafflesia* spp., *Shorea curtisii*, and *Shorea glauca*. Data on the number of individuals or area of these stands are unavailable. *Ex situ* conservation of most species is limited to fewer than ten accessions (except for *Anisoptera costata*, *C. equisetifolia*, *D. aromatica*, *Dryobalanops oblongifolia*, *Durio* spp., *D. costulata*, *E. zwageri*, *Garcinia* spp., *H. odorata*, *I. palembanica*, *Metroxylon rumphii*, *N. heimii*, *Nephelium* spp., *S. macrophylla*, *S. splendida*, and *S. stenoptera*).

Identification of threats and degree of security

The threats facing priority species are not well documented. In general, however, valuable timber species are likely to be threatened by logging whereas medicinal plants will be threatened by over-exploitation. Mangrove species (e.g. *Avicennia alba* and *Sonneratia alba*) may be threatened by reclaiming of mangrove forest land for agriculture. Abdul Latiff and Mat-Salleh (1991) report that *Rafflesia* populations in Sabah's Trus Madi and Crocker ranges are threatened by local people and irresponsible logging companies.

Endemic and rare species

Table 8 lists 85 endemic and rare species in Malaysia. The identification of these species is based on Chin and Kiew (1985), Kiew *et al*. (1985), Jacobson (1987), Weber (1988), Kiew (1989), Abdul Latiff and Mat-Salleh (1991), Kiew (1991a, 1991b), Kiew and Pearce (1991), Abdul Latiff (1998a, 1998b), IUCN (1998), Kiew (1998a, 1998b, 1998c), Soepadmo (1998) and Wong (1998). The number of plant species that have gone extinct in Malaysia in modern times is not known as only a handful of the country's 15,000 species have been documented and studied. It is possible, however, to say which trees are rare, which are found only in restricted locations, which locations are under threat and which habitats have been destroyed. According to Ng (1991), 511 tree species are endangered by habitat loss. Hyper-endemic and rare species are automatically endangered because of their narrow distribution ranges, and should receive special attention.

Table 7. *Management and location of genetic resources by species. Source: Ng and Tang (1974), Patrick and Muhammad (1980), Anon (1991), Saw and Raja Barizan (1991), Appanah and Weinland (1993), IUCN (1998).*

Species (family)	Protected area/ National park	Conservation stand (in situ/ex situ)	Managed forest (species protected)	Managed forest (no protection)	Plantation	Farmers field/ homesteads	Experiment and field trial
1. *Acalypha hispada* (Euphorbiaceae)	K[a)]	✓ (ex)[b)]		K			
2. *Acorus calamus* (Araceae)	K	✓ (ex)[b)]		K			
3. *Agathis borneensis* (Coniferae)	K	✓ (in & ex)[b)]		K			✓
4. *Alangium serraca* (Alangiaceae)	K	✓ (ex)[b)]		K			
5. *Alstonia scholaris* (Apocynaceae)	K			K			
6. *Andrographis paniculata* (Acanthaceae)	K	✓ (ex)[b)]		K			
7. *Anisoptera costata* (Dipterocarpaceae)	K	✓ (ex)		K			
8. *Anisoptera curtisii* (Dipterocarpaceae)	K			K			
9. *Antiaris toxicaria* (Moraceae)	K	✓ (ex)[b)]		K			
10. *Aquilaria malaccensis* (Thymelaeaceae)	K	✓ (in & ex)[b)]		K			✓
11. *Artocarpus elastica* (Moraceaae)	K	✓ (ex)[b)]		K			✓
12. *Artocarpus lanceaefolia* (Moraceae)	K	✓ (ex)[b)]		K			
13. *Avicennia alba* (Verbanaceae)	K			K			
14. *Azadirachta excelsa* (Meliaceae)	K	✓ (ex)[b)]		K	✓		✓
15. *Brucea javanica* (Simaroubaceae)	K			K			
16. *Calamus manan* (Palmae)	K	✓ (in & ex)[b)]		K			✓
17. *Calamus subinermis* (Palmae)	K			K			
18. *Calophyllum lanigerum* var. *austrocoriaceum* (Guttiferae)	K			K			
19. *Casuarina equisetifolia* (Casuarinaceae)	K	✓ (ex)		K			✓
20. *Centella asiatica* (Umbelliferae)	K			K			✓
21. *Chukrasia tabularis* (Meliaceae)	K			K			✓
22. *Cotylelobium lanceolatum* (Dipterocarpaceae)	K	✓ (ex)[b)]		K			
23. *Cycas* sp. (Cycadaceae)	K	✓ (ex)[b)]		K			
24. *Dillenia grandifolia* (Dilleniaceae)	K	✓ (ex)[b)]		K			
25. *Dipterocarpus baudii* (Dipterocarpaceae)	K	✓ (ex)[b)]		K			✓
26. *Dipterocarpus cornutus* (Dipterocarpaceae)	K	✓ (ex)[b)]		K			✓
27. *Dipterocarpus costulatus* (Dipterocarpaceae)	K	✓ (ex)[b)]		K			✓
28. *Dipterocarpus crinitus* (Dipterocarpaceae)	K	✓ (ex)[b)]		K			✓
29. *Dipterocarpus grandiflorus* (Dipterocarpaceae)	K	✓ (ex)[b)]		K			✓

Table 7. *(continued)*

Species (family)	Protected area/ National park	Conservation stand (in situ/ex situ)	Managed forests (species protected)	Managed forest (no protection)	Plantation	Farmers field/ homesteads	Experiment and field trial
30. *Dipterocarpus oblongifolius* (Dipterocarpaceae)	K[a)]	✓ (ex)[b)]		K			✓
31. *Dryobalanops aromatica* (Dipterocarpaceae)	K	✓ (in & ex)	✓	K	✓		✓
32. *Dryobalanops oblongifolia* (Dipterocarpaceae)	K	✓ (ex)		K			✓
33. *Durio* sp. (Bombacaceae)	K	✓ (ex)		K			✓
34. *Dyera costulata* (Apocynaceae)	K	✓ (ex)		K	✓		✓
35. *Endospermum diadenum* (Euphorbiaceae)	K	✓ (ex)[b)]		K			✓
36. *Eurycoma longifolia* (Simaroubaceae)	K	✓ (ex)[b)]		K	✓		✓
37. *Eusideroxylon zwageri* (Lauraceae))	K	✓ (ex)		K			✓
38. *Fagraea fragrans* (Loganiaceae)	K	✓ (ex)[b)]		K			✓
39. *Ficus deltoidea* (Moraceae)	K			K			
40. *Garcinia* sp. (Guttiferae)	K	✓ (ex)		K			
41. *Gigantochloa scortechinii* (Gramineae)	K			K			
42. *Goniothalamus velutinus* (Anonaceae)	K			K			
43. *Gonystylus bancanus* (Thymelaeaceae)	K	✓ (ex)[b)]		K			
44. *Heritiera javanica* (Sterculiaceae)	K	✓ (ex)[b)]		K			
45. *Hopea nervosa* (Dipterocarpaceae)	K	✓ (ex)[b)]		K			✓
46. *Hopea nutans* (Dipterocarpaceae)	K	✓ (ex)[b)]		K			✓
47. *Hopea odorata* (Dipterocarpaceae)	K	✓ (ex)		K		✓	✓
48. *Intsia palembanica* (Leguminosae)	K	✓ (ex)		K			✓
49. *Johannesteijsmannia* sp. (Palmae)	K			K			
50. *Koompassia malaccensis* (Leguminosae)	K	✓ (ex)[b)]		✓			✓
51. *Labisia pumila* (Myrsinaceae)	K			K			
52. *Metroxylon rumphii* (Palmae)	K	✓ (ex)		K			
53. *Metroxylon sagu* (Palmae)	K	✓ (ex)[b)]		K			
54. *Neobalanocarpus heimii* (Dipterocarpaceae)	✓	✓ (in & ex)	✓	K			✓
55. *Nepenthes* sp. (Nepenthaceae)	K			K			
56. *Nephelium* sp. (Sapindaceae)	✓[c)]	✓ (ex)		K			
57. *Oncosperma tigillaria* (Palmae)	K	✓ (ex)[b)]		K			
58. *Orthosiphon grandiflorus* (Labiatae)	K	✓ (ex)[b)]		K			

Table 7. *(continued)*

Species (family)	Protected area/ National park	Conservation stand (in situ/ex situ)	Managed forests (species protected)	Managed forest (no protection)	Plantation	Farmers field/ homesteads	Experiment and field trial
59. *Palaquium maingayi* (Sapotaceae)	K[a)]	✓ (ex)[b)]		K			✓
60. *Palaquium rostratum* (Sapotaceae)	K	✓ (ex)[b)]		K			✓
61. *Paphiopedilum* sp. (Orchidaceae)	K	✓ (ex)[b)]		K			
62. *Parashorea lucida* (Dipterocarpaceae)	K			K			
63. *Parashorea stellata* (Dipterocarpaceae)	K			K			
64. *Parkia javanica* (Leguminosae)	K	✓ (ex)[b)]		K			
65. *Parkia speciosa* (Leguminosae)	K	✓ (ex)[b)]		K		✓	✓
66. *Phalaenopsis* sp. (Orchidaceae)	K	✓ (ex)[b)]		K			
67. *Pterocarpus indicus* ((Leguminosae)	K	✓ (ex)[b)]		K			✓
68. *Rafflesia* sp. (Rafflesiaceae)	✓	✓ (in)		K			
69. *Santiria laevigata* (Burseraceae)	K	✓ (ex)[b)]		K			
70. *Schima wallichii* (Theaceae)	K			K			
71. *Senna alata* (Leguminosae)	K			K			
72. *Shorea acuminata* (Dipterocarpaceae)	K	✓ (ex)[b)]		K			✓
73. *Shorea bracteolata* (Dipterocarpaceae)	K	✓ (ex)[b)]		K			
74. *Shorea curtisii* (Dipterocarpaceae)	K	✓ (in & ex)[b)]		K			✓
75. *Shorea glauca* (Dipterocarpaceae)	K	✓ (in & ex)[b)]		K			✓
76. *Shorea hemsleyana* (Dipterocarpaceae)	K	✓ (ex)[b)]	✓	K			✓
77. *Shorea kunstleri* (Dipterocarpaceae)	K	✓ (ex)[b)]		✓			✓
78. *Shorea laevis* (Dipterocarpaceae)	K	✓ (ex)[b)]		K			✓
79. *Shorea lepidota* (Dipterocarpaceae)	K	✓ (ex)[b)]		✓			✓
80. *Shorea leprosula* (Dipterocarpaceae)	K	✓ (ex)[b)]		✓			✓
81. *Shorea longisperma* (Dipterocarpaceae)	K	✓ (ex)[b)]		K			
82. *Shorea macrophylla* (Dipterocarpaceae)	K	✓ (ex)	✓	K			✓
83. *Shorea macroptera* (Dipterocarpaceae)	K	✓ (ex)[b)]		K			✓
84. *Shorea maxwelliana* (Dipterocarpaceae)	K	✓ (ex)[b)]		✓			✓
85. *Shorea multiflora* (Dipterocarpaceae)	K	✓ (ex)[b)]		K			✓
86. *Shorea ovalis* (Dipterocarpaceae)	K	✓ (ex)[b)]		K			✓
87. *Shorea parvifolia* (Dipterocarpaceae)	K	✓ (ex)[b)]		K			✓

Table 7. *(continued)*

Species (family)	Protected area/ National park	Conservation stand (in situ/ex situ)	Managed forests (species protected)	Managed forest (no protection)	Plantation	Farmers field/ homesteads	Experiment and field trial
88. *Shorea pauciflora* (Dipterocarpaceae)	K[a)]	✓ (ex)		K			✓
89. *Shorea platyclados* (Dipterocarpaceae)	K	✓ (ex)[b)]		✓			✓
90. *Shorea resinosa* (Dipterocarpaceae)	K	✓ (ex)[b)]		K			✓
91. *Shorea roxburghii* (Dipterocarpaceae)	K	✓ (ex)[b)]		✓			
92. *Shorea splendida* (Dipterocarpaceae)	K	✓ (ex)	✓	K			
93. *Shorea stenoptera* (Dipterocarpaceae)	K	✓ (ex)	✓	K			
94. *Sindora coriacea* (Leguminosae)	K	✓ (ex)[b)]		K			
95. *Sonneratia alba* (Sonneratiaceae)	K			K			
96. *Tinospora crispa* (Menispermaceae)	K			K			
97. *Toona sinensis* (Meliaceae)	K			K			
98. *Toona sureni* (Meliaceae)	K			K			
99. *Vatica maingayi* (Dipterocarpaceae)	K			K			
100. *Vatica pauciflora* (Dipterocarpaceae)	K	✓ (ex)[b)]		K			

a) K = Insufficient data.
b) Fewer than ten accessions.
c) *Nephelium hamulatum*.

Table 8. *List of endemic and rare species in Malaysia. The list is confined to species in IUCN (1998) and those reported by Chin and Kiew (1985), Kiew et al. (1985), Jacobson (1987), Weber (1988), Kiew (1989), Abdul Latiff and Mat-Salleh (1991), Kiew (1991a, 1991b), Kiew and Pearce (1991), Abdul Latiff (1998a, 1998b), Kiew (1998a, 1998b, 1998c), Soepadmo (1998) and Wong (1998).*

Acrymia ajugiflora (Labiatae)	*Johannesteijsmannia magnifica* (Palmae)
Actinodaphne cuspidata (Lauraceae)	*Justicia subalternans* (Acanthaceae)
Aglaia densitricha (Meliaceae)	*Kibatalia borneensis* (Apocynaceae)
Alphonsea kingii (Annonaceae)	*Koilodepas ferrugineum* (Euphorbiaceae)
Ardisia lankawiensis (Myrsinaceae)	*Kostermanthus malayanus* (Chrysobalanaceae)
Begonia eiromischa (Begoniaceae)	*Lagerstroemia langkawiensis* (Lythraceae)
Begonia rajah (Begoniaceae)	*Litsea scortechinii* (Lauraceae)
Beilschmiedia penangiana (Lauraceae)	*Maclurochloa montana* (Gramineae)
Brownlowia velutina (Tiliaceae)	*Madhuca calcicola* (Sapodaceae)
Calamus balingensis (Palmae)	*Mallotus smilaciformis* (Euphorbiaceae)
Calamus viminalis (Palmae)	*Mangifera superba* (Anacardiaceae)
Castanopsis catappaefolia (Fagaceae)	*Mezzettia herveyeana* (Annonaceae)
Cleistanthus major (Euphorbiaceae)	*Nepenthes gracillima* (Nepenthaceae)
Croton macrocarpus (Euphorbiaceae)	*Nepenthes northiana* (Nepenthaceae)
Cryptocoryne elliptica (Araceae)	*Oberonia calcicola* (Orchidaceae)
Cycas pectinata (Cycadaceae)	*Paphiopedilum niveum* (Orchidaceae)
Dendrobium lankaviense (Orchidaceae)	*Paphiopedilum phillippinense* (Orchidaceae)
Didymocarpus pumila (Gesneriaceae)	*Peperomia maxwellana* (Piperaceae)
Diplodiscus hookerianus (Tiliaceae)	*Phyllagathis stonei* (Melastomataceae)
Dipterocarpus lamellatus (Dipterocarpaceae)	*Polyalthia glabra* (Annonaceae)
Dipterocarpus perakensis (Dipterocarpaceae)	*Polyalthia hirtifolia* (Annonaceae)
Dipterocarpus rotundifolius (Dipterocarpaceae)	*Popowia pauciflora* (Annonaceae)
Eugenia camptophylla (Myrtaceae)	*Popowia velutina* (Annonaceae)
Eugenia gageana (Myrtaceae)	*Pseudoeugenia tenuifolia* (Myrtaceae)
Eugenia johorensis (Myrtaceae)	*Rafflesia kerrii* (Rafflesiaceae)
Eugenia klossii (Myrtaceae)	*Sauropus elegantissimus* (Euphorbiaceae)
Eugenia scalarinervis (Myrtaceae)	*Schefflera cephalotes* (Araliaceae)
Eugenia taipingensis (Myrtaceae)	*Schefflera kuchingensis* (Araliaceae)
Glycosmis crassifolia (Rutaceae)	*Schoutenia corneri* (Tiliaceae)
Glycosmis monticoja (Rutaceae)	*Shorea bentongensis* (Dipterocarpaceae)
Glycosmis tomentella (Rutaceae)	*Shorea kuantanensis* (Dipterocarpaceae)
Goniothalamus subevenius (Annonaceae)	*Shorea kudatensis* (Dipterocarpaceae)
Hexapora curtisii (Lauraceae)	*Shorea lumutensis* (Dipterocarpaceae)
Homalium spathulatum (Flacourtiaceae)	*Shorea maxima* (Dipterocarpaceae)
Hopea auriculata (Dipterocarpaceae)	*Shorea palembanica* (Dipterocarpaceae)
Hopea depressinerva (Dipterocarpaceae)	*Shorea singkawang* ssp. *scabrosa* (Dipterocarpaceae)
Hopea johorensis (Dipterocarpaceae)	*Strobilanthes pachyphyllus* (Acanthaceae)
Hopea polyalthioides (Dipterocarpaceae)	*Symplocos nivea* (Symplocaceae)
Hopea subalata (Dipterocarpaceae)	*Tristania pontianensis* (Myrtaceae)
Horsfieldia sessilifolia (Myristicacceae)	*Vaccinium whitmorei* (Ericaceae)
Hydnocarpus scortechinii (Flacourtiaceae)	*Vatica flavida* (Dipterocarpaceae)
Ilex pauciflora (Aquifoliaceae)	*Zollingeria borneensis* (Sapindaceae)
Johannesteijsmannia lanceolata (Palmae)	

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