

Pasoh Forest Dynamics Plot, Peninsular Malaysia

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Site Location, Administration, and Scientific Infrastructure

The Pasoh Forest Reserve lies in the Jelebu District of the State of Negeri Sembilan in peninsular Malaysia. When gazetted in 1917, Pasoh was the largest forest reserve in the Malayan system, but over the years, portions have been de-gazetted for agriculture. Today the entire reserve encompasses less than 11,000 ha. It is administered by the State of Negeri Sembilan as a Permanent Forest Estate for goods and services such as timber. The southernmost 1200 ha of the reserve is the Pasoh Research Forest, which is administered by the Forest Research Institute of Malaysia (FRIM), headquartered in Kepong, Kuala Lumpur, on behalf of the State Forest Department. The State Forest Department, which retains ultimate responsibility for the research forest, has made a commitment to total protection for the Pasoh Forest Reserve as long as research continues.

Because Pasoh is one of the most intensively researched rainforests in Asia, it is also one of the best understood (Okuda et al. 2003). Silvicultural regeneration surveys were carried out in various parts of the original Pasoh Forest Reserve beginning in the 1950s, but the first study in the research forest was undertaken by Wong Yew Kwan of FRIM in 1961 when he established ten 1-acre, permanent north-south-oriented strip plots. In these plots, all trees greater than 12 inches dbh were censused (Wong and Whitmore 1970). In 1970, P. S. Ashton extended five of these plots to 2-ha, 200 × 100 m blocks. In the early 1970s, the International Biological Program (IBP), a joint Malaysian–Japanese–British project, selected the Pasoh Forest Reserve as a site for leading international research (Ashton et al. 2003; Soepadmo 1978). In 1986, FRIM, Harvard University, and the Smithsonian Tropical Research Institute initiated a 50-ha Forest Dynamics Plot, encompassing two of the previously established 2-ha IBP plots. The 50-ha plot lies within a core remnant of primary forest that is at least 600 ha and is located 1.6 km from the forest edge (fig. 36.1). Oil palm plantation surrounds the western half of the forest primarily. Rubber plantations are found on the south and southeast. In 1991, the National Institute of Environmental Studies (NIES) of Japan established a forest

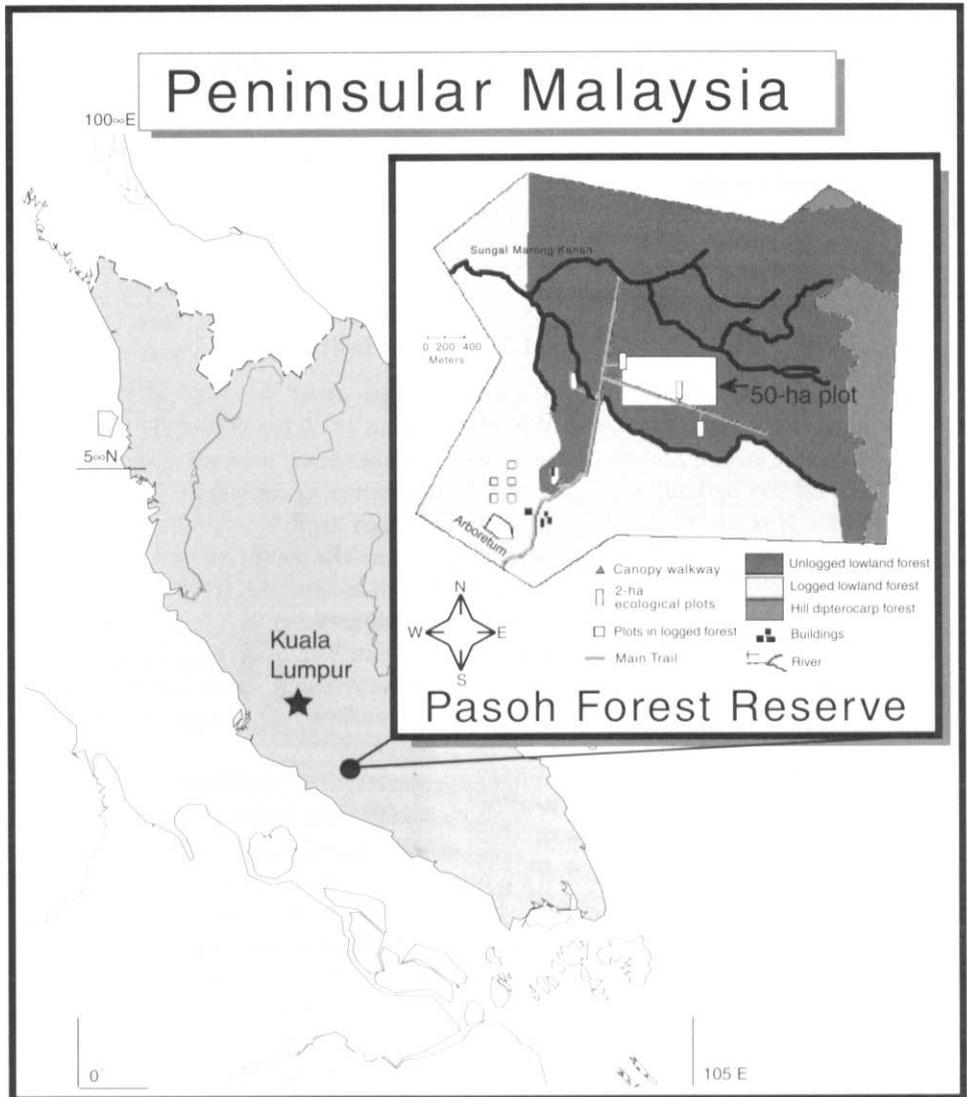


Fig. 36.1. Location of the 50-ha Pasoh Forest Dynamics Plot.

research program of rainforest research in collaboration with FRIM and Universiti Putra Malaysia (UPM), which partially utilized the 50-ha plot. Later NIES became a partner in the Forest Dynamics Plot research.

The research station in the Pasoh Research Forest includes housing, a variety of long-term ecological facilities, and canopy towers.

Table 36.1. Pasoh Climate Data

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total/ Averages
Rain (mm)	94	109	153	167	162	125	115	120	162	189	224	168	1788
ADTMx (°C)	32.0	33.1	33.9	34.6	34.4	33.8	32.8	33.3	33.2	33.7	32.0	31.6	33.2
ADTMn (°C)	21.9	22.2	22.6	23.1	23.4	23.1	22.6	22.8	22.8	22.9	22.7	22.8	22.7
Q (kW/m ²)	0.14	0.17	0.18	0.17	0.16	0.14	0.14	0.16	0.16	0.15	0.12	0.10	0.15
Wind (kph)	0.08	0.07	0.06	0.04	0.03	0.03	0.02	0.03	0.04	0.05	0.05	0.10	0.05

Notes: Data for mean monthly rainfall are for 1975–1998 and average daily temperatures (maximum and minimum) for 1991–1997 (Malaysian Meteorological Service 1977–2000; Nur Supardi 1999; Hydrology Unit FRIM, unpublished data). Data for solar radiation (Q) and wind speed are for 1991–1993 (Saifuddin et al. 1994). Rainfall data between 1975 and 1998 excludes 3 years with incomplete records; data were collected by the Malaysian Meteorological Service from Pasoh Dua, a town 4 km to the south of Pasoh Forest Reserve. Temperature data from December 1991 to June 1995 were taken at an automatic weather station in the clearing of Pasoh Research Station. From July 1995 to December 1997, temperature data were taken from an automatic weather station positioned on a tower located about 600 m NE of the other weather station at Pasoh.

Climate

The climate of the Pasoh area is the driest and hottest of the southern Malay peninsula (see table 36.1). Mean annual rainfall recorded at Pasoh Forest Reserve from 1996 to 1999 was 1571 mm with a range of 1182 to 2065 (Tani et al. 2003). Long-term data from Pasoh Dua, an agricultural settlement 4 km from Pasoh, recorded a mean annual rainfall of 1788 mm over 24 years (Malaysian Meteorological Service 1977–2000). According to climate data collected at Kuala Pilah, 30 km away from the Pasoh Reserve, each year on record has at least one 20-day period without rain, typically in late January and/or late July. Average annual minimum and maximum temperatures are 22.7°C and 33.2°C, respectively (Nur Supardi 1999; Hydrology Unit FRIM unpublished data).

Topography and Soil

At approximately 80 m above sea level, the Pasoh Forest Reserve lies on a level plain of raised Pleistocene alluvium from which low undulating hills of Triassic sediments and granite arise (figs. 36.2 and 36.3). It is bordered to the east by a sharp north-south granite ridge that reaches a peak at Bukit Palong, 645 m above sea level. The 50-ha Pasoh Forest Dynamics Plot differs by only 24 m from high to low point. While the plot contains no permanent streams, a significant portion lies under standing water for more than 1 month, typically during November and December. Allbrook (1973) mapped Pasoh soils using the Malaysian agricultural

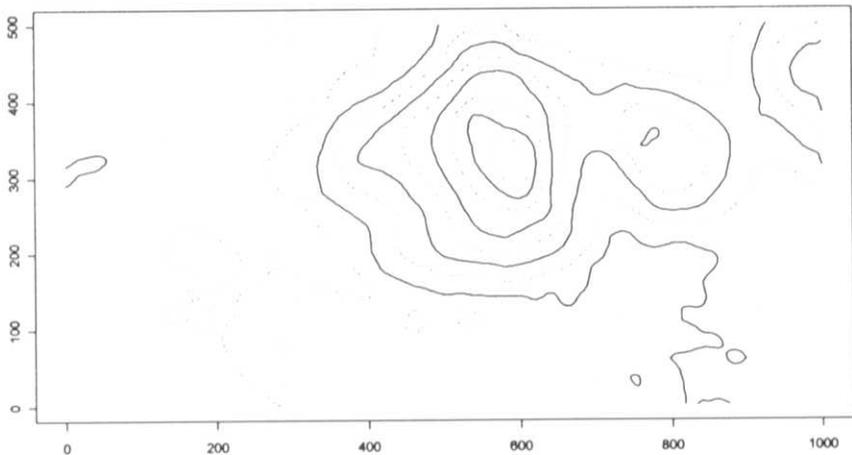


Fig. 36.2. Topographic map of the 50-ha Pasoh Forest Dynamics Plot with 5-m contour intervals (solid line) and intermediate 2.5 m contour intervals (dashed line).

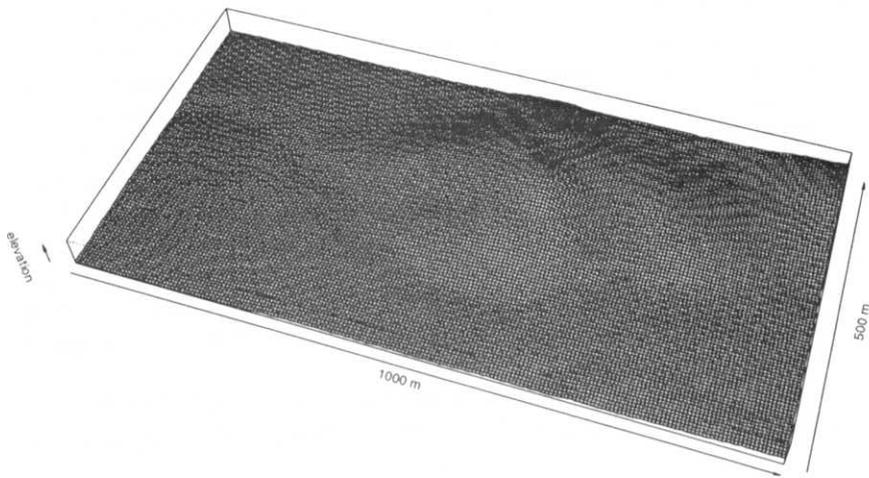


Fig. 36.3. Perspective map of the 50-ha Pasoh Forest Dynamics Plot.

soil classification system based on substrate and profile morphology. Dr. Amir Husni extended this work by mapping in detail soils of the Pasoh Forest Dynamics Plot (Amir Husni and Miller 1990; Amir Husni et al. 1991). Throughout the 50-ha Pasoh Forest Dynamics Plot, soils on the hills are predominantly well-drained Ultisols derived from alluvial sediment except in the northeast portion where granite is the parent material. Sandy, usually well-drained Entisols predominate on the plains. Poorly drained clay Entisols occur along the water courses.

Forest Type and Characteristics

Pasoh Forest Reserve includes one of the last remnants of the lowland mixed dipterocarp forests that once covered the south central peninsula. Following the classification of Wyatt-Smith (1987), they are sometimes described as south central red-meranti-keruing forest. An interesting and perhaps unique feature of Pasoh is the strong co-abundance of *Neobalanocarpus heimii* (Dipterocarpaceae) and *Dipterocarpus kunstleri* (Dipterocarpaceae). The closed canopy averages 35 m tall, with the emergent layer reaching 50–60 m. The upper canopy is noticeably dominated by the Dipterocarpaceae family: meranti (*Shorea* section Muticae, especially *S. leprosula* Miq., *S. acuminata* Dyer, and *S. macroptera* Dyer), keruing (*Dipterocarpus cornutus* Dyer), balau (*Shorea maxwelliana* King), and chengal (*Neobalanocarpus heimii* King). There are three main types of tree communities found in the plot: a low-lying swamp community in the north and northwestern corner, the hill community in the center and eastern portion, and the alluvium

forest community in the remaining portions of the plot (Davies et al. 2003). This last type can be further broken down into sandy alluvium in the western portion of the plot, clay alluvium in the east, and an intermediate community in the northwest. There are strong species associations with each of these community types, including *Saraca thaipingensis* (Leguminosae), *Diospyros andamanica* (Ebenaceae), and *Iguanura wallichiana* (Palmae) in the swamp community; *Cleistanthus myrianthus* (Euphorbiaceae), *Pentace strychnoidea* (Tiliaceae), *Anisophyllea corneri* (Anisophylleaceae), and *Elateriospermum tapos* (Euphorbiaceae) in the hill community; and *Shorea maxwelliana* (Dipterocarpaceae), *Dipterocarpus crinitus* (Dipterocarpaceae), *Hopea mengarawan* (Dipterocarpaceae), and *Pavetta graciliflora* (Rubiaceae) in the alluvium communities. For census data and species rankings see tables 36.2–36.7.

Flowering and fruiting in the plot occur throughout the year, though supra-annual general mast flowering tends to occur from March to May (Yap and Chan

Table 36.2. Pasoh Plot Census History

Census	Dates	Number of Trees (≥ 1 cm dbh)	Number of Species (≥ 1 cm dbh)	Number of Trees (≥ 10 cm dbh)	Number of Species (≥ 10 cm dbh)
First	January 1986–September 1988	335,352	814	26,554	678
Second	January 1990–October 1990	323,237*	814	27,699	666
Third	January 1995–November 1996	320,808*	817*	29,288	674
Fourth	February 2000–July 2001	305,942 [†]	816 [†]	28,279	673

* In the Pasoh Forest Dynamics Plot dataset, during a recensus, trees whose main stems were broken or had disappeared and whose secondary stems were alive and larger than 1 cm dbh, were recorded as alive in the dataset, but their dbh measurements were not entered. These individuals have not been included in this table. However, if one were to include them in the dataset and assume that their measurement is between 1 and 10 cm dbh, then the following numbers (all in ≥ 1 cm dbh class) would be modified for the second the third censuses:

Number of trees for second census: 326,797

Number of trees for third census: 338,262

Number of species for third census: 818

[†] Number of trees and species do not include the new recruits in the fourth census.

Note: Four censuses have been completed, the next census is expected to begin in January 2005.

Table 36.3. Pasoh Summary Tally

Size Class (cm dbh)	Average per Hectare							50-ha Plot				
	BA	N	S	G	F	H'	α	S	G	F	H'	α
≥ 1	31.0	6707	495	210	68	2.31	123.9	814	288	82	2.45	100.3
≥ 10	25.7	531	206	115	44	2.15	124.9	678	250	72	2.45	126.7
≥ 30	15.9	76	47	35	21	1.57	53.5	375	163	56	2.13	103.2
≥ 60	7.8	15	10	7	5	0.94	17.2*	103	58	30	1.61	32.7

* Based on 47 hectares.

Notes: BA represents basal area in m^2 , N is the number of individual trees, S is the number of species, G is the number of genera, F is the number of families, H' is the Shannon–Wiener diversity index using \log_{10} , and α is Fisher's α . All individuals were identified. Data are from the first census.

Table 36.4. Pasoh Rankings by Family

Rank	Family	Basal			Family	% Trees			Species
		Area (m ²)	% BA	% Trees		Trees	Family		
1	Dipterocarpaceae	437.2	28.2	9.2	Euphorbiaceae	44,096	13.1	Euphorbiaceae	85
2	Leguminosae	132.3	8.5	3.3	Dipterocarpaceae	30,913	9.2	Lauraceae	48
3	Euphorbiaceae	106.7	6.9	13.1	Annonaceae	23,888	7.1	Myrtaceae	48
4	Burseraceae	96.5	6.2	5.4	Rubiaceae	19,395	5.8	Rubiaceae	45
5	Myrtaceae	52.6	3.4	3.1	Burseraceae	18,035	5.4	Meliaceae	43
6	Fagaceae	51.2	3.3	1.6	Sapindaceae	16,512	4.9	Annonaceae	42
7	Annonaceae	50.4	3.3	7.1	Myristicaceae	14,347	4.3	Guttiferae	34
8	Anacardiaceae	46.7	3.0	2.3	Ebenaceae	13,996	4.2	Anacardiaceae	32
9	Sapindaceae	42.4	2.7	4.9	Myrsinaceae	11,814	3.5	Myristicaceae	31
10	Myristicaceae	42.2	2.7	4.3	Guttiferae	11,072	3.3	Dipterocarpaceae	30

Notes: Top 10 tree families for basal area, number of trees ≥ 1 cm dbh, and number of species, and percentage of all trees in plot. Data are from the first census.

1990; Numata et al. 2003). Since 2001, 247 traps (0.5 m²) have been censused weekly for flowers, fruits, and seeds, following the same protocol used in the Barro Colorado Island and Yasuni Forest Dynamics Plots.

Fauna

In the Pasoh Forest Reserve, 89 mammal species, of which 12 are bats, are known to occur (Kemper 1988). Based on geographic distributions and habitat preferences, an additional 98 species may also reside in the forest reserve. Resident mammals within the research forest number 42 species, with perhaps four local extirpations. Mammal species include the long-tailed giant rat (*Leopoldamys sabanus*), lesser mouse deer (*Tragulus javanicus*), Malayan flying lemur (*Cynocephalus variegates*), slow loris (*Nycticebus coucang*), siamang (*Hylobates syndactylus*), red giant flying squirrel (*Petaurista petaurista*), spotted giant flying squirrel (*P. elegans*), and large black flying squirrel (*Aeromys tephromelas*) (Kemper 1988). Resident birds of the primary forest number approximately 166, with no known local extirpations, although populations of several species—especially the larger hornbills—have ostensibly declined from pre-1970 levels. The Pasoh forest also contains 489 ant species (Malsch et al. 2003). A survey on herpetofauna conducted from 1968 to 1991 in the Pasoh Forest Reserve recorded 75 species comprising 26 amphibians, 24 tortoises, turtles, and lizards, and 25 snakes (Lim et al. 2003).

Natural Disturbances

In general, the south central Malay peninsula lacks large-scale natural disturbances such as floods, droughts, fire, typhoons, and volcanoes. Lightning strikes

Table 36.5. Pason Rankings by Genus

Rank	Genus	Basal Area		Genus	Trees	% Trees	Genus	Trees	% Trees	Genus	Species
		(m ²)	% BA								
1	<i>Shorea</i> (Dipterocarpaceae)	301.6	19.5	<i>Shorea</i> (Dipterocarpaceae)	21,437	6.4	<i>Eugenia</i> (Myrtaceae)	45			
2	<i>Dipterocarpus</i> (Dipterocarpaceae)	65.8	4.2	<i>Aporosa</i> (Euphorbiaceae)	17,000	5.1	<i>Diospyros</i> (Ebenaceae)	23			
3	<i>Eugenia</i> (Myrtaceae)	50.7	3.3	<i>Diospyros</i> (Ebenaceae)	13,996	4.2	<i>Aglaia</i> (Meliaceae)	22			
4	<i>Neobalanocarpus</i> (Dipterocarpaceae)	43.5	2.8	<i>Ardisia</i> (Myrsinaceae)	11,545	3.4	<i>Garcinia</i> (Guttiferae)	16			
5	<i>Koempassia</i> (Leguminosae)	36.8	2.4	<i>Knema</i> (Myristicaceae)	10,697	3.2	<i>Litsea</i> (Lauraceae)	14			
6	<i>Dacryodes</i> (Burseraceae)	35.1	2.3	<i>Dacryodes</i> (Burseraceae)	10,614	3.2	<i>Shorea</i> (Dipterocarpaceae)	14			
7	<i>Ixonanthes</i> (Ixonanthaceae)	27.8	1.8	<i>Eugenia</i> (Myrtaceae)	10,044	3.0	<i>Aporosa</i> (Euphorbiaceae)	13			
8	<i>Quercus</i> (Fagaceae)	26.0	1.7	<i>Xerospermum</i> (Sapindaceae)	8,969	2.7	<i>Knema</i> (Myristicaceae)	13			
9	<i>Santiria</i> (Burseraceae)	25.9	1.7	<i>Rinorea</i> (Violaceae)	8,544	2.5	<i>Mangifera</i> (Anacardiaceae)	13			
10	<i>Canarium</i> (Burseraceae)	23.8	1.5	<i>Anaxagora</i> (Annonaceae)	7,076	2.1	<i>Memecylon</i> (Melastomataceae)	12			

Notes: The top 10 tree genera for trees ≥ 1 cm dbh ranked by basal area, number of individual trees, and number of species with the percentage of trees in the plot. Data are from the first census.

Table 36.6. Pasoh Rankings by Species

Rank	Species	Number Trees	% Trees	Species	Basal Area (m ²)	% BA	% Trees
1	<i>Xerospermum noronhianum</i> (Sapindaceae)	8961	2.7	<i>Shorea maxwelliana</i> (Dipterocarpaceae)	54.7	3.5	1.7
2	<i>Rinorea anguifera</i> (Violaceae)	8262	2.5	<i>Shorea leprosula</i> (Dipterocarpaceae)	53.0	3.4	0.9
3	<i>Ardisia crassa</i> (Myrsinaceae)	7641	2.3	<i>Neobalanocarpus heimii</i> (Dipterocarpaceae)	43.5	2.8	1.0
4	<i>Anaxagorea javanica</i> (Annonaceae)	7076	2.1	<i>Shorea lepidota</i> (Dipterocarpaceae)	41.4	2.7	0.4
5	<i>Aporosa microstachya</i> (Euphorbiaceae)	6509	1.9	<i>Shorea pauciflora</i> (Dipterocarpaceae)	40.5	2.6	0.7
6	<i>Shorea maxwelliana</i> (Dipterocarpaceae)	5676	1.7	<i>Koompasia malaccensis</i> (Leguminosae)	36.8	2.4	0.2
7	<i>Dacryodes rugosa</i> (Burseraceae)	5649	1.7	<i>Shorea acuminata</i> (Dipterocarpaceae)	36.4	2.4	0.7
8	<i>Knema laurina</i> (Myristicaceae)	4489	1.3	<i>Dipterocarpus cornutus</i> (Dipterocarpaceae)	34.6	2.2	0.4
9	<i>Gironniera parvifolia</i> (Ulmaceae)	3961	1.2	<i>Ixonanthes icosandra</i> (Ixonanthaceae)	27.8	1.8	1.0
10	<i>Barringtonia macrostachya</i> (Lecythidaceae)	3705	1.1	<i>Shorea parvifolia</i> (Dipterocarpaceae)	26.7	1.7	0.5

Notes: The top 10 tree species for trees ≥ 1 cm dbh are ranked by number and percentage of trees and basal area. Data are from the first census.

are extremely frequent in this region but are not known to ignite forest fires. Windthrows of less than 1-ha size are relatively common during April, especially in areas with impeded drainage and shallow rooting. Small-scale disturbances created by wild pigs (*Sus scrofa*) are also common. Pigs root through soil for food and build nests with hundreds of saplings each, significantly reducing plant recruitment. Termites (*Microcerotermes dubius*) are also known to destroy living trees in the area, causing forest gaps (Tho 1982).

Human Disturbance

Humans have lived in the Malay peninsula for perhaps 40,000 years and have traded extracted forest products since prehistoric times (Dunn 1975). Until recently, there has been no history of shifting cultivation in this area of predominantly proto-Malay Semelai and Mon-Khmer (Jakun) people. Jakun collectors had traditionally tapped various species of *Dipterocarpus* in the Pasoh forest for keruing oil. This practice continued until very recently through resin extraction of the highly productive *D. kerrii*. In 1970–71 the area immediately surrounding the forest to the north, west, and south sides of the reserve was cleared for oil palm (*Elaeis guineensis* [Palmae]) production. At this time, a large number of

Table 36.7. Pasoh Tree Demographic Dynamics

Size Class (cm dbh)	Growth Rate (mm/yr)			Mortality Rate (%/yr)			Recruitment Rate (%/yr)			BA Losses (m ² /ha/yr)			BA Gains (m ² /ha/yr)		
	86-90	90-95	95-00	86-90	90-95	95-00	86-90	90-95	95-00	86-90	90-95	95-00	86-90	90-95	95-00
1-9.9	1.36	0.63	0.42	1.16	1.42*	1.78*	0.65	2.37*	1.33*	0.07	0.10	0.11	0.40	0.25	0.15
10-29.9	2.33	2.13	1.38	1.19	1.49	1.98	3.39	3.05	1.84	0.13	0.19	0.21	0.41	0.39	0.26
≥ 30	3.37	3.79	2.45	1.11	1.76	2.05	2.37	2.39	1.90	0.18	0.32	0.37	0.33	0.34	0.26

*In the Pasoh Forest Dynamics Plot dataset, during a census, trees whose main stems were broken or had disappeared and whose secondary stems were alive and larger than 1 cm dbh, were recorded as alive in the dataset, but their dbh measurements were not entered. These individuals have not been included in these tables. However, if one were to include them in the dataset and assume that their measurement is between 1 and 10 cm dbh, then the following rates (all in the 1-9.9 cm dbh class) would be modified:

Mortality for 90-95: 1.47%/yr

Mortality for 95-00: 2.00%/yr

Recruitment for 90-95: 2.39%/yr

Recruitment for 95-00: 0.88%/yr

forest fragments were formed in areas of similar soil and topography to the reserve, within the watershed of the Pertang river. Between 1930 and 1960, logging with buffalo was carried out in many of the peripheral compartments of the Pasoh forest, but not within the core forest compartments that include the 50-ha plot.

Occasional hunting exists in the nature reserve as native pigs are abundant due to the additional food supply from surrounding oil palm plantations. Locally extirpated populations include the rhinoceros, tapir, elephant, and tiger, although all species—except the rhino—may still rarely wander into the Pasoh Forest Reserve. The only invasive plant species is the neotropical *Clidemia hirta* (Melastomataceae) which has become increasingly common in the forest during the last 10 years. Plans for an east-west road north of the research forest are currently underway. In general, the central human disturbance in Pasoh has been the indirect effects of fragmentation and size reduction of the forest.

In the 1950s, a buffer zone of 700 ha within the western and southern area of the reserve was logged under a regime called the Malayan Uniform System (MUS). Distinct differences were found between the primary (unlogged) and regenerating (logged) forest in canopy height, canopy structure, stand structure, and tree species compositions (Manokaran and Swaine 1994; Okuda et al. 2003), flower-visiting beetles (Fukuyama et al. 2003), termite communities (Takamura 2003), small mammal community (Yasuda et al. 2003; Lim et al. 2003), herpetofauna (Lim and Yaakob 2003), fungi (wood-decaying basidiomycetes) (Hattori and Lee 2003), and bird community (Styring and Ickes 2003).

Plot Size and Location

Pasoh is a 50-ha, 1000 × 500 m plot; the long axis lies east-west. The southwest corner of the plot (coordinates 0, 0) is located at 2° 58' 47" N, 102° 18' 29" E.

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