4 Environment

Rapid economic development, population growth, rapid urbanisation, limited land area, and industrial expansion have resulted in different environmental challenges for Penang, such as air and water pollution, hill cutting, floods, and solid waste management. There is an urgent need for sustainable management of the environmental resources of the state.

4.1 Pollution

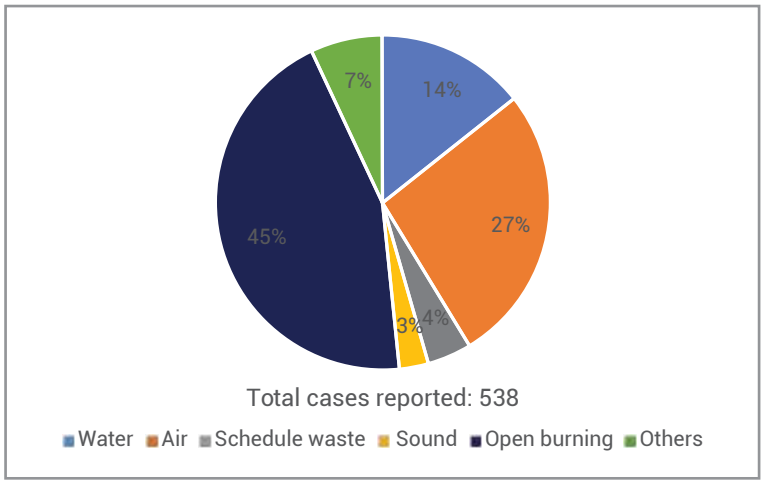
There are different types of pollution from different sources reported in Penang (Figure 4.1). Pollution cases reported in Penang decreased by about 3% from 555 cases in 2016 to 538 cases in 2017. Open burning, air pollution, and water pollution are the major pollutions in Penang, and can have a measurable effect on both the environment and human health.

4.1.1 Air pollution

The Air Pollution Index (API) system, which is a simple and generalised way to describe the air quality, includes five main air pollutants which could cause potential harm to human health if they reach unhealthy levels. The air pollutants included in Malaysia's API are ozone (O_3), carbon monoxide (CO), nitrogen dioxide (NO_2), sulphur dioxide (SO_2), and particulate matter with a diameter of less than 10 microns (PM_{10}). API levels of up to 50 is considered good, between 51 and 100 moderate, 101 and 200 unhealthy, 201 and 300 very unhealthy, and 300 and above hazardous.

The air quality of Penang is monitored at four stations: Perai, Seberang Jaya, USM, and Balik Pulau[29]. As presented in Table 4.1, the air quality pattern has improved since 2012, as the number of days with good API levels increased and the number of unhealthy days reduced significantly. In 2015 there was a different pattern, mostly due to transboundary pollution such as the haze. In 2016, the overall air quality in Penang was good with only two days of unhealthy air quality. The air quality improved further in 2017. On average, the air quality was good 77.6% of the time, moderate 20.2%, and 1.3% at an unhealthy level.

Figure 4.1 Types of pollution reported in Penang, 2017



Source: Department of Environment, Penang.

[29] Balik Pulau is the newest station as of 13 April 2017.

Table 4.1 Air quality status in Penang, 2012 - 2017

Station	Air quality level	Air quality status (day/year)					
		2012	2013	2014	2015	2016	2017
Perai	Good	305	340	150	151	242	312
	Moderate	60	23	213	202	124	48
	unhealthy	0	0	2	12	0	2
Seberang Jaya	Good	229	246	141	32	96	244
	Moderate	136	117	216	317	270	114
	Unhealthy	0	0	8	15	0	1
	Very unhealthy	0	0	0	1	0	0
USM	Good	319	272	107	78	173	49
	Moderate	46	91	249	272	191	51
	Unhealthy	0	0	9	14	2	0
	Very unhealthy	0	0	0	1	0	0
Balik Pulau	Good	-	-	-	-	-	247
	Moderate	-	-	-	-	-	9
	Unhealthy	-	-	-	-	-	1
	Very unhealthy	-	-	-	-	-	0

**The data for USM is from 1 January to 13 April 2017; Balik Pulau began collecting data from 13 April to 31 December 2017.*
Source: Department of Environment, Penang.

Some of the most excessive sources of air pollution include emission from vehicles, industrial emissions, and open burning – meaning that air pollution is mostly the result of human activities.

4.1.2 Water pollution

The water quality of rivers has always been an area of concern for various authorities, government agencies, and the public at large. The Water Quality Index (WQI) is a tool to assess the quality of river water and to indicate the corresponding suitability in terms of water uses according to the National Water Quality Standards (NWQS) for Malaysia. In Malaysia, the WQI is computed based on six main physico-chemical parameters, namely pH, biochemical oxygen demand (BOD), chemical oxygen demand (COD), ammoniacal nitrogen (NH_3N), suspended solids (SS), and dissolved oxygen (DO). WQI levels of between 81 and 100 is considered good, 60 and 80 moderate, and 0 and 59 unhealthy. WQI can also be used as a water pollution indicator by providing feedback on water quality to policymakers and environmentalists.

As presented in Table 4.2, over the past five years the overall river basin water quality in Penang has been moderately polluted. Industrial effluent and public apathy have the main causes of water pollution, mostly due to a lack of enforcement. The overall WQI increased slightly by 0.8% in 2016 compared to 2015. In 2016, the water quality of Sungai Jejawi and Sungai Pinang improved, while Sungai Juru, Sungai Keluang, Sungai Perai, Sungai Kerian, and Sungai Bayan Lepas were found to be slightly more polluted compared to 2015.

Table 4.2 River Basin WQI in Penang, 2012–16

Rivers	2012	2013	2014	2015	2016
Juru	63	63	62	63	61
Pinang	60	64	62	58	64
Jejawi	71	73	69	57	71
Keluang	83	81	79	84	76
Perai	56	58	67	63	59
Kerian	70	86	81	84	83
Bayan Lepas	70	73	69	70	69

Source: Department of Environment, Penang.

The Marine Water Quality Index (MWQI) is used to assess the status of marine water quality. Marine water quality monitoring plays a key role in assessing the degree of pollution from land- and sea-based sources that can threaten the marine resources. In Malaysia, the MWQI is calculated based on seven main parameters, namely DO, nitrate (NO_3), phosphate (PO_4), unionised ammonia (NH_3), faecal coliform, oil and grease (O&G), and total suspended solids (TSS). The resulting MWQI with a rating of between 0 to 100 would define the category of the marine water quality, ranging from "Excellent" to "Poor".

In 2016, a total of 14 coastal, 7 estuaries, and 8 island stations were monitored in Penang. The MWQI monitoring results for coastal areas classified 3 stations as Good, 10 stations as Moderate, and 1 station as Poor. Some areas such as Gurney Drive and Jelutong had seen significant improvements in MWQI in 2016 compared to 2015. In 2016, the overall marine water quality in Penang remained moderately polluted (Table 4.3). In terms of marine water quality status for estuaries in 2016, five stations were classified as Moderate and two stations as Poor. The most polluted estuaries were Kuala Sungai Jawi and Kuala Sungai Kerian (Table 4.4).

Table 4.3 Marine water quality status for coastal areas in Penang, 2015–16

Area	MWQI value		Category (2016)
	2015	2016	
Gertak Sanggul	53.11	53.91	Moderate
Kawasan Perindustrian Bayan Lepas III	53.88	50.05	Moderate
Pantai Bersih	52.63	76.02	Moderate
Pantai Miami	69.18	61.60	Moderate
Pantai Pasir Panjang	70.46	63.77	Moderate
Batu Feringgi (Casuarina)	66.07	79.68	Moderate
Luar Pantai Teluk Bahang	65.36	88.10	Good
Persiaran Gurney	48.03	83.66	Good
Rumah Pam Baru Perai	52.80	66.44	Moderate
Rumah Pam Lama Perai	55.26	61.75	Moderate
Selat PP Selatan (Jelutong)	49.68	60.39	Moderate
Tanjung Bungah	61.82	83.73	Good
Teluk Tempoyak	52.55	51.15	Moderate
Batu Maung	52.83	46.69	Poor

Note: The MWQI is classified into four categories, namely Excellent: 90–100, Good: 80 – <90, Moderate: 50 – <80, and Poor: 0 – <50.
Source: Department of Environment, Malaysia.

Table 4.4 Marine water quality status for estuary in Penang, 2015–16

Area	MWQI value		Category (2016)
	2015	2016	
Kuala Sungai Jawi	49.63	45.56	Poor
Kuala Sungai Juru	59.40	70.61	Moderate
Kuala Sungai Kerian	60.38	34.21	Poor
Kuala Sungai Pinang	47.28	58.39	Moderate
Kuala Sungai Perai	56.22	64.89	Moderate
Kuala Sungai Tengah	67.81	65.19	Moderate
Kuala Sungai Pinang (Balik Pulau)	46.17	60.11	Moderate

Note: The MWQI is classified into four categories, namely Excellent: 90–100, Good: 80 – <90, Moderate: 50 – <80, and Poor: 0 – <50.
Source: Department of Environment, Malaysia.

4.2 Waste management

Managing waste more efficiently is a core component of sustainability. Rapid economic development, industrialisation, and population growth have caused remarkable increases in the quantity and types of solid waste generated in Penang. However, substantial amounts of solid waste can be recycled and reused if separated.

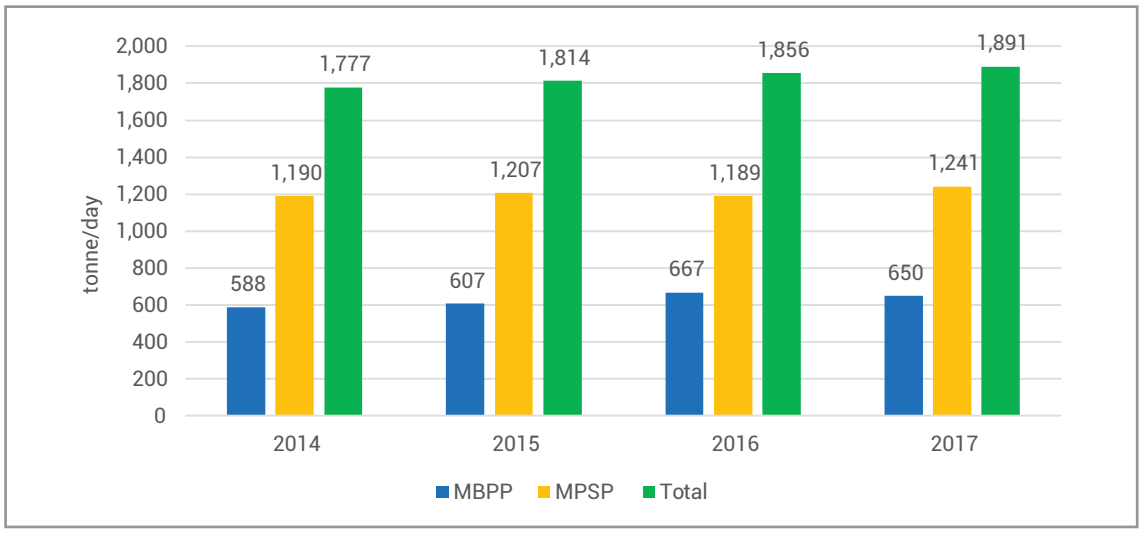
Municipal solid waste (MSW) consists of all types of solid waste generated by households and commercial establishments. Wastes that come from households and public areas, including residential buildings, litter bins, streets, marine areas, and parks, are known as domestic solid waste. Commercial solid waste comes from shops, restaurants, hotels, offices, and markets in private housing estates, while other waste which is produced by all industries, except construction, hazardous, or other special waste; would be classified as industrial solid waste (Kadir and Abidin, 2016).

In Penang, MSW is commonly disposed of through landfills. However, this method is not sustainable and introduces other environmental problems such as surface and groundwater pollution; soil contamination; air pollution through burning of wastes; spreading of diseases by different vectors like birds, insects, and rodents, odour in landfills; and uncontrolled release of methane (Samsudina and Don, 2013).

4.2.1 Solid waste disposal and recycling

In 2017, the total waste disposed at Penang's landfills in Penang was 1,891.2 metric tons per day (650 metric tons on Penang Island and 1,241.2 metric tons in Seberang Perai), an increase of 1.9% over 2016. The growth rate of total solid waste disposal remained steady over the last four years (Figure 4.2). With a population of about 1.7 million in 2017, the disposal rate of domestic waste was 0.8 kg per capita per day, compared to 0.7 kg per capita per day in 2016. The relatively stable domestic waste disposal rate in recent years reveals that the growth in domestic waste has generally been in line with population growth. In addition, rising domestic waste correlates with consumption activities.

Figure 4.2 Waste disposed at landfills in Penang, 2014–17



Source: Penang Island City Council (MBPP) and Seberang Perai Municipal Council (MPSP).

Based on a waste characterisation study conducted by USM in June 2014, the composition of MSW at the Pulau Burung landfill indicated that food waste accounts for about 40% of overall waste, followed by plastic-based waste (22.8%) and papers (13.4%) (USM, 2014). In Penang, hotels are the main generators of food waste (Khor, 2016). Food waste or decomposable waste has a high water content, resulting in high proportions of moisture in the waste. In addition, food waste disposed in municipal sanitary landfills would release greenhouse gasses, causing environmental and health problems due to high chemical oxygen demand (Kapoor et al., 2016).

Hence, strategies need to be applied to reduce, reuse, and recover waste. Food waste can be recycled into new products. For instance, some food waste can be used as low-cost feed stock for bioprocesses or to produce a high-value fertilizer. Penang has introduced different programmes and initiatives to reduce the amount of food waste sent to the landfill. In 2011, a food composting programme introduced Bio-Regen food waste machines to convert food waste into bio-liquid soil enhancers; Penang is the only state in Malaysia with this technology. In addition, the Penang State Food Waste Challenge Incentive Programme was introduced in 2017 to incentivise hotels and factories to install a proper food waste management system. The campaign "Makan Sampai Habis" was also launched to educate people about the importance of minimising food wastage.

Rapid economic development and population growth, changing consumption habits, insufficient infrastructure and expertise, and land scarcity make the management of MSW become one of the most critical environmental issues in Penang. Integrated waste management would help reduce harm to the environment. This includes waste reduction methods to achieve maximum economic and environmental return, such as recycling, reusing, and composting. This would help save space at the landfill while reducing the tipping fee. Since 1993, different recycling programmes were launched in Penang to reduce the volume of solid waste sent to the landfill, such as a recycling campaign and waste separation at the source. There are about 49 recycling agents registered with the Penang Island City Council (MBPP) and 42 unregistered recycling agents on the Penang Island. As presented in Table 4.5, the quantity of recycled waste in 2017 was 445,452.7 metric tons, an increase of 9% compared to 2016. In 2017, the overall recycling rate was about 39.2%, an increase of 1.6% from 37.6% in 2016. Records from the Seberang Perai Municipal Council (MPSP) show that 86% of recycled items, based on weight, comprise paper products, followed by construction waste (5.9%) (Figure 4.3). Paper products also make up the major recycled items on the island (62.5%), followed by plastic (26.3%)[30].

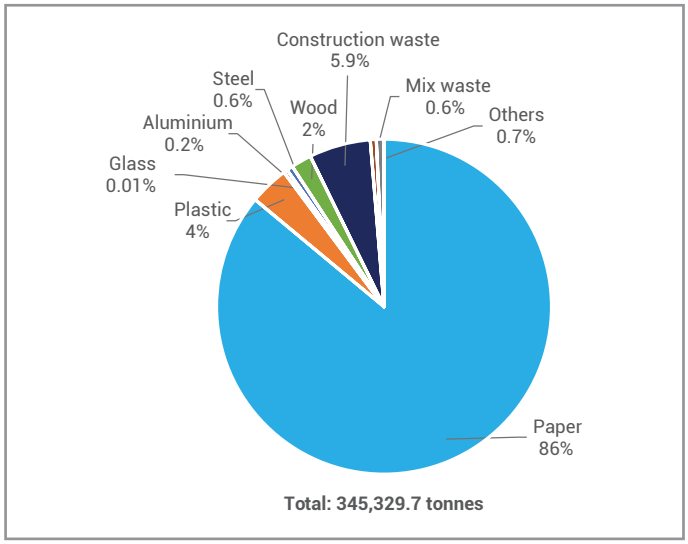
Table 4.5 Total waste generation in Penang, 2014–17

	Waste disposed at landfill (metric tons)			Recycling (metric tons)			Total waste generation (metric tons)	Recycling rate (%)
	MBPP	MPSP	Total	MBPP	MPSP	Total		
2014	214,609.0	434,175.0	648,784.0	80,233.4	233,791.0	314,024.4	962,808.4	32.62
2015	221,576.0	440,460.0	662,036.0	84,100.0	289,259.0	373,359.0	1,035,395.0	36.06
2016	243,563.4	434,008.5	677,571.9	86,464.0	322,189.5	408,653.5	1,086,225.4	37.62
2017	237,239.9	453,035.2	690,275.1	100,123.0	345,329.7	445,452.7	1,135,727.7	39.22

Source: Penang Island City Council (MBPP) and Seberang Perai Municipal Council (MPSP).

[30] Considerable amounts of waste were unaccounted for, and several specific items are not included in the statistics on the composition of solid waste on the island.

Figure 4.3 Composition by weight of recycled items for MPSP, 2017

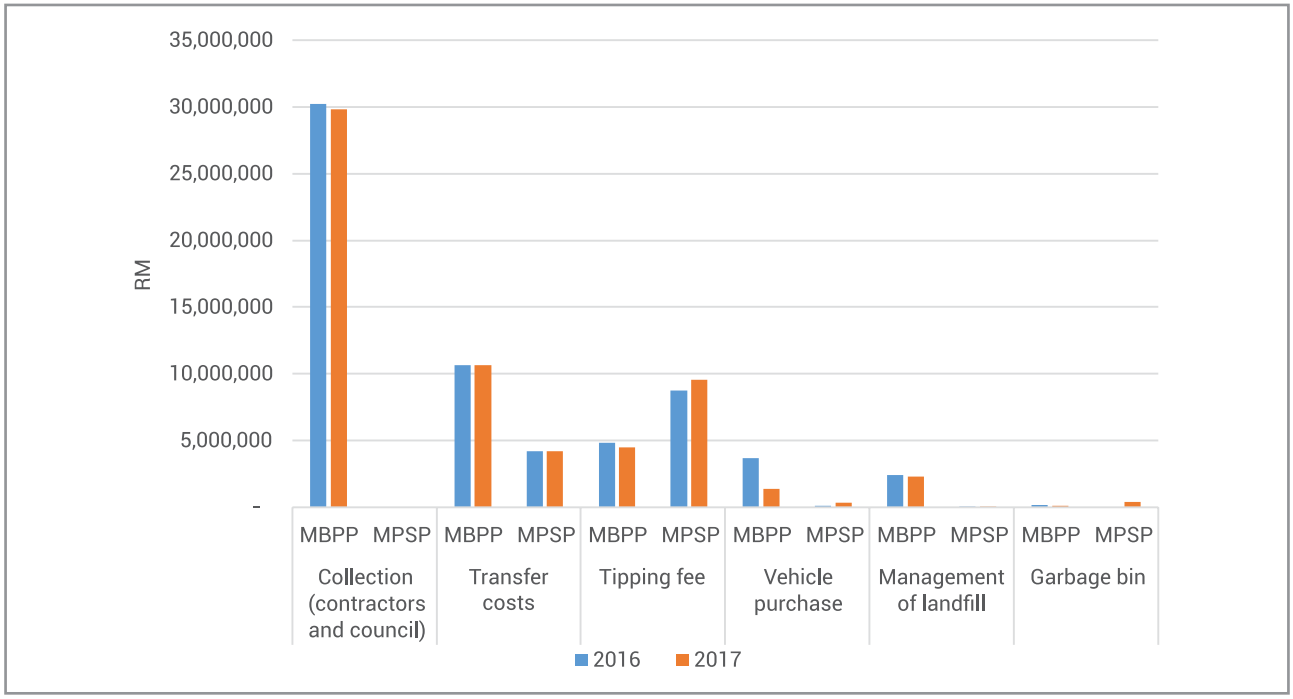


Source: Seberang Perai Municipal Council (MPSP).

4.2.2 Solid waste management costs

In 2017, solid waste management (SWM) cost recorded by MPSP and MBPP was about RM17.3 million and RM48.9 million respectively, covering collection, transport, tipping fee, management of landfill, garbage bins, land rental, and vehicle purchase costs. Nearly half of SWM costs is accounted for by the cost of collection (Figure 4.4). Separating waste into categories such as recyclable and non-recyclable wastes can increase the collection value and reduce the collection frequency and, therefore, the collection cost. The total SWM cost in Penang decreased by about 1.8% (RM66.2 million) in 2017 compared to 2016 (RM67.4 million), mainly due to a reduction in the purchase of vehicles.

Figure 4.4 Solid waste management (SWM) costs incurred by MBPP and MPSP, 2016–17



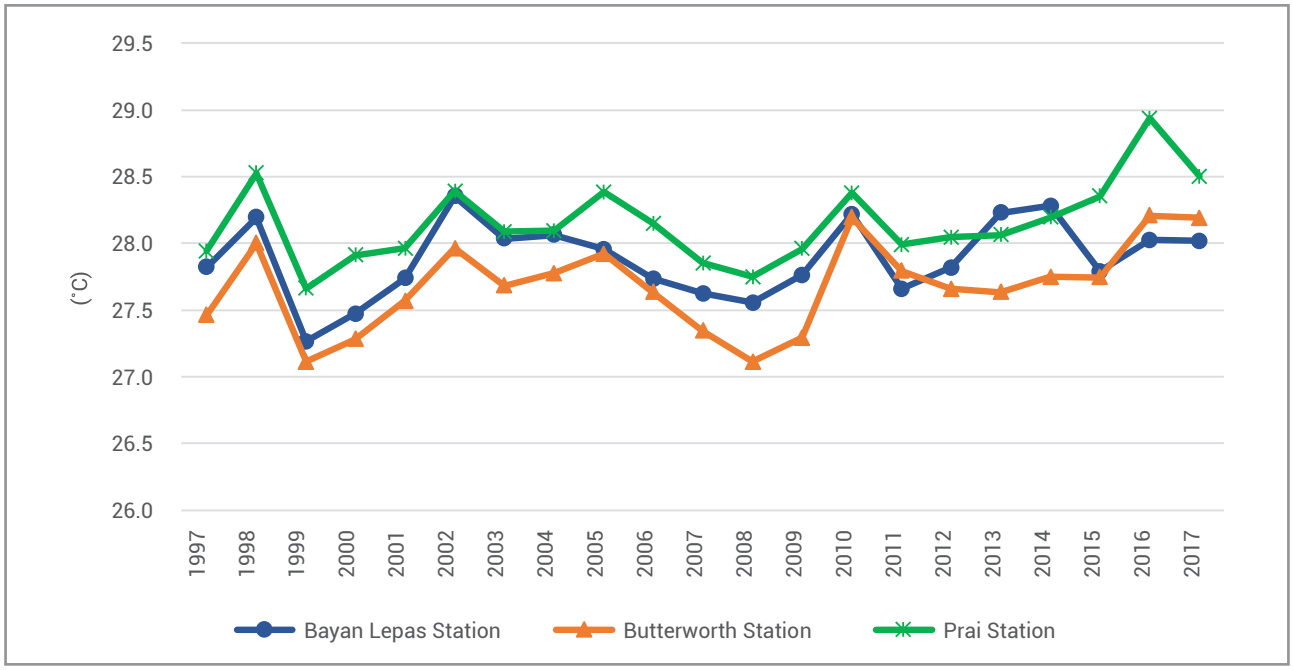
Note: The MPSP took over the services of private contractor waste collectors in 2013. The council waste collection cost data for MPSP is not available.
Source: Penang Island City Council (MBPP) and Seberang Perai Municipal Council (MPSP).

4.3 Climate change

The main cause of global warming and climate change is greenhouse gas pollution or carbon emissions, which are mainly derived from energy consumption, transportation systems, and waste decomposition. Penang is already facing many challenges caused or worsened by climate change, such as floods caused by extreme events and increased fish mortality as a result of higher water temperatures. Previous studies indicate that climate change will change rainfall patterns, increase temperatures, raise the sea level, increase soil salinity, change the level of soil moisture, and increase the severity and frequency of extreme weather events (Ercan et al., 2013; Kwan et al., 2013). These changes will pose risks to the economy, environment, and human basic needs such as food, water, health, and shelter (Vaghefi et al., 2016; Anang et al., 2017).

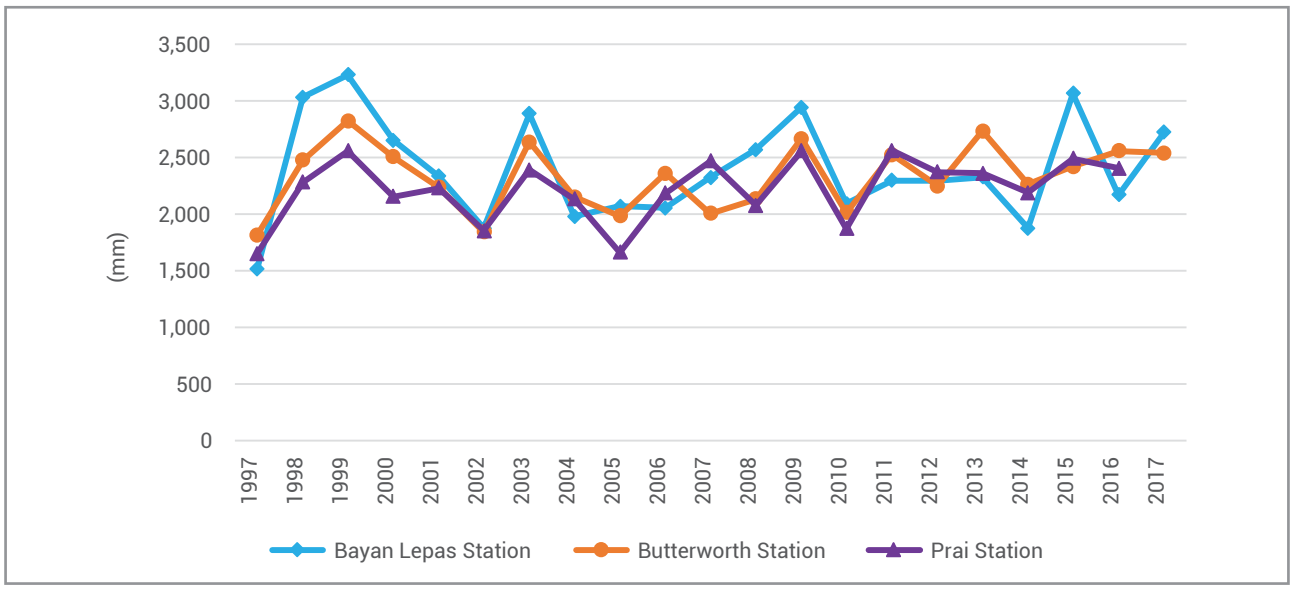
Rainfall and temperature are major parameters that determine the climatic conditions of a region. The historical data from three weather stations in Penang indicate that, over the past 20 years, the average temperature in Penang has increased by 0.09˚C per year, with the mainland experiencing higher average temperatures than the island (Figure 4.5). This is most likely due to the increase in greenhouse gas concentrations. Growing industrialisation and the increasing use of fossil fuels are affecting regional and global temperatures, which in turn influence overall rainfall patterns. Figure 4.6 shows the long-term variation in rainfall trends in Penang. On average, an annual rainfall of 2,633 mm was recorded for Penang in 2017, 253.2 mm more than 2016. In 2017, the driest weather was in February when an average of about 73 mm of rainfall occurred, while the wettest weather was recorded in September with an average rainfall of about 475 mm.

Figure 4.5 The average annual temperature in Penang, 1997–2017



Source: Malaysian Meteorological Department.

Figure 4.6 The average annual rainfall in Penang, 1997–2017



Note: Data for 2017 are not available for Prai Station.
Source: Malaysian Meteorological Department.

Extreme events, such as droughts and flooding, are increasingly linked to global warming and climate change. It is possible that, in a warmer climate, heavy rainfall will increase and be produced by fewer more extreme events. This may cause longer dry spells and a higher risk of flooding (Pohl et al., 2017). For instance, unpredictable weather patterns, coupled with unusually heavy rainfall in November 2017, resulted in one of the worst floods in Penang's history. The average rainfall from five rainfall stations in Penang on 4 and 5 November alone was 278 mm; however, the average rainfall in the month of November 2017 was about 450 mm. A total of 159 areas were affected by the floods, 68 of which had never been flooded before. It should be noted that most of the areas affected were in the Barat Daya and Timur Laut districts (Table 4.6). According to the Penang Social Welfare Department, 7,498 flood victims from 1,728 families were housed in 61 relief centres. Seberang Perai Utara was the worst-hit flood area with 4,549 victims as of 6 November 2017.

The November floods had a major impact on the agricultural and fisheries sectors. In the crops sub-sector, 2,626 farmers and 3,464.4 hectares of agricultural land were affected by the floods. Paddy fields were affected the most since they are usually located in low-lying areas. As reported by the Department of Agriculture of Penang, total economic losses caused by floods to the crop sub-sector were estimated to be about RM5.7 million. Furthermore, according to the Department of Fisheries, a total of 164 culturists and inland fishermen were affected by typhoon and floods. About 149 ponds, 135 tanks, and 4,415 cages were damaged. The fisheries sector suffered a total loss of about RM57.5 million.

Table 4.6 Flood hotspots and their corresponding rainfall amounts by district on 4–5 November 2017 in Penang

	Timur Laut	Barat Daya	Seberang Perai Utara	Seberang Perai Tengah	Seberang Perai Selatan
Number of affected areas	41	43	35	35	5
Rainfall (mm/15 hours)*	289	237	372	327	165

*Note: *The rainfall data is gathered from five rainfall stations including Sungai Pinang Station at Jalan P. Ramli, Taliar Besar Sungai Pinang Station, Pajak Song Station, Cherok Tok Kun Station, and Simpang Empat Station.*
Source: Department of Irrigation and Drainage, Penang.