

mountain ranges rise to more than 1,520 m and contain the largest cave in the world. The largest river, the Rejang, is 564 km long and is navigable for about 160 km.

2.3 Geological Aspects

Peninsular Malaysia is generally hilly or mountainous, with about 40 per cent of the total land area rising above the 310 m contour and 23 per cent above 155 m. The only low-lying areas are near the coasts on both flanks of the peninsular from where they extend inland for a few kilometres up to a maximum of 64 kilometres before becoming moderately undulating, mostly between 15 and 150 metres above sea level. Further inland the very steep main mountain ranges rise abruptly from the surrounding lowlands.

The mountains occur as a series of parallel ranges running approximately north-south. The largest of these ranges, the Main Range, is a continuous granite ridge extending from the Perak-Thailand border to the Negeri Sembilan-Malacca boundary near Tampin. This range is usually regarded as the backbone of the country, but it is certainly not a central axis, as the highly-developed lowland region to the west represents only about a fifth of the total land area, while three-fifths lies to the east of this ridge.

Basically, Peninsular Malaysia can best be pictured as a land mass built around an intrusive core of solid granite, the uneven roof of which reaches the surface in a number of places to form the principal mountain ranges. The sedimentary rocks older than the granite, of Palaeozoic and Mesozoic age, occur along the flanks of these ranges and in the intervening lower-lying areas, while Recent, Quaternary and Tertiary sediments, which have accumulated since the emplacement of the granite, are confined principally to the coastal areas and to the main basins and valleys of the interior.

The geology of East Malaysia (Sabah and Sarawak) is more complex and dominated by the Borneo Basement ancient rocks. In Sabah, younger rocks are the result of past volcanic activities, though volcanoes are unknown in recent times.

2.4 Climate

The climate of Malaysia is typically humid tropical or wet equatorial and is characterised by year-round high temperatures and seasonal heavy rain, especially during the North-east monsoon from October/November to February/March. The mean temperatures during the day and night are 32°C and 22°C respectively.

3.0 THE FOREST

3.1 Forest Cover

Malaysia has been fortunate to be endowed with extensive areas of valuable natural tropical rainforest which are extremely complex ecosystems and rich in tree species as in similar areas of Africa and South America. In fact, Malaysia has one of the most species-rich communities in the world. The flora is estimated to comprise 7,500 species of seed plants in which 4,100 are woody. An estimated 2,900 species reach a diameter of 10 cm at breast height (dbh)

while about 1,680 species in 375 genera are trees reaching a diameter of 30 cm dbh (Whitmore, 1975). About 890 of these species reach exploitable sizes of at least 45 cm dbh and 408 have been marketed to the international market under the Malayan Grading Rules.

The total area of forests in Malaysia is estimated to be 18.91 million hectares or nearly 58 per cent of the total land area. The extent of the forest cover is shown in Figure 1. The proportion of forested land is higher in Sabah and Sarawak than in Peninsular Malaysia, as shown in Table 1 (Ahmad Zainal, 1996). In the ASEAN region, Malaysia lies third in terms of amount of forested areas after Indonesia and Thailand, but fourth with regard to percentage to total area of the country (Haron, 1996).

Table 1: Distribution and Extent of Forests in Malaysia, (million ha)

Region	Land Area	Natural Forest			Plantation Forest	Total Forested Land	% Total Forested Land
		Dipterocarp Forest	Swamp Forest	Mangrove Forest			
Peninsular Malaysia	13.16	5.38	0.30	0.10	0.07	5.85	44.45
Sabah	7.37	3.83	0.19	0.32	0.11	4.45	60.40
Sarawak	12.33	7.20	1.20	0.20	0.01	8.61	69.73
Malaysia	32.86	16.41	1.69	0.62	0.19	18.91	57.55

While most plantation forest originated from areas used to be covered by natural stands with forest reserves there have been encouraging developments recently to replant neglected alienated land with fast-growing commercial timber species of *Azadirichta excelsa* (Sentang) and the high quality but slower growing *Tectona grandis* (Teak), besides the earlier favoured *Acacia mangium* (Akasia), *Paraserianthes falcataria* (Batai), *Gmelina arborea* (Yemane) and *Swietenia macrophylla* (Mahogany). This development, coupled with likely reforestation of agricultural lands, now planted with *Hevea brasiliensis* (rubber), into forest plantation may in the long-run increase the area of forests, although the net increase will depend on the reduction of the current annual deforestation rate of 2.6% in Peninsular Malaysia alone, ironically, mainly for conversion to agriculture. Although the deforestation rate for the whole country is 2.10%, it is still higher than the ASEAN average 1.08% per annum (Haron, 1996). However, if the tree agricultural crops of rubber and oil palm are regarded as forest plantations since both can be utilised for wood (timber), then the total tree (forest) cover in Malaysia is about 75% of the total land area, not 58% (see Table 1).

Areas under shifting cultivation and degraded land status in the Peninsular are small. However, they are being rehabilitated, wherever necessary. In Sabah and Sarawak, such areas can be quite extensive, covering about 4.62 million hectares, but concerted efforts are being undertaken to re-forest them with fast-growing species, particularly *Acacia mangium*.

3.2 Permanent Forest Estate

Most of the forests in Malaysia are managed on a sustainable basis. Some forests, however, are licensed for logging without any minimum girth limits, particularly those forested areas demarcated for conversion to other land-uses including agriculture, housing and other land developments. Such forests are known as the Stateland forest.

More than 75% of Malaysian's forests have been gazetted as forest reserves, also known as Permanent Forest Estate (PFE) in the National Forestry Act. This also constitutes about 43% of the country's total land area. The distribution of these forests are shown in Table 2. Actually, another 185,000 ha of Stateland forest in Peninsular Malaysia are in various stages of being gazetted as PFEs which will further increase the size of the latter. The PFEs are sustainably managed either for production, protection or amenity purposes. Harvesting of timber from the production forest is regulated according to the recognised system of the day. So too, are the protection and amenity forests which have special management procedures quite different from that of a normal production forest. The security of tenure is guaranteed under the National Forestry Act (NFA) except perhaps for certain PFEs lying in the remaining lowland Dipterocarp forest. If de-gazettement does occur, there is a commitment in the NFA that for every hectare of PFE dissolved, the same amount of suitable area in the Stateland forest must be gazetted to replace it, wherever possible. However, Aiken and Leigh (1992) did not see how the rainforest would not keep on vanishing, but certainly every effort is being made by Malaysia to conserve its forest in the light of rapid economic development.

Table 2: Permanent Forest Estate in Malaysia (million ha)

Region	Land Area	Total Forested Land	Total Forested Land		Percentage of to	
			PFE	Stateland Forest	Total Land Area	Total Forested Land
Peninsular Malaysia	13.6	5.85	4.68	1.17	34.41	80.00
Sabah	7.37	4.45	3.60	0.85	48.85	80.90
Sarawak	12.33	8.61	6.00	2.61	48.66	69.69
Malaysia	32.86	18.91	14.28	4.63	43.46	75.52

There are no significant private forests in Malaysia. However, there may be tiny pockets of reserved forested land alienated to certain organisations for special purposes such as education and research. It must also be noted that there are, of late, individual landowners or companies involved in agricultural plantations who have converted their land to forestry purposes. These lands usually started off as a forested area which was alienated for conversion to agricultural crops such as cocoa or rubber, and have now reverted to forests with fast-growing hardwoods

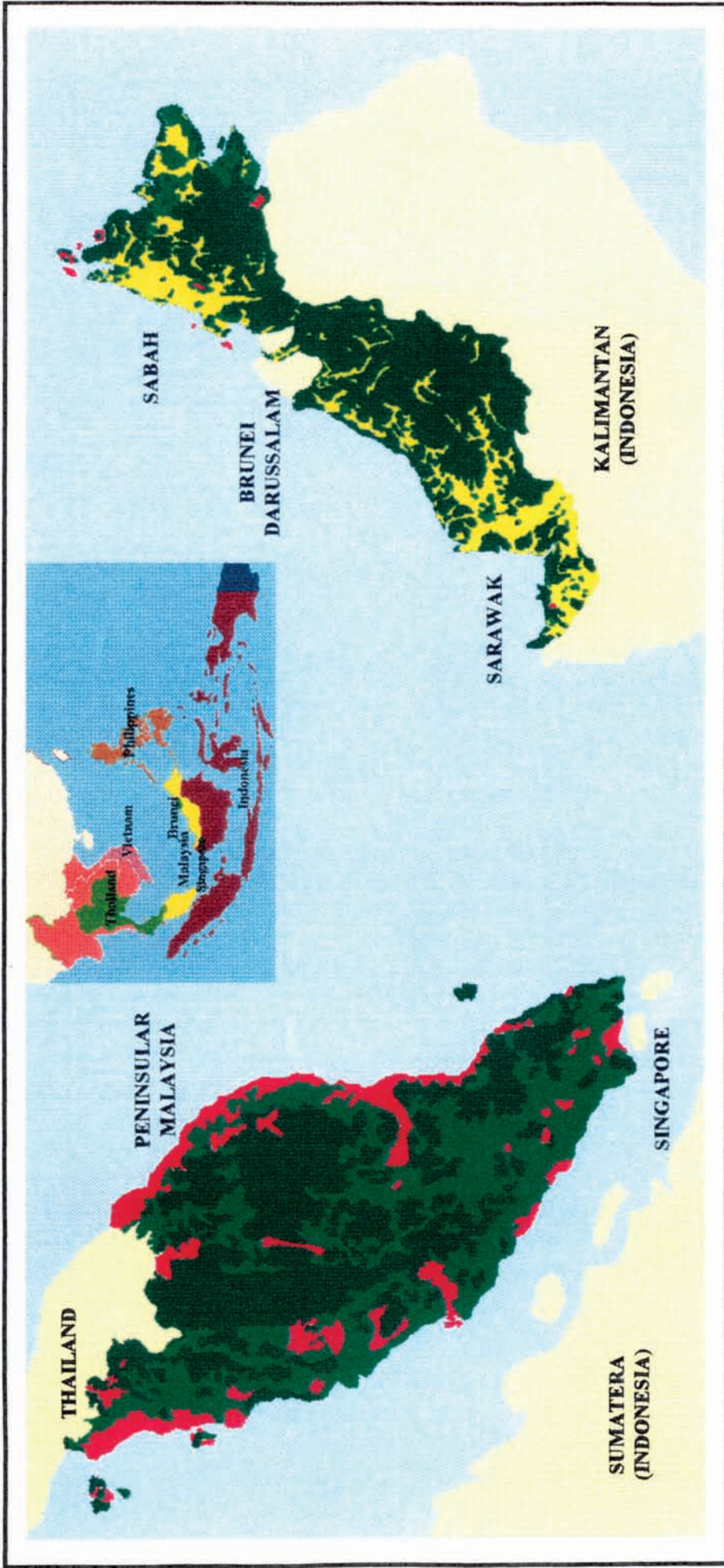


FIGURE 1: Forest Cover in Malaysia

such as *Acacia mangium* (Akasia), *Azadirichta excelsa* (Sentang), and *Tectona grandis* (Teak), and non-wood produce such as *Calamus spp.* (Rattan). Reforestation such as this, and afforestation of degraded land or that which has been left fallow, are good signs towards increasing the country's reserved and productive forests.

3.3 Forest Types

The tropical rainforests of Malaysia are generally synonymous with the species-rich lowland and hill dipterocarp forests which make up 92% of the total forested area in Peninsular Malaysia, and 87% of the total forest in the country. Other forest types include the mangroves, peat swamp forests, heath forests and montane forests. The dipterocarp forests are of vital economic as well as ecological importance to the country while the mangrove forests have long been managed for the sustainable production of charcoal, poles and firewood. The mangroves are also important for protection and conservation of the coastal ecosystem, and especially vital for sustaining fish and sea-food production (Haron, 1981). In this context, the tropical rainforests may be classified into the following ten major forest types (Wyatt-Smith, 1963 and Fox, 1978):

(i) *Lowland Dipterocarp Forests*

These forests are found in the plains, undulating lands and foothills to an elevation of about 300 m above sea level and are primary climatic climax forests comprising thousands of trees species, as well as shrubs, herbs and woody climbers (see Figure 2). The upper or emergent storey is usually about 30 m to 45 m high, though trees nearly 60 m in height may also be present in certain localities. It is usually characterised by a high occurrence of the family Dipterocarpaceae with many of the species from the genera *Anisoptera*, *Dipterocarpus*, *Dryobalanops*, *Hopea*, *Shorea* and *Parashorea*. Other common large trees of this storey are *Dyera costulata*, *Gluta spp.*; *Intsia palembanica*.; *Koompassia malaccensis*.; *Melanorrhoea spp.*; *Palaquium spp.*; *Sindora spp.*; and *Tarrietia spp.*

The main storey, or second-tree layer, which occupies a region of about 20 m to 30 m from the ground, forms a continuous canopy except immediately below the large emergent storey trees. This storey consists of young trees of the upper storey species together, with predominant families of *Burseraceae*, *Guttiferae*, *Myristicaceae*, *Myrtaceae* and *Sapotaceae*. The under-storey, or third-tree layer, consists of saplings of the upper two stories together with mainly members of families such as *Annonaceae*, *Euphorbiaceae*, *Flacourtiaceae* and *Rubiaceae*.

The density of the shrub layer varies and comprise of species of *Annonaceae*, *Euphorbiaceae* and *Rubiaceae*. The herb layer consists mainly of young seedlings of the other layers and lianas, with ferns near streams and in moist valleys.

(ii) *Hill Dipterocarp Forests*

These forests occur on the inland ranges approximately between the latitudinal limits of 300 metres and 800 metres. Aspects and site, however, are important factors, and the forests have a tendency to flourish at the lower limits, even down to 150 m above sea level, on

exposed ridges. At the higher limits they are found in the more sheltered valleys. The main difference between the lowland Dipterocarp and hill Dipterocarp forest is a shift in the floristic composition of the dominants in the upper and main tree storeys. The large trees in hill forest are usually slightly smaller and shorter than the tallest in the lowland forest, except for the big trees on ridge tops which are generally taller. The density of trees on ridge tops is greater than that in the lowland forest and there are correspondingly fewer trees in the under-storey and in the lower part of the main storey. The vegetation on hill slopes, particularly steep slopes, is often ground ferns and poorly stocked in woody species.

The under-storey is usually very rich in stemmed palms such as *Arenga westerhoutii*, *Oncosperma horrida* and *Orania macrocladus*; stemless palms such as *Licuala spp*; and rattans such as *Calamus castaneus*. In valley bottoms, large woody species are poorly represented and the forest is more characterised by the richness of *Alocasia spp*, *Colocasia spp*, *Donax grandis*, and many other ground ferns in the ground flora and shrub layer.

(iii) Upper Hill Dipterocarp Forests

These forests are found on the higher hills, approximately between the latitudinal limits of 750 metres to 1,200 metres but, as in the case of the hill Dipterocarp forests, they may also be found in narrower and much lower belt on coastal rangers or on isolated mountains. The species are very different from those in the hill Dipterocarp forests. Although the forest structure is much the same, namely three-layered, the upper layer is lower and varies between 25 metres and 30 metres in height and with a more even upper canopy level. The second and upper tree layers are frequently less distinct as separate entities. The family *Dipterocarpaceae* is represented by only a few species and this forest is often characterised by the presence of *Shorea platyclados*.

The shrub layer in this forest is often characterised by the presence of rattans and dwarf palms, while the ground flora by species of *Argostemma* (Rubiaceae), *Sonerila* (Melastomaceae), *Selaginella atroviridis* and the fern *Thelypteris chalamydophora*.

(iv) Lower Montane Forests

These forests are found above the upper Dipterocarp forests in the latitudinal range of 1,000 metres to 1,500 metres but these limits vary considerably according to the locality. They are generally three-layered forests with tree heights varying from 20 metres to 25 metres. The upper canopy is fairly even with emergent absent, and trees are relatively short-boled, and are not strongly buttressed. Normally, Dipterocarps are not found in these forests though *Dipterocarpus retusus* and some *Vatica spp*. are occasionally found. The common and characteristic species are representatives of the families *Fagaceae* with many of the genera *Quercus*, *Lithocarpus*, *Castanopsis* and *Lauraceae*.

The climbers *Aeschynanthus spp*. and *Poikilospermum* and the fern *Asplenium nidus* are common epiphytes while rattans, stemmed palms and tree ferns dominate the shrub layer with liverworts and mosses being the ground flora.

(v) Upper Montane Forests

These forests occur in the cloud belt above the lower montane forests. They may, however, be found on exposed ridges and summits at lower altitudes of less than 1,500 metres. They differ from the lower montane forests in specific composition, typically a reduction to a single tree layer in structure and a general dwarfing of the forests to about 10 metres tall. Besides, there is normally a greater increase in development of liverworts, mosses and filmy ferns, both on the trunks of the trees and on the ground. *Sphagnum spp.* are also common.

The forest is characterised by the prevalence of ericaceous species, such as *Pieris ovalifolia*, *Rhododendron spp.* and *Vaccinium spp.* Undergrowth species include *Argostemma* and *Burmannia spp.*. Epiphytic orchids are common and rhododendrons also occur frequently.

(vi) Heath Forests

Heath forests are generally included as part of "hill forests" and are found mainly in the states of Sabah and Sarawak. They contain trees of poor form and small size and are generally found on white sandy soils, or on beach terraces at all elevations, or on weathered steep ridges at higher elevations. The main species are *Casuarina*, *Agathis alba*, *Dacrydium*, *Tristania* and *Shorea albida*.

(vii) Freshwater Alluvial Swamp Forests

The freshwater alluvial swamp forests usually occur under varying degrees of inundation and under varying conditions. Accordingly, their floristic composition and general structure varies enormously from open scrub with a few large 25 to 30 metres-tall, scattered trees, a dense 10 to 20 metres-tall pole forest, to a 30 metres-tall peat, swamp-like forest where the predominance of single species is common.

Common tree species that are found in some of these swamp forest are *Koompassia malaccensis*, *Calophyllum*, *Eugenia*, *Madhuca*, *Melanorrhoea* and *Palaquium spp.*

(viii) Peat Swamp Forests

These forests are of a very special type found on peat with depth ranging from 0.5 metre to about 6 metres. They occur just behind the coastline and have a three-layered tree structure. This comprises a broken, upper emergent layer, often reaching to a height of 30 to 35 metres and is frequently represented by scattered, truly emergent trees and a fairly continuous understorey of considerable depth, usually ranging from about 10 to 20 metres above ground level. Frequently, a dense thicket of stemless palms is found in waterlogged areas, otherwise the shrub layer is generally rather sparse.

The ground flora is comparatively poor, both in species and in cover as shown in Figure 3. Species represented in these forests include *Amoora rubiginosa*, *Anisoptera marginata*, *Blumeodendron tokbrai*, *Calophyllum retusum*, *Cratoxylon aborescens*, *Gonystylus bancanus*, *Shorea albida* *Dactylocladus stenostachys* and *Eugenia spp.*

(ix) Riparian Fringes

Numerous types occur as narrow strips along the banks of estuaries, rivers and streams. Their composition, and hence their structure, vary enormously and depend on tidal influence, the rate of water flow, the elevation, the width of the river or stream, the nature and aspect of the terrain, and the enrichment of the side by water or silt. Common tree species found in these riparian fringes or on the low-lying land beyond the banks are *Artocarpus peduncularis*, *Ficus retusa*, *Intsia palembanica*, *Dipterocarpus coriaceus*, *Calophyllum spp.*, *Cratoxylon spp.*, *Dialium spp.* and *Hopea spp.*

(x) Mangrove Forests

Mangrove forests are confined to muddy shores, lagoons, and the estuaries of tidal rivers. The vegetation is simple in structure, 6 m to 25 m in height depending on the community, with a comparatively even and unbroken canopy and a very poor understorey layer. The principal tree species are restricted to this habitat, and are frequently characterised by special root formations such as still roots and pneumatophores. Some species such as *Brugueira spp.*, *Ceriops spp.*, *Kandelia spp.*, *Rhizophora spp.*, *Avicennia spp.*, *Sonneratia spp.* and *Xylocarpus spp.* are also characterised by the habit of their seeds which start to germinate long before the fruits are ripe (Figure 4).

Two types of swamp palm are also present in the mangroves. These are *Nypa fruticans* (nipah) and *Oncosperma horrida* (nibong). *N. fruticans* is a general utility species providing local products such as housing thatch, cigarette paper, sugar, alcohol, vinegar and salt. It is frequently inundated and occurs in pure stands while *O. horrida* prefers the drier zones.

While this forest type classification may still be good for Malaysia, an attempt has been made towards a standard classification for the ASEAN region (Haron, et al, 1997, unpublished) whereby the forest has been categorised into four major classes, viz: Montane Forest, Hill Forest, Swamp Forest, and Mangrove Forest. In this classification all the Dipterocarps are included in the Hill Forest.

3.4 Forest Functional Classification

The Forest Functional Classes (FFCs) have been developed and applied in Malaysia over the past decade. The FFCs are described in a report (Anon, 1986) entitled *Pengelasan Kawasan Hutan Simpanan Kekal* in accordance to *Seksyen 10 (1)*, of the National Forestry Act, 1984 along with guidelines for the interpretation of the eleven classes which are legislated in the Act.

The FFCs are delineated on maps and used for forest planning, management, and development purposes. The classes zone the forest reserves for different functions and therefore give the forest manager a broad overview for forest planning and management. In addition, there is a land classification which demarcates all land in Peninsular Malaysia for forestry (proposed classification of land for forestry in Peninsular Malaysia). The FFCs are classified as follows:

Class a: Timber production forest under sustained yield

These are forest lands which are inherently productive or with a high timber production potential and are capable of supplying timber which can be economically produced under sustained yield, both for the domestic and export markets. Generally, these are forest lands with average slope of less than 40° and with easy to moderately difficult access. They include Class 1 (Superior), Class 2 (Good), Class 3 (Marginal) and part of Class 4 (Restrictive) as defined in the paper "Proposed classification of land for forestry in Peninsular Malaysia" by Mok and Thang (1983).

Class b: Soil protection forest

These are forest lands which are located in environmentally sensitive areas and particularly on steep terrain. Exploitation and the absence of vegetation cover could result in soil erosion, flash floods, landslips, siltation, loss of nutrients and other forms of environmental degradation which would be detrimental to the well-being of the populace. Such forests, when destroyed, would require expensive alleviation and rehabilitation works. They include part of Class 3 (Marginal), Class 5 (Conservation) and Class 6 (Poor) land. Classification of such forest may vary according to soil, geology and rainfall characteristics of the area.

Class c: Soil reclamation forest

These are generally low-lying forest lands usually formed through a gradual process of soil accretion and forest formation, and include forests established on reclaimed lands. They may be seasonally or permanently subjected to inundation; mainly mangrove and inland swamps. They are equivalent to Class 4 (Restrictive) land.

Class d: Flood control forest

These are forest lands that act as reservoirs for water storage during the monsoon season. The exploitation of such forests could result in massive downstream flooding which is not only undesirable but also detrimental to both agricultural crops and human life. Such forest lands can be identified through historical records and meteorological data on flood-prone areas in the country. Generally, they include fresh-water swamp (seasonal) and the peat swamp forests.

Class e: Water catchment forest

These are forest lands which function as a regulating system against excessive run-off and have water retention capacities. They are vital for ensuring the supply of water to meet the increasing demand for domestic, industrial and agricultural uses. Proper management of such forests is essential for the maintenance of desirable water quality, stable stream flow regime, and the avoidance of damaging floods. Generally, it is made up of hilly, forested land from which rainfall flows into a river system. Such forest is of particular importance where dams are constructed.

Class f: Forest sanctuary for wildlife

These are forest lands where indigenous wildlife exists and which should be reserved for the protection of biodiversity. Sanctuaries may be established for the protection of one or a few species, but generally they are intended for the protection of all species. Such forests are established to prevent the extinction of the already dwindling endangered species of flora and fauna in the country, and access are restricted only to authorised persons undertaking activities compatible with the purpose of the sanctuaries.

Class g: Virgin jungle reserved forest

These are forests which are established to serve as permanent nature reserves and natural arboreta, as controls for comparing with the exploited and silviculturally-treated forests, and as undisturbed natural areas for general ecological and botanical studies.

Class h: Amenity forest

Under the National Forestry Policy, these forests are defined as forest land which are conserved for various purposes such as recreation, education, research and protection of the country's unique flora and fauna.

Class i: Education forest

These are forest lands which are earmarked or reserved for the purposes of furthering education and creating better public awareness with regard to the vital role of forest in the preservation of a balanced physical, social and economic environment.

Class j: Research forest

These are forest lands earmarked or reserved for research purposes. Among the research plots which have been set up throughout the country are Silvicultural Plots, Phenological Plots, Forest Plantation Plots, Ecological Plots, Big Tree Plots, Hydrological Plots, and Growth and Yield Study Plots.

Class k: Forest for federal purposes

These are forest lands earmarked or reserved for federal purposes such as the setting up of Continuous Forest Inventory (CFI) Plots and Research Stations.

4.0 IMPORTANCE OF THE FORESTS

Forests play a very significant role in furthering resource-based industrialisation and the socio-economic development of Malaysia. Besides, they have long been recognised as an important contributor to environmental stability and better quality of life for the country. They protect, maintain and safeguard fresh-water supply and help keep the climate stable and reduce the level of the carbon dioxide content. The forests also enrich the soil and prevent soil erosion. Forest products are wide-ranging, from timber to furniture, medicines, food, paper and many