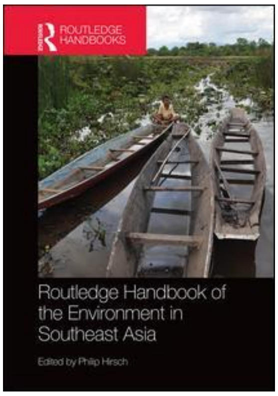

Routledge Handbook of the Environment in Southeast Asia

Philip Hirsch

Understanding the physical environment of Southeast Asia

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PART 2

Thematic approaches to environment

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UNDERSTANDING THE PHYSICAL ENVIRONMENT OF SOUTHEAST ASIA

A prerequisite for better environmental management

Avijit Gupta

Introduction

Southeast Asia is currently moving at a rapid pace of accelerated economic development. The perception of development as being in conflict with the environment and as a degrader of the environment has changed. Now economic development is expected to occur in tandem with improved environmental management, keeping the price of unavoidable environmental degradation as low as possible.

Marrying development with improved environmental management is a difficult job. Successful environmental management in Southeast Asia is complicated and multifaceted and thus requires, among other things, an in-depth understanding of the physical characteristics of the region in order to avoid (a) accelerated environmental degradation and (b) costly exposures to natural hazards. This chapter highlights the physical characteristics of Southeast Asia in order to demonstrate that understanding of the physical environment is a necessary prerequisite for proper environmental management.

The environment in Southeast Asia's sustainable development

Southeast Asia can be described as a corner of the Asian continent that ends in an assemblage of peninsulas, archipelagos and partly enclosed seas (Figure 2.1). Its physical environment is a creation of plate tectonics and people. The outer boundary of Southeast Asia is an arc formed by the islands of Indonesia and the Philippines, an area of active subduction that manifests itself in frequent earthquakes, occasional tsunamis and periodic volcanic eruptions. The inner mainland part of the region was shaped by tectonic movements associated with the collision of India with the Eurasian landmass, which has raised the Himalaya mountains over millions of years. Stress from this event created the alternate pattern of highlands and valleys of the Southeast Asian mainland. The uplift of the Himalayas also intensified the monsoonal system of winds.

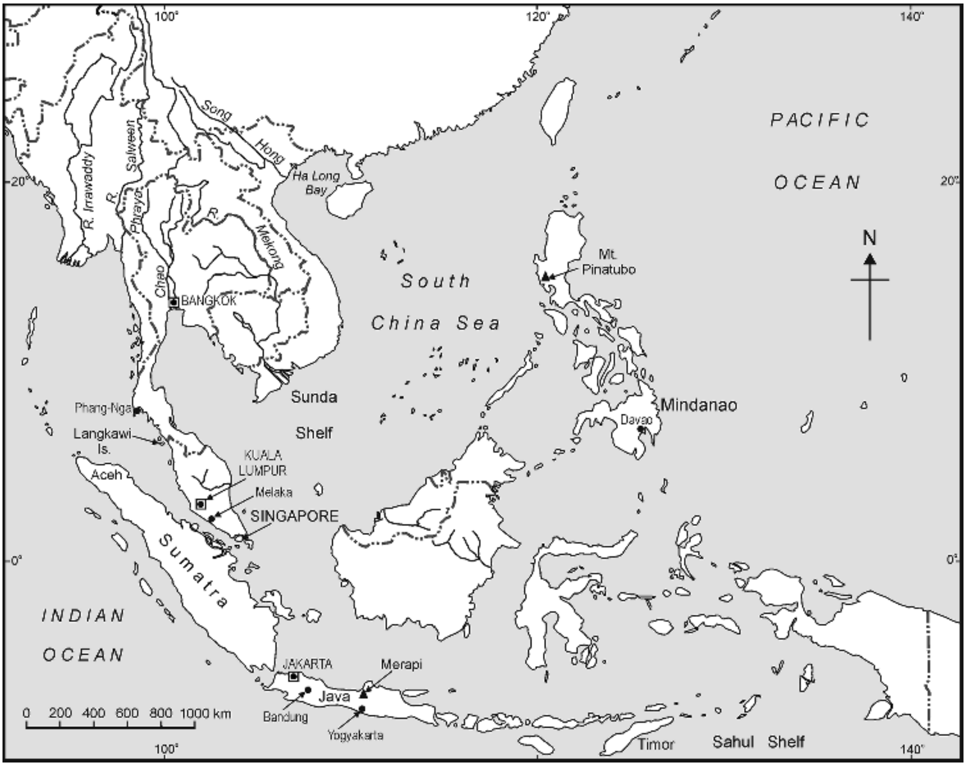

Figure 2.1 Location map showing places referred to in the text

Boundaries of the individual countries are plotted as broken lines, but their names have not been printed in order to make the map easier to read.

During the past two million years of geological history (known as the Pleistocene), the climate of the Earth changed repeatedly between cold (glacial) and warm (interglacial) conditions. This resulted in the lowering and raising of the sea level at intervals. As the offshore Sunda and Sahul Shelves of Southeast Asia and northern Australia are shallow, the edge of the sea moved hundreds of kilometres laterally with every cooling and warming phase, exposing and inundating large areas in sequence. This had an impact not only on geological features, but also on the distribution of flora and fauna in Southeast Asia.

Most of the region receives at least 2,000 millimetres of rain annually, usually in the form of intense showers. The potential for a high rate of land erosion, however, used to be neutralized by the natural vegetation of Southeast Asia. Corlett (2005) described Southeast Asia as a region of forest climate. Forests used to be naturally absent only from a limited part of the region, such as the highest mountains of Papua and Myanmar, where it is too cold for forest growth, or from areas undergoing periodic disturbances, such as slopes of active volcanoes or floodplains of large rivers. This protection has disappeared to a large extent, and currently forests occupy less than half the region, being replaced by various types of anthropogenic vegetation. The natural landscape of Southeast Asia has been strikingly changed by people over the past three centuries; first by the demands of the plantation and extraction economies of colonial times, and then, since the second half of the twentieth century, by widespread deforestation, agricultural expansion, the establishment of plantations with new crops, resettlement and urbanization. As a result, parts of Southeast Asia now carry a very high erosion rate and sediment yield with figures as high as 3,000 t km^{-2} yr^{-1} (Milliman and Meade, 1983; Milliman and Syvitski, 1992). The high figures come not only from the volcanic slopes of the outer islands, but also from parts of river basins inland.

The geomorphic features and processes, on land and offshore, should no longer be perceived as entirely natural for a large part of the region. The effect of economic development has been highly destructive in places, particularly on tropical forests, peat swamps, mangroves and coral reefs. The sustainability of water resources, coastal lowlands and lower deltas are especially under pressure. So are a number of cities in the region.

Sustainable development of Southeast Asia requires amelioration of past environmental degradation, management of future projects that may have an impact on the environment and recognition of the implications of climate change. This is achievable, but it needs communication between practitioners in various disciplines. Unfortunately, there seems to be limited interaction between earth scientists, environmental managers and government administrators in Southeast Asia. This chapter explores the perils of ignoring the constraints of the physical environment in decision-making. We identify the major constraints set by the physical environment of Southeast Asia in the next section, highlighting the vulnerabilities in the environment that should not be ignored. More detailed discussions of the physical environment of Southeast Asia are available in a number of publications (such as Gupta, 2005a and references therein).

The physical framework of Southeast Asia: A review

The geological environment

The geology of Southeast Asia dictates that the islands of Indonesia (with the main exception of Borneo) and the Philippines will be affected by earthquakes, volcanic eruptions and the associated ramifications. The intensity of impact depends on geological location. Human occupation on these islands, therefore, in the words of the historian Will Durant, is subject to geological consent. For example, the city of Yogyakarta in Java will always be in the shadow of a potential destructive eruption from the active volcano Merapi, which is located only a short distance away. The northward expansion of the suburbs of the city of Bandung has reached the slopes of Tangkuban Perahu, another volcano that is periodically active. The threat of pyroclastic flows, lahars and ash falls tends to hang over the intensely farmed fertile slopes of volcanoes. The 1991 eruption of Mount Pinatubo in the Philippines is a prime example (Newhall and Punongbayan, 1996). Along with the earthquakes, the outer coast of maritime Southeast Asia is exposed to the threat of tsunamis. The 26 December 2004 tsunami that destroyed part of the city of Banda Aceh and the north-west coast of Sumatra is a well-known example (Liew *et al.*, 2010). Evidence of past tsunamis has been found on the same coast, implying that this is a recurring natural hazard (Monecke *et al.*, 2008). All developments in these areas need to plan for such regional hazards.

Mainland Southeast Asia in general has a stable existence, but its geology is too complex for a brief discussion. It can, however, be stated that large faults, such as the Sagaing Fault in Myanmar, and variations in rock types control the landforms to a large extent. The past history of the region involved a great mountain-building event in the Tertiary, which is a period in the geological history from 65 to 2 million years before the present. A number of granitic bodies were emplaced in Southeast Asia during the Tertiary. A landscape of steep hills, narrow valleys and deeply weathered rocks is thus common in mainland Southeast Asia – for example, in central Peninsular Malaysia and northern Thailand. Other rock types that characterize the landscape are plateaus of volcanic rocks and sandstone uplands. In general, these form stable landscapes, but the regional presence of limestone may create environmental problems with subsidence – especially in urbanized areas, as discussed later in this chapter. The lowering of sea level during the last ice advance in the Pleistocene and its subsequent rise have resulted in a submerged landscape over limestone, with the peaks of former hills rising above the water to form spectacular cave-intruded islands attracting tourism and associated development. Good examples are the Ha Long Bay area of northern Vietnam, Phang-Nga province in southern Thailand and the Langkawi group of islands in north-western Malaysia. Neglect of hazards imposed by the local geology in development has led to disasters, especially in urban areas. For example, steep slopes in cities are commonly hazardous, being potential locations for landslides.

Landforms and drainage

Southeast Asia is connected to the rest of Asia via a mountainous region to the north-west. From here, several large elongated river valleys run north–south or north-west–south-east: the valleys of the Irrawaddy, Salween, Chao Phraya, Mekong and Sông Hồng (Red River). An east–west traverse across mainland Southeast Asia shows a succession of alluvium-filled valleys of large rivers, separated by mountain chains or plateaus that are drained by smaller steep streams flowing into major rivers. Further to the south and the east are coastal plains, rocky peninsulas and a series of deltas of various sizes. Beyond lies maritime Southeast Asia of the arcuate islands of Indonesia and the Philippines, with steep volcanic slopes, intermontane basins and flat coastal plains. In general, Southeast Asia is a land of short steep slopes marking the limits of flat valley floors of varying width. Its physiography has not only given rise to a distinctive set of landforms, but also influenced the migrations and settlements, economic practices and social and political patterns of the region.

Four large rivers (Irrawaddy, Salween, Mekong and Sông Hồng) originate close to each other on the eastern Tibetan Plateau north of the region, and they flow south-east like outstretched fingers through valleys that follow lines of geological weakness. Other major rivers (Chao Phraya, Pahang, Brantas, Rajang, Mahakam and so on) start and end within Southeast Asia. The rivers are entirely rain-fed except the Mekong, which gets part of its discharge from seasonal snowmelt on the Tibetan Plateau. Their discharges usually have a seasonal pattern, the peak season depending on whether the basin receives the south-western or the north-eastern monsoon. Some flow through wide flat floodplain-bound channels, but bedrock influences the morphology of others. The Mekong traverses the first 4,000 of its 4,800-kilometre course on rock or thin alluvium on rock; the Salween flows almost entirely through a series of huge gorges; and the Sông Hồng flows in a narrow valley in rock for all its length except the last 250 kilometres, where it crosses the coastal plain of northern Vietnam. Smaller rivers may be classified into three groups: streams that originate in uplands with or without floodplains; lowland rivers on gentle slopes that flow through fine-grained sediments of coastal plains and usually form estuaries; and rivers of volcanic areas with channels cut deep into volcanic deposits.

Deltas are wedges of sediment that extend from the shoreline where a river meets the sea. They are only about several thousand years old, their deposition starting only when the sea level became stable after the last cold period. The upper part of the sediment wedge is subaerial, but a delta also has a subaqueous part below the sea. The higher part of the delta is formed by rivers, but the lower section near the sea can be influenced by any of the riverine, marine or aeolian processes, giving rise to different landforms. The Mekong Delta, for example, has a riverine upper part with levees and backswamps, but the lower part is controlled by waves and tides, as indicated by low sand ridges separated by linear depressions. The deltas in Southeast Asia have been extensively settled only in the past several hundred years because of the technical challenges of inhabiting and cultivating these areas. They have a propensity to flood, the environment is brackish, innumerable narrow and wide channels dissect their surface, extensive areas need to be drained before farming and vector-driven diseases such as malaria used to be common. These deltas are now densely populated and extensively farmed for rice, but they are also exposed to natural hazards such as floods and tropical cyclones. The deltaic environment needs to be carefully monitored because of the high population, the propensity of the settlers to change the land use to profitable practices such as aquaculture from rice and the threat of a global-warming-driven rise in sea level. A number of urban settlements, such as Bangkok, grew up in deltaic locations. These are especially vulnerable. The deltas of Southeast Asia are vulnerable to natural hazards and the costs of such hazards are rising.

People have lived in the river valleys for a long time, and water management is a much-honed skill in Southeast Asia. The best example of the hydraulic civilizations of the past is the Khmer Empire, which lasted from the seventh to the sixteenth centuries, leaving behind magnificent structures and evidence of water engineering. The importance of river basins, even of small sizes, was demonstrated in the pre-colonial history of the Malay Peninsula, where individual kingdoms were located in separate basins and routes inland from the coastal plains were along river valleys. The rising population and the economic development of recent times, however, have led to considerable modification of the basin environment, which has had an impact on the river systems. Deltas, which may have presented a challenge to pre-technical societies, now support large populations due to successful management of inundation for rice cultivation over the past two or three centuries. Currently, the landscapes of delta-faces and coastal plains are being physically converted to more profitable aquaculture. The implications for the future are discussed below in the section on the effect of climate change.

The hydrological environment

Southeast Asia has a humid climate, with a very large part getting an annual rainfall of at least 2,000 millimetres. This figure may approach up to 8,000 millimetres where rain-bearing winds meet mountainsides. There are also areas that are relatively dry, with an annual rainfall of between 1,000 millimetres and 1,500 millimetres, as in eastern Java, central Myanmar and Thailand, and parts of the Indochina Peninsula. Extreme drought, however, is usually not a problem in Southeast Asia. The drier El Niño years are seen more as opportunities to burn secondary vegetation. The rainfall tends to be concentrated in a few months and falls with high intensity, causing slopes to fail, floods to occur and land to erode except where it is covered with vegetation. A high percentage of rainfall comes in short-duration disturbances that cause continuous and intense rain while they last. Thunderstorms form a number of these disturbances, often as a linear system of squalls along a strong zone of convergence. The seasonal sumatras of south-west Malaysia and Singapore, with a 200–300-kilometre-long band of clouds, are an oft-quoted example. The general pattern of a rainstorm is a short heavy downpour, when most of the rain falls within the first half hour or so, after which the storm may tail off slowly. The erosive power of tropical rain has been estimated to be much higher than that of rainfall in temperate areas (Hudson, 1971). Tropical cyclones, known in this region as typhoons, visit the eastern part of Southeast Asia (the Philippines and Vietnam) and penetrate into Lao PDR, Cambodia and Thailand. These storms are capable of causing great damage due to high winds, storm surges and heavy intense rainfall. For example, about 300 millimetres of rain was reported to have fallen over Davao in east Mindanao, the Philippines in several hours on 4 December 2012 from the super-typhoon Bopha. This is undoubtedly an extreme case, but dealing with heavy intense short-term rainfall is an integral part of environmental management in Southeast Asia.

In spite of this being a humid part of the world, environmental management in Southeast Asia also involves meeting high water demands for agriculture and cities. Attempts to meet such demands have resulted in significant environmental degradation.

The changing vegetation cover of Southeast Asia

According to Corlett (2005), permanent non-forest vegetation occurred before human impact only on coastal cliffs and beaches, seasonally flooded river plains, active volcanoes and areas with poor soils. Currently, however, forest vegetation has disappeared over more than half the region due to human impact. It has been replaced by various types of anthropogenic vegetation. The famous tropical lowland evergreen rainforests of Southeast Asia now occur in two separate blocks: a western block covering mainly Sumatra, the Malay Peninsula and Borneo, and an eastern one over Papua New Guinea. Between the blocks, small patches of the rainforests have survived in the wetter areas. The tropical seasonal forests that once grew over the drier areas have been much reduced due to the spread of agriculture in areas suitable for cultivation, and also due to fire. There is a general conversion into a more fire-tolerant deciduous type of vegetation and also into savanna and grassland. Fires have been in action since modern humans arrived in Southeast Asia (Hope, 2005).

Corlett (2005) has identified the rest of the forests as disturbed by human impact. Apart from agricultural fields, large areas of Southeast Asia are currently under plantation crops, especially oil palm, rubber and coconuts. The area under montane vegetation is limited, but Southeast Asia carries a wide spread of wetland vegetation where, but for humans, forests would have prevailed. These include mangroves, swamp forests and peat forests. Rice fields have replaced a large area of original wetland vegetation.

Environmental management in Southeast Asia needs to cope with this widespread and intensive alteration of the natural vegetation cover. Although humans have been in the area for at least 50,000 years, and probably more, around 80 per cent of Southeast Asia carried forest cover into the twentieth century. Vast tracts of the lowland forests have disappeared only since the 1970s. The main cause of deforestation is agricultural expansion. Other causes include commercial logging, which is often poorly managed and allows access to farmers via the logging roads. The health of the vegetation cover in Southeast Asia is important for proper environmental maintenance.

Development, degradation and environmental problems

The impact of a particular type of development project on the ambient environment is determined by a combination of physical factors. There are two excellent and much-used examples. The first is from a number of studies on logging's effect on the rainforest of Malaysia (Douglas *et al.*, 1992; Lai, 1993; Murtedza and Ti, 1993). The studies highlight active erosion and high sediment yield immediately after logging. These are manifested in a spike of sediment in local rivers, the concentration of which reduces with time. This happens because logging takes place on fairly steep slopes underlain by a deeply weathered and easily erodible soft layer on which intense rain falls directly onto the ground once the rainforest canopy is removed. A second example is from the city of Bangkok, prone to long periods of inundation late in the wet monsoon when floodwaters arrive overland and along river channels. Bangkok has no escape, as it is located in a very flat low deltaic wetland in which depressions have been created by the withdrawal of subsurface water to meet the demand of the city, leading to localized subsidence. Both these examples are repeated in many parts of Southeast Asia, with local variations associated with the ambient environment.

Table 2.1 Representative sediment measurements from different types of land use

Type of land use	*Sediment yield ($tkm^{-2}yr^{-1}$)*
Forest	10^0–10^1
Logging, early stage	10^3, recorded maximum 15,000
Shifting cultivation	10^3 from plot measurements, 10^2 for entire drainage basins
Agriculture	10^2–10^3, depending on conservation measures used
Urbanization	10^3
Large river basins (mixed land use)	10^2–10^4

Source: Gupta, 2005b. Compiled from a large number of case studies.

Economic and social developments frequently impact on the environment. The effect of different kinds of development on the environment of Southeast Asia can be measured by comparing sediment yields from different types of land use (Table 2.1). If we take forests as representative of the natural environment of Southeast Asia, it is evident from the rising values of sediment yield that economic changes create environmental degradation, at least partially. Environmental impacts are not limited locally to areas that are changing due to logging, new plantations or urban spread. Their signatures, as sediment plumes, may extend regionally far enough to reach coastal waters.

It is not feasible to discuss in detail the entire gamut of environmental changes that are taking place in Southeast Asia and their associated physical transformations. The ongoing economic and social activities that are prominent in this respect and require ameliorating management practices are deforestation; the expansion of agriculture, with particular reference to plantations; coastal changes, including intensive utilization of deltas; and urbanization. Some of these have been more extensively studied, but all economic changes that have the potential to create environmental problems should be studied and monitored. We need to develop our knowledge of the ambient environment for management. Even then, as the following examples show, such information, when available, is not adequately utilized. Examples discussed below only highlight several major environmental issues of Southeast Asia; many other problems exist.

Traditionally, many farmers of Southeast Asia take advantage of the dry conditions before the arrival of the monsoon to clear the land for cultivation. This is done by burning the secondary vegetation and leaving the ash on the ground before the rains appear. The vegetation that is burnt is usually not part of the primary rainforest, as such a forest is wet and too difficult to burn. For the past several decades, much of the burning has been carried out as large-scale business ventures. Plantation agriculture, mainly oil palm, is replacing the land cover of the coastal lowlands of eastern Sumatra and Borneo. Plantations of trees suitable for manufacturing pulp and paper also have started to replace the peat wetlands in these areas. Here, burning starts around August–September and is over by November, when the rains arrive from the northeast. There is a second spell of burning in central Sumatra around March. This is a large-scale enterprise and requires clearing and burning vegetation, draining wetlands and putting a suitable infrastructure in place. The local waterways and the coastal waters are polluted and a large volume of aerosols is released into the atmosphere. Such activities are obviously heightened in a dry year, and every El Niño year is a potential hazard. The rains are delayed then, and the smoke from the fire persists and turns into large-scale transboundary air pollution, with the aerosols drifting over the major cities of Kuala Lumpur and Singapore. The arrival of the transboundary air pollution depends on the location of the burn and the prevailing winds. In general, aerosols sourcing from the province of South Sumatra tend to pollute the atmosphere over

Singapore, and those from Riau and Jambi in central Sumatra drift over Malaysia, polluting the skies over Melaka, Kuala Lumpur and towns further north. Shifts in the wind pattern occasionally alter this generalized pattern (Figure 2.2).

One of the worst cases happened during the El Niño year of 1997, when the Pollutant Standards Index (PSI), which is a measure of air pollution, locally crossed an unprecedented level of 800μgm[3]. Readings above 200 were common in Singapore and the cities of Malaysia and western Indonesia. Readings above 200 units are considered very unhealthy, and anything above 300 is classed as hazardous. Streets were deserted, airports were temporarily closed and life almost came to a standstill in particularly affected areas. The fires were out of control, and only the arrival of monsoon rains put them out. Versions of this atmospheric degradation happen every dry year. On 21 June 2013, the three-hour PSI reading over Singapore rose to 401 (NEA, undated). A similar disastrous condition was again created by biomass burning in 2015, which was a dry El Niño year. Air pollution originating from Sumatra and Kalimantan reached an extremely high level close to the burning biomass in Indonesia and directly affected a number of transboundary cities for weeks.

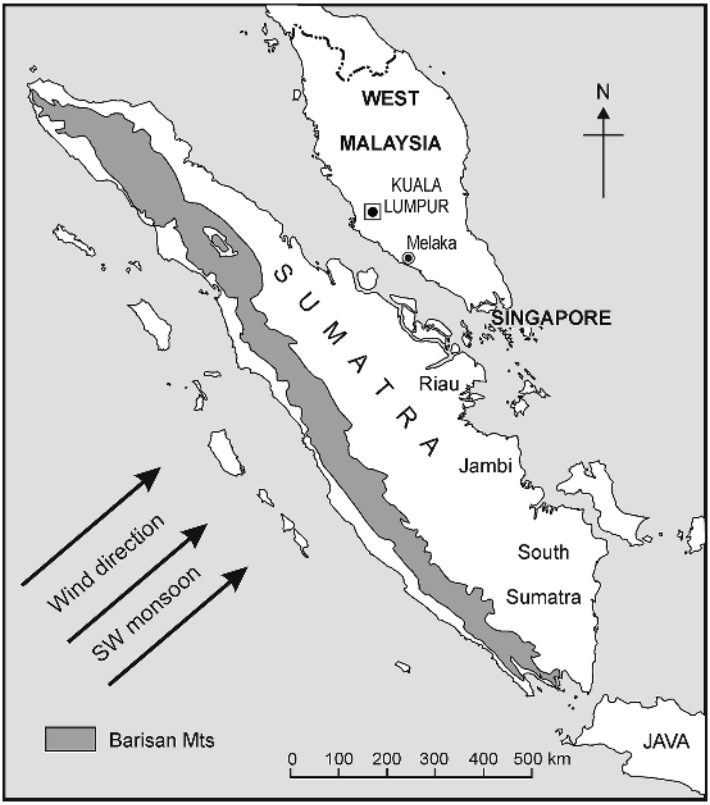

Figure 2.2 Background of transboundary air pollution from Sumatra to west Malaysia and Singapore during the south-western monsoon

In Sumatra, land east of the volcanic Barisan Mountains slopes down to a wide coastal plain with peat swamps. The burning of vegetation in this area brings air pollution over the Malay Peninsula. The affected location depends on the part of eastern Sumatra being burnt and the exact direction of the wind.

Such atmospheric disasters are supposed to be monitored by an office set up by the Association of Southeast Asian Nations (ASEAN). Fires in Southeast Asia are routinely monitored in Singapore using satellite imagery and their locations are reported. Scientific knowledge regarding the background of these fires and the related passage of transboundary air pollution has grown over the years. A new blaze is identified, located and reported immediately. The fires, however, are continuing. This is an example of where knowledge of the physical environment and detecting mechanisms are available but, for whatever reason, not properly utilized. Miettinen *et al.* (2013) commented that the regional and even global effects of fire in insular Southeast Asia are underestimated. Environmental degradation associated with such fires includes not only long-distance air pollution, but also the release of carbon into the atmosphere and destruction of peat swamps.

Miettinen *et al.* (2011) surveyed the current state of the forest cover for insular Southeast Asia between 2000 and 2010 by comparing two maps prepared with 250-metre spatial resolution satellite images. The maps show an annual decline of 1 per cent in the natural forest cover, which has been replaced mainly by plantations and secondary vegetation. Annual deforestation reached the highest figure (5 per cent) in two areas: the eastern lowlands of Sumatra and the peatlands of Sarawak. In general, the lowland forest declined at an average rate of 1.2 per cent per annum, but the peat swamp forests, across insular Southeast Asia, showed the highest average annual rate of loss, 2.2 per cent. Both Sumatra and Sarawak lost about half their peat swamp forests during this period. We know that such changes endanger the survival of a number of endemic species and that loss of peat swamps or burning of them elevates carbon emissions. Such practices should be abandoned forthwith, or at least monitored, but even the threat of regional or global environmental disasters is sometimes not enough for a policy change. A set of observations using higher resolution satellites (10–20 metres) by Miettinen and Liew (2010) identified even greater degradation. Less than 4 per cent of the peatland area is now covered by pristine peat swamp forests and 37 per cent is in various states of degradation. Ferns, shrubs and secondary growth cover much of this degraded landscape.

The starkest examples of deterioration in the quality of people's lives that results from ignoring the physical environment come from the towns and cities. Urbanization by itself makes cities flood-prone due to the increased imperviousness of the surface and the efficiency of storm sewers, which carry rainwater rapidly into the major drainage channels. The problem, however, is easier to solve if the floods are limited in size and the city is in possession of the necessary technical and economic resources. Singapore is a good example. The natural regional landscape of the southern Malay Peninsula is that of small, steep, forested hills in sharp contact with valley flats, which carry the swampy floodplain of a river in the middle. The forested slopes and the swampy floodplain attenuate the passage of storm water into the channel. As Singapore grew on a similar landscape, arterial roads spread along the valley flats and residential expansion climbed the hills on either side, converting most of the ground to impervious surfaces. This naturally increased the flood frequency, which in prosperous Singapore could be dealt with using appropriate knowledge and technical resources. Large lined channels were built before the development of new townships, and space was found for such drainage lines in the older parts of the city under decorative pedestrian malls and walkways. Flood alleviation in Singapore depends on the capacity of drains to keep up with urbanization, and the race continues. Other techniques for flood alleviation used in Singapore are flood diversions to neighbouring basins and porous pavements (Figure 2.3).

The technical and managerial capacities and financial resources required for flood alleviation are not always available for many cities. Furthermore, the location of major cities was often decided for reasons other than a stable environment. Bangkok, for example, was selected as a defensive site protected on the west by the Chao Phraya River. The old section of Bangkok is

Figure 2.3 Canalized natural channel in concrete between Bukit Timah and Dunearn Roads in Singapore

Houses cover the granitic slopes on either side of the channel. The land is practically impervious, with an efficient storm drainage system that brings water from rainstorms rapidly to the canalized channel. This area copes with a changed hydrology by enlarging the drainage channel, speeding up the flow, and diverting excess water to a neighbouring basin.

Source: Gupta, 2011, reprinted with permission.

located on the levee, but the expansion of the city had to be on low backswamps away from the river. Here, in the 1960s and 1970s, the rapidly increasing demand for water for both domestic consumption and industrial use was met by pumping water out of sand beds that function as aquifers within the Quaternary thick marine clay underneath the city. This led to a rapid drop of the groundwater table and subsidence of the ground surface, resulting in structural damage and the sinking and buckling of road systems. The cumulative effect of the subsidence created a bowl-shaped depression over part of eastern Bangkok. This is a shallow depression, but it is difficult to drain. Given the very low elevation of the city, located in the middle of the Chao Phraya Delta; the lowering of the ground-surface due to the withdrawal of subsurface water; and the inability to pump water out of the depressions into the Chao Phraya running high in the wet monsoon, floods in Bangkok are expected to last for lengthy periods. In parts of Bangkok, the flood of 2011 lasted for the months of October and November. The scale of the problem has accelerated research on the local Quaternary geology that forms the subsurface material in Bangkok. The surface of the city has been carefully surveyed and models have been designed to image the floods. The nature, causes and rates of Bangkok's subsidence are now well known, and the solution lies in stopping the subsidence and, if possible, raising the level of the land. We know the solution, but it is very difficult and costly to implement (ESCAP Secretariat, 1988; Nutalaya *et al.*, 1996).

Subsidence and associated hazards related to groundwater withdrawal happen also in metropolitan Jakarta, where about 70 per cent of the population depends on groundwater – most of which is extracted from tens of thousands of shallow wells and more than 3,000 deep wells. The rapid increase in groundwater extraction after 1970 has caused a significant drop in the groundwater level, allowing the intrusion of saline water that particularly affects the old city near the coast. Saline water intrusion in the deeper aquifer system has advanced 3–7 kilometres inland (Douglas, 2005a and references therein).

It is not only the major cities that are growing at a rapid rate, but also smaller towns and cities. The resulting urban spread is often over less desirable grounds, such as steep slopes, alluvial fills and subsurface limestone. This happens even when the subsurface geology and the surface drainage systems and weathered layers have been documented. It is unsurprising that less desirable locations, such as swampy grounds, are left to impoverished immigrants and squatters, but, more surprisingly, expensive suburbs built with wonderful vistas are also designed at perilous locations. Douglas (2005b) identified two stages of geomorphic impacts: during and post-construction. Unless precautions are taken, construction of large building projects in the wet monsoon results in slope failures and gully formation on the hills. These, in turn, produce large volumes of sediment that may block drainage channels, fill local rivers with sediment and in certain cases affect the coastal system of beaches, mangroves and corals. Satellite imagery of the south-west coast of Peninsular Malaysia has shown a series of sediment plumes that reach the Strait of Malacca and have been doing so for years.

Kuala Lumpur provides some striking examples of the other type of impact. The city has expanded rapidly since the 1970s, an expansion that resulted in construction over undesirable sites. Such sites included slopes of more than 25° to the north-west of the city in the Ampang and Ulu Klang areas, where the weathered granite is commonly 20 metres or more thick, and on weaker metasediments near the Ulu Gombak area. Both areas have recorded disastrous landslides resulting in loss of life and the destruction of roads, tunnels and condominiums. Smaller slope failures are also common. Such losses are not a result of ignorance, but rather come from not taking into consideration the nature of the ambient environment (Douglas, 2005b).

Climate change and the future

Planning for development and transferring such plans into reality are acts related to shaping future conditions. The future, however, is likely to differ significantly from the present due to climate change and associated sea-level rise. It we accept the robust environmental changes as listed in the recent publication of the Intergovernmental Panel on Climate Change (IPCC, 2013), we have some indication of the physical environment of the future in Southeast Asia. We may expect changes in annual rainfall, enhanced seasonality, stronger large storms such as tropical cyclones of categories 4 and 5, increased rainfall from large events, a rise in sea level with regional variations, and so on. The available resolution of these impacts of climate change is not always at the level of regional planning, but it is getting better. Basically, we should anticipate a more unstable landscape with slope failures and episodic floods. We should not be surprised if the rivers significantly change the form of their channels and their hydrologic and sedimentological behaviour (Gupta, 2010).

Milly *et al.* (2008) have suggested an increase in runoff for Southeast Asia. They have also stated that with climate change, stationarity is dead. This implies that natural systems cannot be taken to fluctuate within an unchanged envelope of variability in the future. This indicates that at least some of the structures on the rivers would be vulnerable to failure, and algorithms for managing specific water resources may need to be revised. The impact of climate change and the effect of anthropogenic structures such as the Lancang Cascade of seven dams on the Upper Mekong River together may drastically alter rivers, lakes and deltas in the Lower Mekong Basin (Gupta *et al.*, 2006).

It is likely that at least the majority of the deltas would go through changes in their physical environment. The major changes are expected to include avulsion (where a river abandons its old channel in favour of a new one) and change of river courses, sediment deposited in backswamps, a rise in sea level with inundation of the delta-face and altered pattern of coastal sedimentation, an increased impact of cyclonic storms, erosion of the delta-face and saline intrusion. The deltas also would be subjected to changes in river sediment arriving from upstream. In deltas, people settle on river levees and use the low areas (backswamps) for farming, and the network of streams provides navigation. Changes in deltaic landforms will seriously affect people's lifestyles. As several major cities of Southeast Asia are located on deltas, at best they would be subjected to floods as experienced by Bangkok in 2011. The progressive utilization of the deltaic environment as an economic resource is likely to increase the amount of loss from climate change. Careful water management over three hundred years has made intensive rice cultivation possible in the Mekong Delta. Currently, rice fields near the delta-face are being replaced by more profitable crops and aquaculture. It goes without saying that any kind of planning and resource management needs to take into account the changing physical environment associated with climate change.

Conclusion

Transforming environmental change to environmental degradation by ignoring the physical environment has happened throughout much of human history (Marsh, 1898). Southeast Asia, especially in recent times, has not been an exception, although there have been attempts to communicate between various disciplines and vocations. In the 1980s, Professor Prinya Nutalaya of the Asian Institute of Technology initiated with his colleagues a multidisciplinary conference, which was known as the Landplan seminar (Nutalaya *et al.*, 1982). It mostly involved scientists and academics and was convened a few times. The UN Economic and Social Commission for Asia and the Pacific (ESCAP), in its role as a promoter of urban and environmental geology, published volumes in a series known as the *Atlas of Urban Geology* from its headquarters in Bangkok, which covered a number of cities in South, Southeast and East Asia. In 1994, ESCAP convened an expert group meeting on the geological aspect of land-use planning in Bangkok, called the Forum on Urban Geology in Asia and the Pacific (FUGAP). Three main objectives were identified: to assess the importance of geology in land-use mapping, urban planning and related exercises; to identify problems of communication between earth scientists and planning communities; and to search for remedial action. Thematic maps seem to have been suggested as the expected vehicle for information diffusion. FUGAP was designed as an attempt to bring together earth scientists, ecologists, urban planners and city managers in order to communicate with each other. There were several meetings, but the sessions were terminated exactly when people from different training and responsibilities began to communicate.

There are overarching bodies to supervise environmental management in Southeast Asia, such as the ASEAN Ministerial Meetings on the Environment. The link between sustainable development and environmental issues was recognized at the 1992 ASEAN Summit Meeting in Singapore. There is now a strategic plan for action, and a summary account, the ASEAN *State of the Environment Report,* is published periodically. The responsibility for protecting the environment is also shared by multinational bodies such as the Mekong River Commission and organizations of national governments. A very impressive amount of both detailed and basic research, examples of which have been used in this chapter, has been carried out by academics in Southeast Asia. One hope is that the managers of the environment of Southeast Asia are aware of such work and are willing to apply it to environmental management.

The lack of application of prior knowledge regarding the environment in development allows both episodic disasters and steady environmental degradation of various types to take place. There is enough information, expertise and resources in Southeast Asia to prevent this.

For example, remarkable satellite coverage of Southeast Asia is now available – a resource that is probably not used as much as it should be. There is always the need for a common platform where people from different disciplines and occupations may meet.

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