

THE CLIMATE OF PENANG ISLAND

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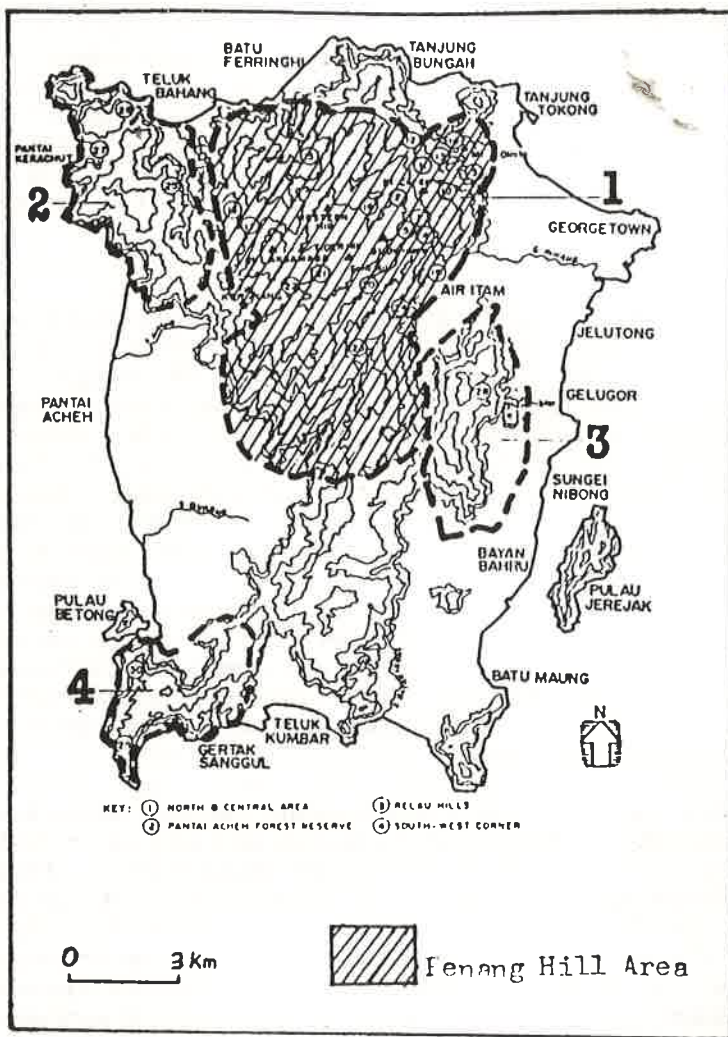
In Penang Island, changes in the weather and climate have been observed in recent years. Penang Island's unique environmental factors that affect its climate include its varying altitude, topography, vegetation, air quality, maritime nature and its exposure to the monsoon winds. Cultural factors also influence the climate of Penang Island to a lesser degree. These include its high rate of industrialisation, pollution, heavy traffic and its rapidly changing land use patterns. All these factors have combined to create a changing climatic regime for Penang Island. This paper is essentially a statistical analysis of the current mean and variability patterns of various climatic elements of Penang Island such as temperature, sunshine, relative humidity, rainfall and wind.

Di Pulau Pinang, perubahan-perubahan di dalam cuaca dan iklim juga telah diperhatikan pada tahun-tahun kebelakangan ini. Faktor-faktor alam sekitar unik di Pulau Pinang yang mempengaruhi iklimnya termasuklah ketinggian yang berbeza, topografi, tumbuh-tumbuhan, kualiti udara, sifat kelautan dan pendedaannya kepada angin monsun. Faktor-faktor budaya juga mempengaruhi iklim di Pulau Pinang. Ini termasuk kadar perindustrian yang tinggi, pencemaran, kenderaan yang banyak dan kadar perubahan pola-pola guna tanah yang pesat. Kesemua faktor tersebut telah secara bergabung mencipta sesuatu rejim iklim yang berubah di Pulau Pinang. Pada dasarnya, kertas ini merupakan sesuatu analisis statistik terhadap pola-pola min dan keubahan beberapa elemen cuaca dan iklim di Pulau Pinang masa kini seperti suhu, pancaran matahari, kelembapan bandingan, hujan dan angin.

INTRODUCTION

Penang Island¹ is located in the equatorial belt between latitudes 5°7' N and 5°35'N and longitudes 100°9'E and 100°32'E. Together with the maritime nature of the island and its exposure to the effects of the monsoons, it has resulted in an equatorial climate which is, however, slightly different from that of the equatorial areas of the Congo (Africa) or the Amazon Basin in Brazil (Ooi, 1959, p. 26). In general, the climate is characterised by abundant sunshine (6 hours of bright sunshine daily), high and uniform temperatures (26.7°C), high humidities (80%) and abundant rainfall (2000mm) throughout the year.² However, because of its latitudinal position, Penang Island experiences a distinct dry season from the beginning of November to the end of March. During these dry months, daily mid-day temperatures can soar well over 35°C in many parts of the island with the exception of the Penang Hill Region which is at a higher altitude of between 700 and 800 metres (Figure 1). Generally, because of its altitude, the mean temperatures in and around the

FIGURE 1



Highland Areas of Penang Island
(Source: Malayan Nature Society, Undated)

various peaks in the Penang Hill area are at least a couple of degrees (Celsius) lower than the surrounding lowlands (Dale, 1963, p. 58). Other notable climatic elements in Penang Hill that differ from the lowland areas are a higher percentage of relative humidity, a much higher rate of occurrence of fog and mist³, a much lower level of foreign matter (pollutants) in the air, a higher rainfall regime, stronger wind profile and more cloud cover (thus less sunshine). The main objective of this study is to describe the climate of Penang Island based on current climatic data. To achieve this objective, the mean and variability patterns of the common climatic elements such as temperature, sunshine, relative humidity, rainfall and wind will be discussed.

METHODOLOGY

The analysis and results of this study are based on both primary and secondary climatic data. Primary climatic data was obtained on various field trips all over Penang Island during the period from January 1991 to June 1991. The objective of these field trips is to record the periodic variation of the various climatic elements in different parts of the island. Some of the locations visited during the field trips where the hourly shade air temperature and the relative humidity were measured are the Penang Hill area, the Botanical Gardens, the Victoria Park area, the Tar's Stream area and the Georgetown area. At each of the above locations a whirling psychrometer was set up and manned by a group of students. The only exception was the Penang Hill area which had an automatic battery-operated psychrodyn. Prior to the field trip, the psychrodyn was calibrated against the temperatures of a pair of dry and wet bulb thermometers. Subsequently, all the other psychrometers were calibrated against the psychrodyn. Measurements of the dry and wet bulb temperatures were taken on an hourly basis and the relative humidity was obtained by using slide rule to read off the value.

Secondary climatic data such as temperature, rainfall, relative humidity, sunshine, global radiation and wind were also obtained from the Malaysian Meteorological Service and the Drainage and Irrigation Division, Ministry of Agriculture Malaysia. This came in the form of tables and also in the form of published data (see Drainage and Irrigation Division, 1961; 1970; 1974; 1977; 1982; and 1987). The data on temperature was obtained for two stations at Bayan Lepas (1968-1990) and Bukit Bendera (1975-1990). Data on sunshine was obtained only for Bayan Lepas (1968-1990) as there was no other reliable record of long enough duration for other stations on the island. Data on relative humidity, however, was obtained for three stations. These were Bayan Lepas, Bukit Bendera and Muka Head (all for the period 1975-1990). The data on rainfall was obtained for 25 selected rainfall stations on the island. Based on the data of these stations, the mean annual, seasonal and monthly rainfall as well as its corresponding variability maps were drawn. Finally, data on wind profiles were obtained for Bayan Lepas for the period 1968 to 1990. It

must be stressed that although the records for some of the climatic elements were for slightly different periods, it is the average value of each element that is discussed.

DISCUSSION

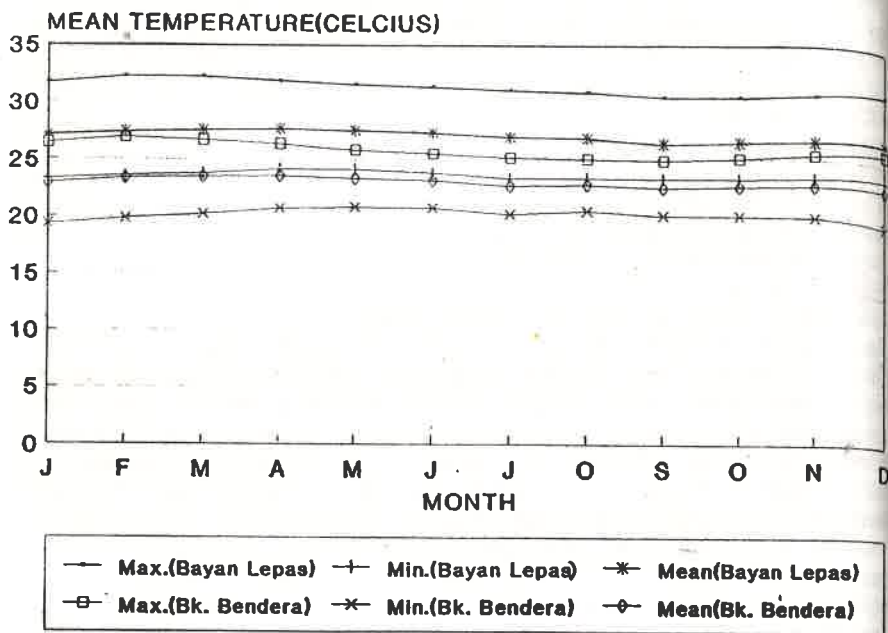
Being a tropical island, the mean daily temperature of most parts of Penang seldom dips below 26.0°C . In general, the mean daily temperature in the lowland areas of Penang Island ranges from about 24°C in the early mornings to 34°C during mid-day. In the highland areas, temperatures are lower depending on the elevation. Penang Hill, a popular tourist attraction because of its cooler environment, has average temperatures of between 15°C and 27°C (Khor, et.al., 1991, p. 24). On the other hand, the lowland station of Bayan Lepas has a much higher temperature range of between 23.6°C and 31.5°C .

The mean maximum and mean minimum monthly temperatures (1975-1990) of Bukit Bendera (Flag Hill), one of the peaks in the Penang Hill area, and Bayan Lepas Airport (a lowland meteorological station near sea level) are shown in Figure 2. From this figure, it is evident that the mean maximum monthly temperatures of Bayan Lepas are always above 31°C . On the other hand, the mean maximum monthly temperatures of Bukit Bendera seldom exceed 26°C . In fact, even the mean monthly temperatures of Bayan Lepas are always higher than the mean maximum monthly temperatures of Bukit Bendera. The mean minimum monthly temperatures of Bukit Bendera are, however, consistently below 21°C while its mean monthly temperatures are between 22°C and 24°C . This gives it a monthly temperature range of only 2°C which is typical of an equatorial climate. On the other hand, the mean minimum monthly temperatures of Bayan Lepas are significantly higher with values of between 23°C and 24°C . The mean monthly temperatures of Bayan Lepas are also markedly higher, between 26°C and 28°C . In fact, the highest mean maximum monthly temperature recorded for the entire period was only 28.7°C for Bukit Bendera as compared to 34.1°C for Bayan Lepas (a difference of 5.4°C). On the other hand, the lowest mean minimum monthly temperature recorded at Bukit Bendera was 18.2°C as compared to 22.4°C for Bayan Lepas (a difference of 4.2°C). On the temporal scale, however, both stations show a similar trend. The hottest months occur between December and April while the coolest months are between June and October. The mean maximum and minimum monthly temperatures for 1990 for both stations are shown in Figure 3. Although the patterns are similar to that of Figure 2, it can be seen that there is a sharp increase of temperature towards the end of 1990 signifying the commencement of the dry season.

The diurnal variation of temperature is much more pronounced than that of the monthly temperatures. In Figure 4, the diurnal variation of temperature for six different locations in Penang Island are shown. The two lowest curves

FIGURE 2

MEAN TEMPERATURE



Mean Maximum, Mean Minimum and Mean Monthly Temperature at, Bayan Lepas and Bukit Bendera, Penang Island.,-

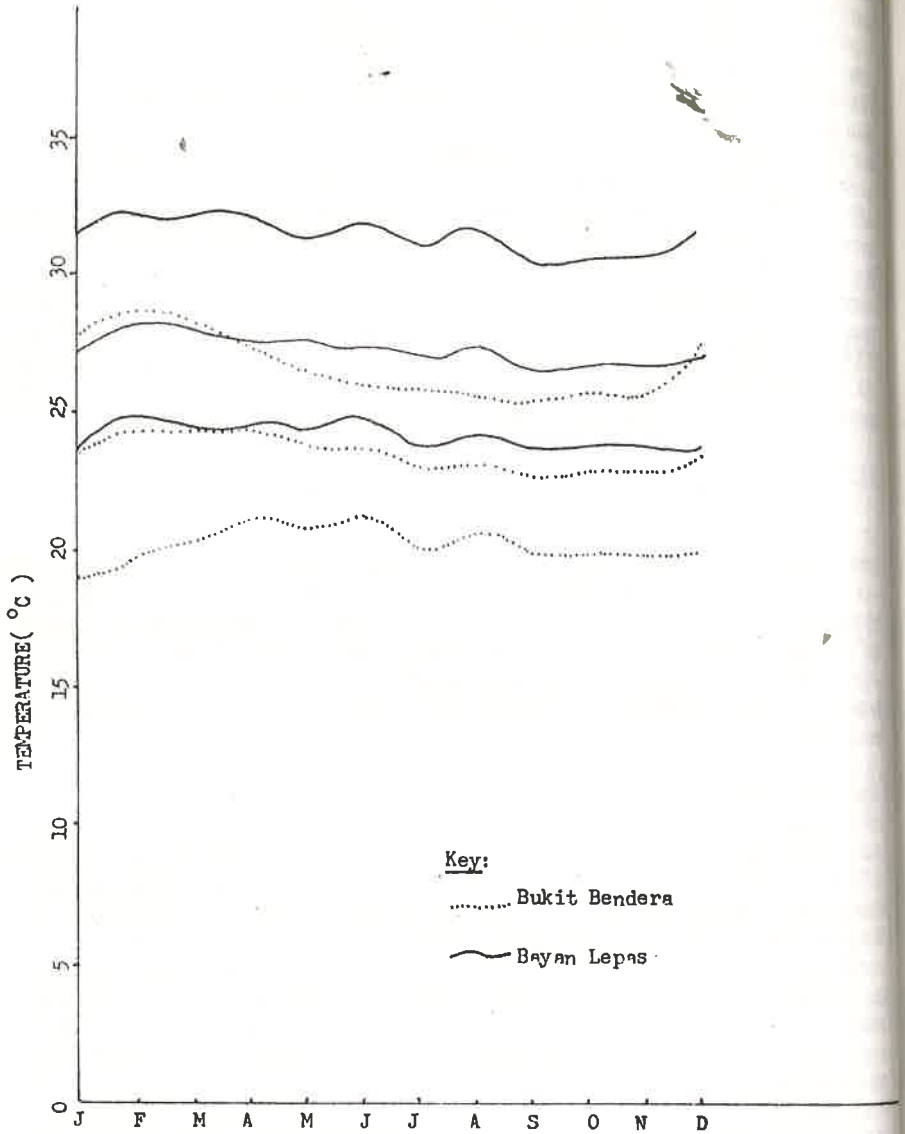
depicting the lowest recorded temperatures are in the Penang Hill area, viz. the Methodist Centre and the Convalescent Bungalow. The other four curves depicting much higher temperature variations during the day are all lowland stations, viz. Georgetown, Botanical Gardens, Tat's Stream and Air Itam area. The only exception is the lower temperatures recorded at the Botanical Gardens during the early mornings between 3.00am and 4.00am. This could be due to the occurrence of a temperature inversion as a result of subsiding cold air from the hill slopes. Such a phenomenon is not uncommon in a cold morning giving rise to the formation of radiation fog (see Sham Sani, 1983, p. 46). Finally, a brief analysis was made on the temporal variation of the mean monthly temperature over the period 1968 to 1990 (Figure 5). Both the curves for Bayan Lepas and Bukit Bendera indicate a slight increase of the mean monthly temperature during recent years, particularly in 1990. For Bukit Bendera, the period between 1975 and 1983 had mean monthly values from 22.8°C to 23.5°C whereas the period from 1984 to 1990 had values between 23.0°C and 23.7°C. The later years for Bayan Lepas also showed a slight tendency towards temperature increase although it is not so pronounced.

SUNSHINE

In a tropical island like Penang, sunshine is abundant, with an average of at least 6 hours of intense sunshine per day (usually from 8.00am to 5.00pm with occasional overcast and cloudy skies in between) for most months of the year. However, variations in the duration of bright sunshine do occur from month to month within a year. For instance, the dry season months from December to April have a generally longer duration of bright sunshine (between 6 and 8 hours) as compared to the wet season months from May to October (between 5 and 6 hours).

According to Dale (1964, p. 20), Penang Island is one of the sunniest parts of Malaysia, averaging more than 2300 hours of bright sunshine per year. According to Holshausen (1963), Bayan Lepas has a mean daily sunshine of 6.78 hours. In terms of the annual percentage of the total possible sunshine, this gives a figure of 56%. In Table 1, the Mean Daily Sunshine Hours for Bayan Lepas station over the period 1968 to 1990 also showed an average sunshine of between 6 and 8 hours. Generally, the months with the most hours of sunshine are the dry season months from November to March. In January and February, the Bayan Lepas station experiences 8.1 and 8.2 hours of daily sunshine respectively. On the other hand, the wet season months from May to October have the least hours of daily sunshine. For example, the values for Bayan Lepas in September and October are 5.1 and 5.5 hours respectively. Although no records on sunshine were available for Penang Hill, records from other hill stations can be used to infer the average conditions. Generally, hill stations have less sunshine as compared to lowland stations because of the higher incidences of cloud cover and fog occurrence. For instance, Cameron

FIGURE 3



Mean Maximum, Mean Minimum and Mean Monthly Temperature at Bukit Bendera dan Bayan Lepas for 1990.

Highlands (1448 metres) and Fraser's Hill (1300 metres) have an average of 4.5 and 4.8 hours of bright sunshine per day (see Table 2). This is lower than most lowland stations which have at least between 6 and 8 hours of intense sunshine per day (Dale, 1964, p.22). The annual average for Cameron Highlands is 1628 hours or 37% of the possible. This is 854 hours less than the figure for Bayan Lepas. In general, it can be assumed that the number of sunshine hours decreases as one moves from the coastal areas toward the interior highlands (Dale, 1964, p. 21).

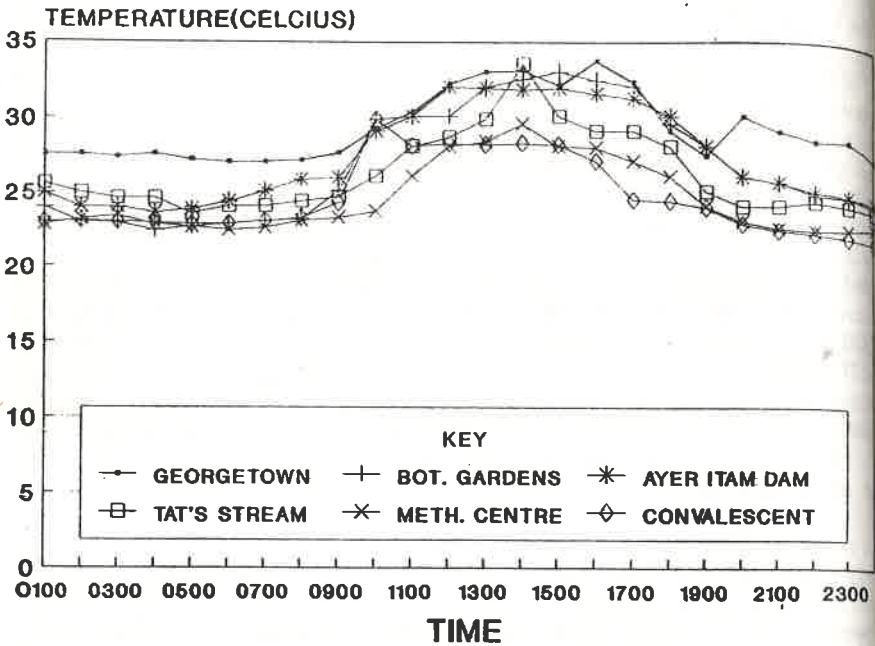
RELATIVE HUMIDITY

Relative humidity, a familiar quantity given in weather reports, is the ratio of the amount of water vapour actually measured to that which a certain parcel of air can hold at saturation (Riehl, 1965, p.68). It is expressed as a percentage. The relative humidity at a certain place is dependant on vegetation cover, soil moisture content, cloud cover, wind speed, temperature, time and the saturation vapour deficit of the air. Most of all, relative humidity varies inversely with temperature. In Penang, the high temperatures coupled with high humidities all year round has often been described as unsuitable for humans in terms of comfort, health and physical work (Ooi, J.B., 1979, p. 51). In general, the relative humidity in Penang is consistently high owing to Penang's insularity and the availability of moisture all year round. It ranges from about near saturation in the early mornings to about 50% during mid-day. In the Penang Hill area which is still largely under tropical rain forest (much of which is still under legislative protection as 'forest reserves'), the relative humidity ranges between saturation (occurrence of mist and fog) in the early mornings and 65 percent in mid-day. In the dense and thickly forested undergrowth, relative humidities can reach saturation point even around mid-day when there is an overcast sky, thus giving rise to the foggy nature of such areas.

A comparison of the mean monthly relative humidity at three selected stations in Penang Island showed that all three stations have humidity values above 75 per cent at all times (Figure 6). It was also noted that the hill station of Bukit Bendera had a slightly higher mean value than the other two lowland stations of Bayan Lepas and Muka Head for all months. A comparison of the diurnal variation of the relative humidity between the three stations was also carried out. The results showed that the early mornings and late nights have the highest relative humidity values (Figure 7). This is not surprising as the relative humidity varies inversely with temperature. For instance, it can be clearly seen that the three hill stations (Forest at Penang Hill, Methodist Centre and Convalescent) have generally higher relative humidity values than the lowland stations (Bayan Lepas, Muka Head, Tat's Stream and Georgetown). As such, the occurrences of mist and fog are much more frequent in the hill stations than the lowland stations.

FIGURE 4

DIURNAL TEMPERATURE VARIATION



Diurnal Temperature Variation at six locations in Penang Island.

In the urbanised areas like Georgetown and Bayan Lepas where most of the natural vegetation has been cleared and replaced with concrete and tar surfaces, relative humidities tend to be much lower because of less evapotranspiration. In fact, the centres of these urban areas have a distinctly lower relative humidity pattern compared to their peripheries. A study by Chandler (1965) in London showed that the centre of London has humidities of between 70 and 80% but the outskirts of the city have values of between 90 to 100%. A traverse through Georgetown in May 1991 showed that the differences in relative humidity levels are not so pronounced during the day as compared to during the night. During mid-day, the values in the outskirts of Georgetown were between 65-70% while the city centre recorded between 60-65%. During midnight, the values in the outskirts were between 85-95% while the values in the city centre were between 80-85%.

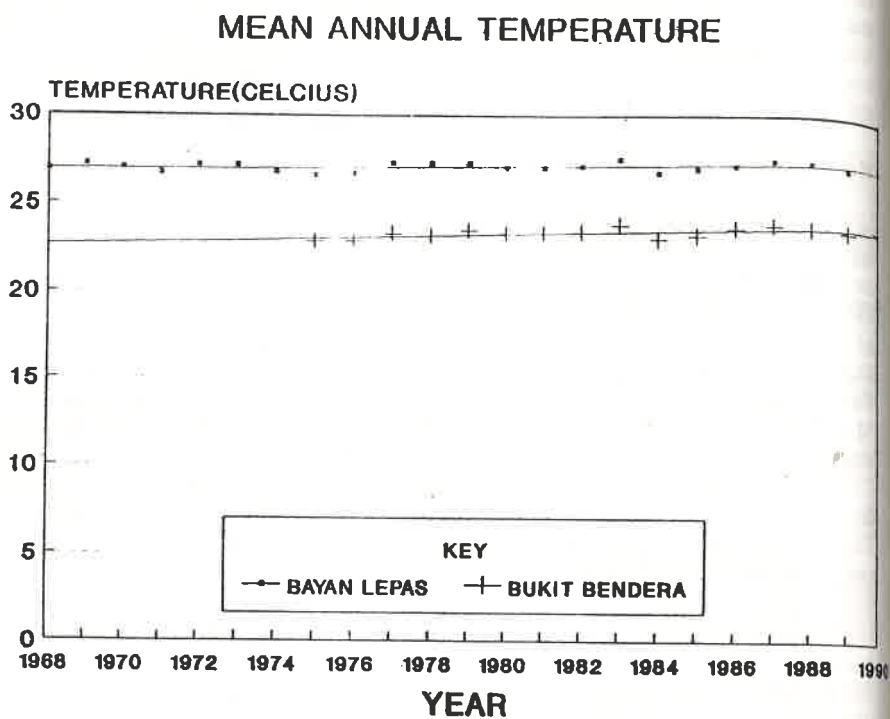
RAINFALL

While temperatures are uniform throughout the year in Penang, it is often incorrect to say that the island has no seasonality. Rather, as in most equatorial areas, the division of a year into various seasons is a function of rainfall. Generally, rainfall in Penang is abundant throughout the year (between 1800mm

and between 250mm and 500mm. However, due to its northerly location, it has a distinctly longer dry season from the months of November to March (during the North-east Monsoon Season in which Penang is in the rain shadow of the Main Range) (see Chan, N.W., 1981, pp.68-71). April and October are inter-monsoon periods where heavy convectional rain storms are frequent. As such, rainfall is heavy during these two months. Dale (1959, p. 35) has delineated the northwestern part of Peninsular Malaysia which encompasses Penang Island as a distinct rainfall region.

In Figure 8, a comparison of the Mean Monthly Rainfall was made between a highland station (Bukit Bendera) and a lowland station (Bayan Lepas). From this figure, it is clear that both stations depict the same rainfall regime with two peaks, one in May and the other in September/October. Both peaks coincide with the inter-monsoon periods where convectional rain storms are predominant. The bar chart also clearly illustrates the difference in total rainfall of the two stations. The rainfall for Bukit Bendera is higher than that for Bayan Lepas for every month of the year. In fact, the mean annual rainfall of the former is 3126mm as compared to 2474mm for the latter (a difference of 652mm). This comparison confirms that the hilly regions of Penang Island generally receive much higher rainfall amounts than the surrounding lowlands. This is due to the orographic nature of the hills which forces the moisture laden winds upwards and thus generating more rainfall.

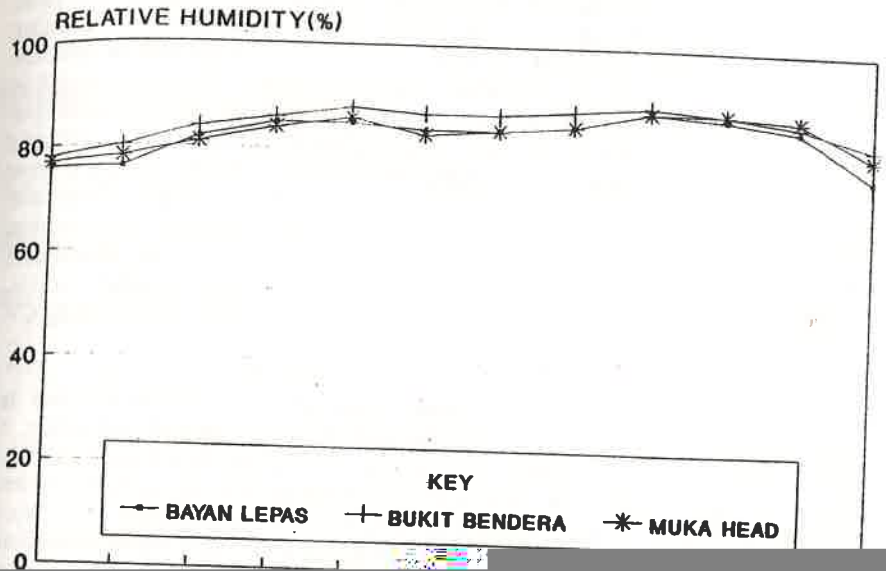
FIGURE 5



Mean Annual Temperature Trend at Bayan Lepas and Bukit Bendera in Penang Island.

FIGURE 6

MEAN MONTHLY RELATIVE HUMIDITY



The mean annual rainfall in Penang Island is high, between 1800mm and 3000mm (Figure 9). For most parts of the island, with the exception of Georgetown and the east coast lowlands, a mean annual rainfall of at least 2000mm can be expected. In general, rainfall increases as one moves westwards. This is due to the more exposed nature of the west coast which generates more orographic rain. In the Penang Hill area, the mean annual rainfall is expected to fall between 2200mm and 2600mm. This total is quite stable, as its variability in terms of Coefficient of Variation (CV) values are rather low. With the exception of Georgetown, most other areas have CVs below 30 per cent. It can also be noted that the mean annual CV values varies inversely with the mean annual rainfall totals.

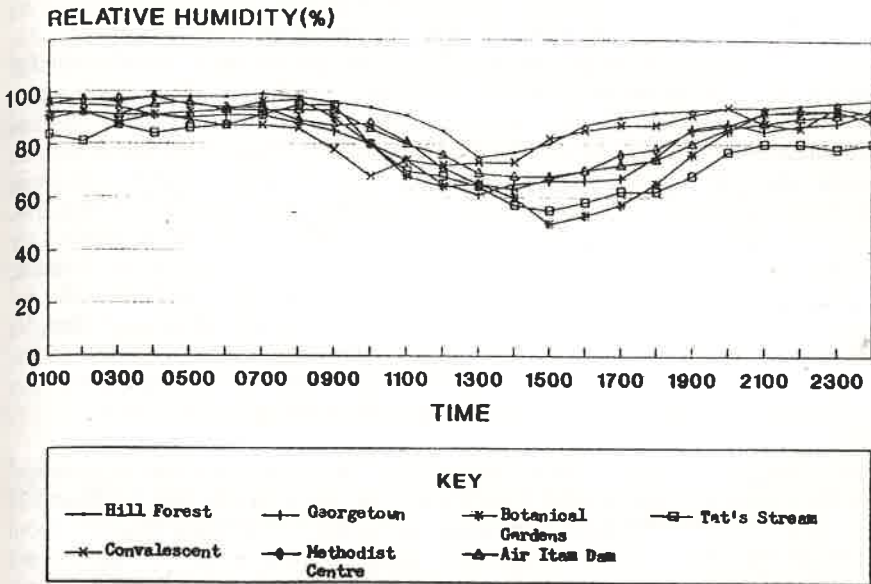
The first inter-monsoon period occurs some time in April. During this short period, winds are variable and characterised by a high percentage of calms. Under such conditions daily heating of the land and sea surfaces can produce turbulent convection currents which bring about heavy rainstorms. The mean rainfall is normally high for this period, varying from 200mm on the east coast of Penang Island to 300mm on the west coast (Figure 10A). The Penang Hill area generally receives between 225mm and 250mm of rain. As the period is short (1 month), its corresponding CVs are high. Most areas in Penang Island have CVs between 40 and 70 per cent during this period. However, a comparison between the CV and mean rainfall showed that there was no identifiable relationship between the two parameters. This confirms that for short periods, there is no relationship between total rainfall amounts and its corresponding CV values.

The second inter-monsoon period occurs some time in October. October is usually the month that coincides with the peak rainfall period in Penang. It is the month where most stations in Penang will record their highest rainfall. Based on Figure 10B, it is clear that most areas in Penang receive between 300mm to 450mm of rain. Only Pulau Jerejak and the central part of the east coast have rainfall below 300mm. The Penang Hill area has a mean rainfall of between 400mm to 450mm during this period. The CV values over the island are generally low (between 20 and 40%) and the CV pattern indicates that there is no significant relationship between the mean rainfall and the CV values. While rainfall values are increasing in a westerly direction, the CV values are increasing in a southerly direction.

The months from May to September represent the South-West Monsoon season. During this season, the prevailing winds have a profound effect on the rainfall of Penang Island, particularly its west coast. During this period, thunderstorm squalls known locally as "Sumatras" occur periodically. These winds not only bring heavy rainfall but can be violent enough to cause havoc to shipping, towns, buildings and agriculture (Ooi. J.B., 1959, p. 37). In Figure 10C, the mean seasonal rainfall for this period ranges from about 900mm in the

FIGURE 7

DIURNAL VARIATION OF RELATIVE HUMIDITY(%)



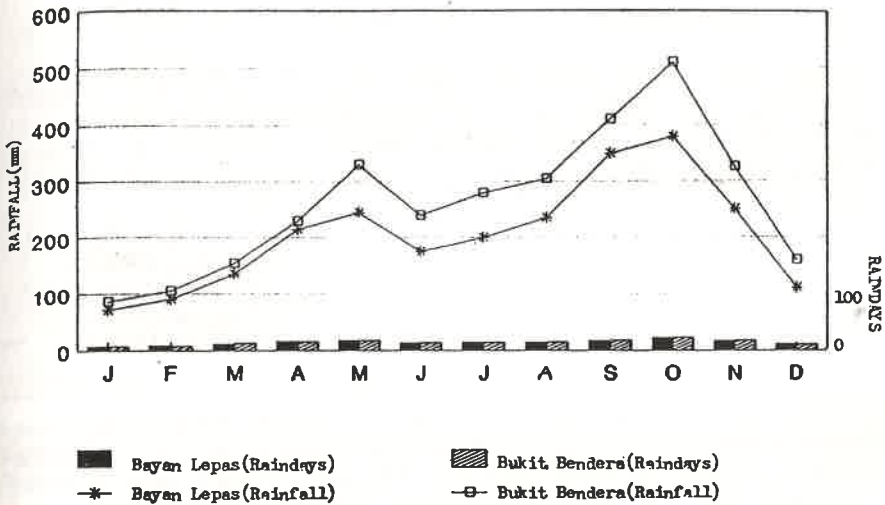
Diurnal Variation of Relative Humidity at various stations in Penang Island

east coast to more than 1300mm in the west coast in Penang Island. The Penang Hill area experiences heavy rainfall during this period. In general, Bukit Bendera receives a mean seasonal rainfall of more than 1200mm but in 1990, its rainfall for this period was 1530mm. As a comparison, Muka Head station and Bayan Lepas station have a rainfall of 1376mm and 1049mm respectively for 1990. Most other parts of Penang Hill have rainfall from 1100mm to 1300mm. The CVs for this period are generally low. Most areas have CVs between about 20 and 30 per cent. Again, there was no relationship between the CV values and its corresponding rainfall totals.

During the months from November to March, the prevailing air masses over Penang Island are the North-east Monsoon winds. During this period, Penang Island lies in the "rain-shadow" of the Main Range of Peninsular Malaysia. As such, it receives less rain than the other months of the year. In general, this period is considered the dry season in Penang where the mean monthly rainfall is less than 100mm most of the time (with the exception of November which is often an extension of the second inter-monsoon period due to the late commencement of the North-east Monsoon winds). Figure 10D shows that the mean seasonal rainfall during this period ranges between 400mm in the east coast of the island

11.

FIGURE 8



Mean Monthly Rainfall and Mean Number of Raindays at Bayan Lepas and Bukit Bendera in Penang Island.

In general, rainfall intensities are generally high in Penang Island. A 50mm depth of rain falling within a 15-minute spell is not uncommon. As such, the rainfall intensities experienced in Penang Island can be considered potentially high erosivity. According to Jackson (1977 p 75), has also 25mm/hour is considered to be the threshold level at which rainfall erosive. Jackson (1977 p 75), has also as those experienced in Penang very which can lead to severe soil erosion. intensities are generally high, usually between 0 and 50mm/hour lowland areas in Penang also experience similar rainfall intensities. diurnal occurrence of rain is frequently in the early mornings and at (monsoonal rains). In the east coast of Penang Island, rain falls mainly in late afternoons (convective rains).

WIND CONDITIONS

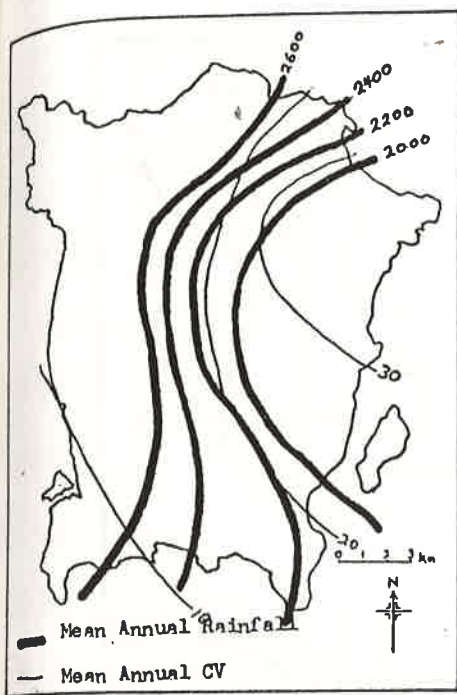
Penang Island is located in the tropical belt known as the Doldrums (which is also described as the belt of equatorial calms) where winds are and variable. As such, Penang does not experience the might and traumas violent tropical cyclones that are experienced elsewhere in the tropical world Strahler A.N., 1978, p. 164 According to Low (1972)

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Penang is also sheltered from the North-east Monsoon winds by the Main Range of Peninsular Malaysia and partly sheltered from the South-west Monsoon winds by the Indonesian island of Sumatra. As such, winds are never strong in Penang throughout the year. Most of the time, one can to be of the magnitude between one and five metres/second (3.5 to

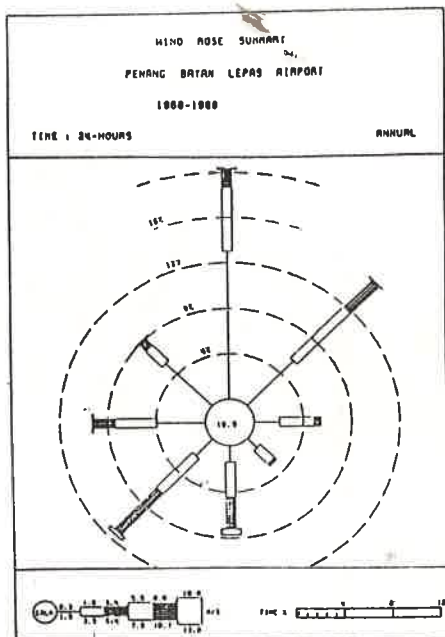
11, the d
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monsoon winds. The incidences of calms (wind speed less than 0.2 metre/second) is relatively high (18.9%), especially during the inter-monsoon periods. Wind speeds are generally below 10. second (38.5 km/hour).

FIGURE 9



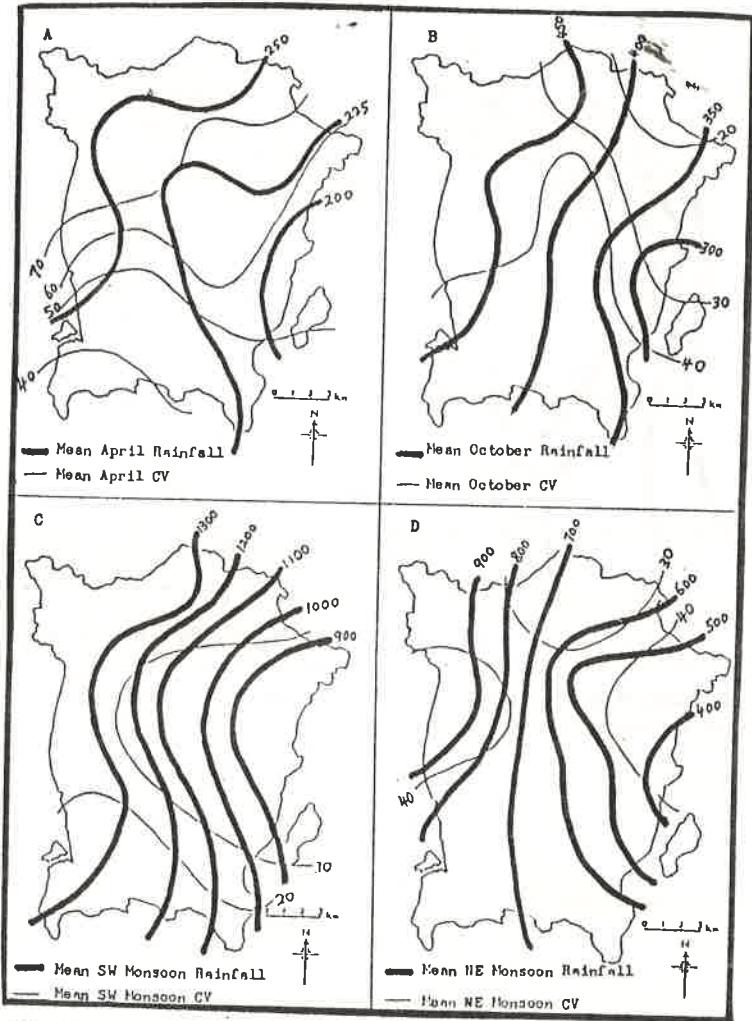
Mean Annual Rainfall (mm) and Coefficient of Variation (%) Over Penang Island.

FIGURE 11



Summary of Wind speed, Direction and Frequency at Bayan Lepas Station, Penang Island.

FIGURE 10



Distribution Patterns for Mean Rainfall (mm) and Coefficient of Variation (%) During different Seasons in Penang Island.

TABLE 1

Station: BAYAN LEPAS

Records of Mean Daily Sunshine Hours
Unit : hour

Lat. : 5° 18' N

Long. : 100° 16' E

Mt. above M.S.L.: 2.8m.

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
1968	7.1	9.6	7.9	7.1	6.2	6.0	5.3	5.2	5.0	5.3	8.7	5.9	6.7
1969	7.0	8.9	8.5	7.9	6.4	5.3	6.7	6.4	5.0	6.6	8.0	7.8	6.8
1970	7.4	9.3	8.0	7.8	6.7	5.9	5.9	6.4	5.4	4.0	5.6	5.1	6.5
1971	7.5	6.7	7.2	8.0	5.6	6.4	6.5	6.1	6.2	4.1	7.1	4.3	6.3
1972	9.1	7.4	8.3	6.5	8.0	6.3	5.7	6.4	5.2	6.6	5.7	7.0	6.9
1973	8.3	9.4	7.9	7.7	6.3	6.6	5.6	6.8	5.0	5.6	3.9	4.4	6.5
1974	7.8	7.5	8.5	6.9	7.0	6.9	7.6	6.0	4.9	4.4	4.3	8.1	6.7
1975	7.6	7.1	6.3	7.8	5.8	5.2	7.1	6.8	4.9	4.8	5.4	5.6	6.2
1976	9.7	8.3	7.3	7.6	6.2	6.8	7.3	6.7	5.1	4.8	5.6	7.6	6.9
1977	9.0	7.4	9.1	7.6	7.1	6.7	6.9	4.5	4.6	7.0	7.1	7.4	7.0
1978	8.3	8.3	7.4	7.9	6.5	6.2	6.0	4.7	5.0	5.1	6.9	7.9	6.7
1979	8.8	7.6	8.6	6.9	7.4	7.2	5.7	7.4	6.4	6.3	6.1	9.1	7.3
1980	8.5	8.3	7.5	7.3	7.1	6.0	7.1	5.1	5.8	5.1	5.7	5.5	6.6
1981	8.1	7.8	8.8	7.1	6.8	7.8	6.9	7.9	5.9	6.3	4.6	7.7	7.1
1982	9.8	8.8	7.3	6.6	6.9	6.5	6.7	6.1	5.3	6.7	6.9	6.9	7.0
1983	8.4	9.1	8.7	7.9	5.9	6.8	6.1	5.7	5.9	5.8	7.3	5.4	6.9
1984	5.9	5.2	7.3	6.8	6.6	7.1	6.8	6.0	6.0	4.9	7.1	5.6	6.3
1985	9.2	8.0	6.8	7.0	6.5	8.1	6.7	5.9	5.0	5.7	6.1	8.0	6.9
1986	6.3	9.5	7.6	6.9	6.8	7.3	7.5	7.0	4.7	5.1	5.4	7.0	6.7
1987	8.1	10.4	7.8	7.7	6.3	7.0	8.1	4.9	4.7	6.2	4.9	6.6	6.9
1988	8.2	8.2	7.8	7.9	6.3	6.8	6.9	7.1	5.2	5.5	5.4	7.5	6.9
1989	8.0	8.7	7.0	7.3	6.9	7.7	6.9	6.3	6.6	4.2	8.2	8.5	7.2
1990	7.7	9.0	9.1	8.1	6.3	7.3	6.6	7.2	4.9	6.4	6.3	8.2	7.3
X	8.1	8.2	7.9	7.5	6.6	6.7	6.6	6.2	5.1	5.5	6.0	6.8	6.8

(Source: Malaysian Meteorological Service)

TABLE 2
AVERAGE NUMBER OF HOURS OF BRIGHT SUNSHINE PER DAY

	SUNSHINE — as hours per day and as a percentage of possible											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
WESTERN MALAYA												
Alor Star	8.0	6.9	8.5	7.2	8.5	7.1	8.2	6.8	6.8	5.6	5.3	5.2
Bayan Lepas	7.8	6.7	8.2	6.9	7.8	6.5	7.3	6.2	6.4	5.2	6.7	5.5
Ipoh	6.9	5.8	7.5	6.3	7.4	6.2	7.0	5.8	6.6	5.4	7.1	5.8
Sitiawan	6.7	5.7	7.4	6.2	7.2	6.1	7.2	6.0	6.7	5.5	7.1	5.8
Port Swettenham	5.9	5.0	6.5	5.5	7.0	6.0	6.7	5.6	6.3	5.3	6.8	5.7
Malacca Town	6.0	5.1	7.0	5.9	7.7	6.5	7.0	6.1	6.9	5.8	7.0	5.8
Singapore*	4.6	3.9	6.1	5.1	6.4	5.3	6.1	5.1	5.9	4.9	6.4	5.3
CENTRAL MALAYA												
Kuala Lipis	4.8	4.1	5.7	4.8	6.8	5.7	6.4	5.4	6.0	4.9	6.0	4.9
Temerloh	5.3	4.5	6.0	5.1	7.0	5.9	6.5	5.5	6.3	5.2	6.2	5.2
EASTERN MALAYA												
Koua Bharu	6.1	5.2	8.1	6.8	8.5	7.2	8.8	7.3	7.3	6.0	7.0	5.7
Kuala Trengganu	5.7	4.9	7.7	6.5	8.5	7.2	8.5	7.0	7.4	6.1	7.0	5.7
Kuantan	4.8	4.1	6.1	5.1	6.8	5.6	6.7	5.6	6.2	5.1	6.4	5.3
Merting	4.9	4.2	6.6	5.6	7.4	6.2	7.6	6.4	6.8	5.7	6.8	5.6
HILL STATIONS												
Cameron Highlands	4.3	3.7	5.0	4.2	5.4	4.5	5.0	4.2	4.4	3.6	5.4	4.5
Fraser's Hill	3.4	2.9	4.6	3.9	5.3	4.4	5.1	4.3	5.2	4.3	5.7	4.6

Kallang Airport

(Source: Dale, W.L., 1964)

CONCLUSION

This study on the climate of Penang has shown that while temperatures are generally uniform throughout the year, variations do occur in the other climatic elements such as sunshine, relative humidity, rainfall and wind. Spatial and temporal variations occur because of local differences in altitude, vegetation cover, land use, aspect and other factors. This study has shown that the temperature on the island is certainly on the increase, particularly towards the end of the 1980s. It can be expected that the slight increase in temperature will continue in the next decade as both physical development and rapid industrialisation are projected to increase many fold (*New Straits Times*, 16.7.89).

Based on the above developments, plans should be made to have more green areas by conserving existing forest as well as the planting of more trees in the urban and housing areas. For instance, the forest reserves in and around the Penang Hill area constitute the only green area of any commendable size that is still relatively untouched and should be preserved. The unique climatic characteristics of the Penang Hill Region are due to its higher altitude, its topography of hills which generates orographic rainfall, its dense vegetation of tropical rain forest which contributes to evapotranspiration and increases albedo, its thinner and cleaner air quality which reduces solar absorption and its slow rate of urban development which keeps it in its natural state. All these factors have either singularly or in combination produced its distinct climate of lower temperatures, higher humidities, higher rainfall, higher incidences of mist and fog, less sunshine, cleaner and fresher air and stronger wind profile.

Any development in the Penang Hill area must bear in mind the imminent changes it can bring about to the weather and climate of the area concerned. Furthermore, increases in rainfall⁵ coupled with the clearing of virgin forest for agriculture along the slopes of the Penang Hill area have been responsible for the recent spate of floods which hit many parts of the island (*New Straits Times*, 10 June 1991). The public should also be made more aware of the need and importance of conserving green areas through activities and campaigns such as the World Environment Day which was celebrated in the Forest Research Institute of Malaysia grounds in Kuala Lumpur recently (*The STAR*, 10.6.91).

This study has also shown that sunshine is abundant in Penang Island. In fact, Penang Island can be considered one of the sunniest parts of Malaysia, receiving on the average between 6 and 8 hours of bright sunshine per day or more than 2300 hours per year. The mean monthly relative humidity is found to be consistently high throughout the year in Penang, averaging between 80 and 90%. However, daily relative humidities are more variable, averaging

between saturation point (100%) in the early mornings and about 60% during mid-day when the sun is overhead. This study has also shown that the seasons in Penang are delineated by the variation in rainfall. Thus, the climatic year can be divided into 4 seasons : viz., the First Inter-monsoon Period (April); the South-west Monsoon Season (May-September); the Second Inter-monsoon Period (October); and the North-east Monsoon Season (November-March). The mean annual rainfall in Penang is high, with most areas receiving more than 2000mm of rain. Rain falls all year round and the average monthly rainfall is between 250 to 500mm. No month is completely dry although during the dry season months, the monthly rainfall is expected to dip below 100mm. The mean annual rainfall variability was found to vary inversely with the mean annual rainfall total. However, no such relationship was apparent for shorter periods of record.

Climatic change and variability has become such a common topic today that even the layman knows about it through the mass media. It is a widely known and accepted fact that our world is slowly but surely warming towards the next century. In fact, many places in the world have already experienced the initial impact of climatic changes (see Lamb, 1972 & 1974; Sham, 1973 & 1982; Whetton & Pittock, 1990; and Wang, 1990). Global climatic change such as the warming of the atmosphere, altered rainfall patterns, varying relative humidity levels, reduced sunshine, increasing levels of air pollution, increasing incidences and intensities of acid rain and other changes are now the norm rather than the exception.

Although the changes in the climatic elements mentioned above are not so serious yet in Penang Island, one should not take it for granted that the situation will not deteriorate. For a start, this study has shown that temperatures are on the increase although the level of increase is still small. In the coming decade more and more areas of natural vegetation will be turned into concrete, tar, cement or other impermeable artificial surfaces. Such surfaces will increase surface flow and with the projected increase of rainfall in the urban and industrial areas, flood occurrences will be more frequent and severe. Taking all the above possible changes into consideration one must indeed think very seriously about leaving the natural order of things as they are. All future developments in Penang Island, whether physical, commercial or industrial by nature, should consider the effects of each development on the weather and climate. The experiences of the so-called advanced economies (in terms of atmospheric pollution and resultant weather changes) in Europe, America and Japan are there for everyone to see. Developments which are "Green oriented" or "Environment friendly" should be given priority over those which are not.

NOTES

- 1 Ever since Penang Island was established as a trading post by Francis Light in 1786, it has grown by leaps and bounds both in terms of its port and trade as well as its physical development. Its capital city, Georgetown, has grown from a modest port for the British East India Company in the 18th Century into one of the major growth centres in Malaysia, serving the north-western states of Peninsular Malaysia (City Council of Georgetown, 1966, p.1).
- 2 Figures in brackets are averages.
- 3 American Meteorological Society (1970, p.227 and p. 373), has defined fog as an occurrence of minute suspended water droplets in the atmosphere near the earth's surface which reduces visibility to below 1 kilometer. Similarly, mist is said to have occurred if visibility is between 1 to 2 kilometer.
- 4 A rainday is defined as a 24 hour period, commencing at 0730 hours (0000 G.M.T.), in which 0.2mm of rain or more is recorded (Dale, W.L., 1960, p. 11).
- 5 The *STAR* (7 June 1991) reported that the rainfall recorded in just one day on the 2nd of June 1991 was 179mm. This was the highest rainfall recorded in Penang Island for the past 15 years.

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