EMPLOYING NATURE TO COMBAT FLOODS: SOME EXPERIENCES FROM MALAYSIA

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Abstract

Natural undisturbed systems possess inherent mechanisms and their own ways and means of maintaining system stability. Forests and floodplains, also commonly known as wetlands, are nature's way of controlling floods. Forests and wetland forests control floods by controlling rainfall at source, a concept only recently adopted by flood control agencies. Layered and densely forested areas intercept a significant amount of rainfall and regulate the flow of rain down branches, trunks and roots before reaching the river. Interception, the amount of rainfall caught in the forest crown, is about 10-15% of total rainfall. Least interception occurs when forests are thinned and exposed due to clearing, while maximum interception (often reaching 100 %) occurs with dense virgin forests made up of evergreen trees. During heavy rainstorms, rainwater commences to drift as mists or droplets to earth as "throughfall" which averages about 75 - 85% of rain in humid climates like Malaysia. Runoff from upstream also has to penetrate the forest before reaching the river, hence increasing lead time. Wetland forests along rivers, estuaries and coastal areas also give runoff from precipitation (which eventually gets into rivers) a place to spread out, serving as natural retention basins. Wetland forests act like sponges soaking and absorbing a lot of water down into the ground and then releasing it slowly over time. As much as 2.3 million litres of water is absorbed per hectare, depending on the nature of the soil. Forests hold the water and release it slowly. When forests are cleared or destroyed, all the rainwater gets into rivers at a relatively rapid time, resulting in flash floods. The concentration of water into the main river channel over a much shorter period of time dramatically increases flooding. It is vital for engineers and all scientists to work with natural systems rather than against them. In this respect, the JPS Malaysia has initiated the mandatory Manual for Environmentally Friendly Drainage for all development projects, indicating an all-important change of mindset from conventional engineering approach to a more comprehensive multi-disciplinary approach that taps on the expertise of all disciplines.

INTRODUCTION

Forests ranging from highland montane forests to lowland rainforests and coastal cum riverine floodplains, commonly known as wetlands, are nature's way of controlling floods. Forests and wetlands such as swamp forests control floods by intercepting rainfall at the canopy and regulating the flow of rain down branches, trunks and roots before reaching the river. Interception, the amount of rainfall caught in the forest crown, is about 10-15% of total rainfall. Least interception occurs when forests are thinned and exposed due to clearing, while maximum interception (often reaching 100 %) occurs with dense virgin forests made up of evergreen trees (Chan, 2001). During heavy rainstorms, rainwater commences to drift as mists or droplets to earth as "throughfall" which averages about 75 - 85% of rain in humid climates like Malaysia (Chan, 1991). Runoff from upstream also has to penetrate wetlands before reaching the river, hence increasing lead time. Wetlands along rivers, estuaries and coastal areas also give runoff from precipitation (which eventually gets into rivers) a place to spread out, serving as natural retention basins. Wetlands act like sponges soaking and absorbing a lot of water down into the ground and then releasing it slowly over time,. Research has shown that as much as 2.3 million litres of water is absorbed per hectare, depending on the nature of the soil (Arland-Fye, 2001). Wetlands hold the water and release it slowly. When wetlands are cleared or destroyed, all the rainwater gets into rivers at a relatively rapid time, resulting in flash floods. The concentration of water into the main river channel over a much shorter period of time dramatically increases flooding.

RAPID DEVELOPMENT AND ENVIRONMENTAL DEGRADATION

Rapid development in Malaysia and many developing countries, some over centuries and some over many decades, has systematically destroyed and decimated forests and wetlands (including the lakes which they surround). This has manifested itself in an ugly way as floods took a heavy toll on the environment and human populations, who have settled on floodplains, which were once rich and diverse wetlands (Chan, 2000; Cai et al., 2001). Scientists to the replacement of wetlands with agriculture, industrial, urban, have linked some of the more severe flood in recent decades and other forms of human land use that are incompatible with the environment. Malaysia's own growth in the last decade is nothing short of phenomenal. For example, the rate of economic, industrial, infrastructural and urban developments during the last two decades has been rapid (Chan, 1996). From the late 1980s to 1997, the Malaysian economy has experienced an average GDP growth rate of about 8 per cent per annum. In 1989, 1990 and 1995, the corresponding GDP growth rates were 8.8 per cent, 10.1 per cent and 9.3 per cent respectively. Guided by the Malaysian Government's so-called Vision 2020 Strategic Plan, the country is poised to become a fully developed country by the year 2020 (Government of Malaysia (1996). Current trends indicate that Malaysia will, at least in the short term (over the next decade or so) enjoy the same rate of growth. However, against this background of rapid economic development and the active pursuit of industrialisation, the country's finite resources (especially its forest) and fragile ecosystems are being threatened. This has led to the frequent occurrence of environmental disasters, most notably landslides and building collapses associated with it (Chan, 1995; Chan et al., 2000).

Thus, in its frantic quest for modernisation and industrialisation, Malaysia is falling into the same trap as many western developed countries had done so in the past, i.e. over-zealous rapid development without stringent environmental protection measures. The desire for rapid economic development in order to catch up with the developed world is often over-emphasized and this can lead to an unbalanced development strategy which often sacrifices environmental principles purely for the sake of economic gains. Noble principles such as reducing the greenhouse effect, curbing ozone depletion, controlling environmental degradation, forest regeneration and sustainable development are often talked about and championed by many developing countries in their negotiations with the developed world. In theory, Malaysia's commitment towards environmental protection is clear, as there are policies, laws, regulations and EIA requirements in developments that can have an effect on the environment. Unfortunately, in practice, however, environmental considerations are often overlooked by economic needs. Hence, despite its noble aspirations and its commitment towards environmental preservation (and its international stance against environmental degradation), many aspects of Malaysia's environment on the local front are still being exploited and degraded by irresponsible parties (Sahabat Alam Malaysia, 2001). In recent years, environmental degradation was the cause of many fatal incidents of landslides such as the collapse of the Highland Towers luxury condominium (caused by landslide) in 1993 which claimed 49 lives; the Genting Highland landslide tragedy in July 1995 which killed 20 persons and injured 23 others; the Pos Dipang landslide which claimed 40 lives (mostly aborigines living on steep hill slopes); the 60 landslides in Penang in September 1995; the north-south highway landslide near Gua Tempurung in January 1996 which claimed one life and caused massive traffic jams for weeks; the Pos Dipang landslide which killed 39 aboriginal people (with another 5 still missing) in August 1996; and most recently in October 1996, the spate of landslides in Cameron Highlands (a highland resort) in which one person was buried alive and hundreds were evacuated (Chan, 1998a). In tandem with accelerated soil erosion and landslides are other environmental issues such as sedimentation, water pollution and downstream flooding (Table 1). These are but a few of the salient examples of classic environmental degradation resulting from human miscalculation and mismanagement of the forces of nature. Although many, notably politicians, have claimed that the majority of such "hazards" and "disasters" are the result of natural causes or even "Acts of God", their frequent occurrence coupled with increasing awareness and improved education amongst the public have made such claims less and less tenable. Despite the fact that such incidents have their origins in the forces of nature, the Malaysian public now demands accountability and many are convinced that such hazards are likely the cause of "Human Mismanagement" rather than "Acts of God" or “Causes of Nature”.

In relation to highland forests, massive deforestation for agriculture, tourism, highways and infrastructure in many of the country’s highlands, notably Cameron Highlands, Genting Highlands, Fraser’s Hill, Penang Hill and Lojing Highlands have resulted in environmental degradation and environmental hazards. In fact, flood disasters in recent years have been attributed to deforestation of highlands. Hence, it is the opinion of many environmental experts that flood preventive measures should not only focus on flood mitigation efforts in the affected area (i.e. downstream) but must target conservation of highland regions, as what happens upstream will be felt downstream (The Star, January 5, 2002). Studies have shown that proper land use management was important to prevent extreme run-offs and soil erosion during heavy rainfalls that would result in sedimentation of waterways and flooding of downstream stretches.

Table 1: Official flood loss estimates for major flood events in Malaysia

Flood Event (Year)	(Place)	Damage (RM million at 1996 prices)	Deaths	Persons Evacuated
1886	Kelantan & Besut Rivers ("Storm Forest Flood")	Destroyed several hundred square kilometers of forests	NA	NA
1926	Most of Peninsular Malaysia	Damage to natural environment	NA	NA
1931	Perak-Kelantan Border Region	NA	NA	NA
1947	Kerian, North Perak	NA	NA	NA
1954	Johor, Terengganu	Hundreds of acres of padi	2	Thousands
1957	Klang Valley, Selangor	NA	NA	4,000
1965/66	Besut, Kelantan-Terengganu	> 30,000 acres of padi destroyed	NA	Thousands
1966	Perlis	NA	1	NA
1967	Kelantan River Basin	221.8	38	320,000
1967	Perak River Basin	171.9	0	280,000
1967	Terengganu River Basin	44.7	17	78,000
1971 (January)	Kuala Lumpur	94.2	24	NA
1971 (December)	Pahang River Basin	103.6	24	153,000
1979	Peninsular Malaysia	NA	7	23,898
1981	Kelantan State	NA	8	2,740
1982	Peninsular Malaysia	NA	8	9,893
1983	Penang State	0.6	0	NA
1983	Other Peninsular Malaysia	NA	14	60,807
1984	Batu Pahat River Basin	22.6	0	8,400
1984	Kelantan and Terengganu States	NA	0	Thousands
Dec.1987	Georgetown, Penang	0	0	Hundreds
1986	Peninsular Malaysia	NA	0	40,698
1988	Kelantan River Basin	36.7	19	36,800
1988	Sabah State	NA	1	NA
1988	Other Peninsular Malaysia	NA	37	100,755
1989	Johor State	NA	1	Thousands
1989	Kuala Lumpur/Petaling Jaya	NA	0	220
1991	Penang State	0.1	0	Hundreds
1991	Other Peninsular Malaysia	NA	11	NA
1992	Peninsular Malaysia	NA	12	NA
1993	Peninsular Malaysia	NA*	22	17,000
1993	Sabah State	NA	5	5,000
1995	Shah Alam/Kelang Valley	222.6	1	8,970
1995	Penang State	5.4	0	0
1995	Klang, Selangor	NA	3	0
1995	Other Peninsular Malaysia	NA	4	14,900
1996	Sabah (June)	NA	1	9,000
29.8.1996	Pos Dipang, Perak	> 100 houses destroyed	44	Hundreds
1996	Sabah (December)	300.0**	241***	23,000
30.12.98	Kuala Lumpur	NA	5	0
5-9.1.99	Penampang, Sabah	NA	6	4,481
11.1.99	Sandakan, Sabah	NA	3	0
23.11.2000	Kg La	NA	6	0
December 2001	Kelantan, Pahang, Terengganu	Crop loss & property damage amounting to tens of millions RM; RM2 million textbooks destroyed;	6	> 10,000
27.12.2001	Gunung Pulai, Johor	Mudslide swept away 4 houses	5	4 families
31.12.2001	Benut, Marang, Terengganu	Crop loss & property damage	4 children	Thousands

NA Not Available

* In the state of Kelantan, a total of 200 schools were closed during the 1993 flood resulting in 113,000 students missing school for a total of between 6 to 11 days.

** The Sabah Government estimated that damage to roads, bridges, schools, power lines, government offices and other public utilities would need at least RM130 million to restore (The Star, 1st January 1997). Another RM170 million was estimated for destruction of properties (more than 4,553 houses were destroyed during this event), and crops and livestock loss.

*** Another 108 people are still missing more than a month after the event (The Star, 27 January 1997).

(Source: DID Malaysia, Malaysian National Security Council and major newspapers)

(i) Interception: Natural undisturbed systems possess inherent mechanisms and their own ways and means of maintaining system stability. Forests and floodplains, also commonly known as wetlands, are nature's way of controlling floods. Forests and wetland forests control floods by controlling rainfall at source, a concept only recently adopted by flood control agencies. Layered and densely forested areas intercept a significant amount of rainfall and regulate the flow of rain down branches, trunks and roots before reaching the river. Interception, the amount of rainfall caught in the forest crown, is about 10-15% of total rainfall. Least interception occurs when forests are thinned and exposed due to clearing, while maximum interception (often reaching 100 %) occurs with dense virgin forests made up of evergreen trees. During heavy rainstorms, rainwater commences to drift as mists or droplets to earth as "throughfall" which averages about 75 - 85% of rain in humid climates like Malaysia. In rainfall studies conducted in the Pantai Acheh Forest Reserve in Penang from 1997 to 2000, it was found that due to interception was between 20 – 30 % of total rainfall (Chan and Wan Ruslan Ismail, 2000). Lai and Osman Salleh (1989) have shown that interception rates vary with the canopy area, canopy density and canopy thickness (Table 2). In terms of tree species, it was found that the Jackfruit and Takiantong trees gave the greatest protection from rain and hence produced the highest interception (Table 3).

Table 2: Tree Characteristics and Variation in Interception Rates (Source: Lai and Osman Salleh, 1989; Wan Ruslan Ismail, 1994).

Plot	Height Range(m)	Average Canopy Diameter (m)	Canopy Density	Canopy Thickness	% Interception	Direct Fall	Trunk Flow
A1	15-20	3.35-5.18	Sparse - moderate	2.5-8.76	1.9-100	0.0-84.0	0.0-14.1
A2	19.88-24.76	2.30-3.70	Sparse-moderate	6.3-9.75	0.1-92.4	7.9-83.6	0.3-21.5
B1	15.84-19.68	3.80-5.40	Sparse	4.65-6.3	1.5-57.3	41.1-97.6	0.9-10.8
B2	19.37-20.16	3.50-4.90	Moderate	4.2-8.52	1.4-68.9	28.1-97.6	1.1-19.4

Table 3: Tree Species and Variation in Interception Rates in Tropical Areas (Source: Witthawatchutikul, 1985:63)

Tree Species	Percentage of Rainfall		
	Interception	Direct Fall	Trunk Flow
Rambutan	21.46	77.38	1.16
Durian	18.16	81.13	0.71
Mango	16.32	82.53	1.15
Rubber	17.05	82.51	0.44
Jackfruit	33.23	65.41	1.36
Takiantong	36.35	60.71	2.95

AVERAGE	23.75	74.95	1.30

Research has also shown that interception is highest between for Acacia mangium forests at between 35 to 39 % of total rainfall (Lai and Osman Salleh, 1989). This is followed by Grewia tomentosa forests at about 34.5 % (Anuar Embong, 1992), Secondary rainforests at 26.9 %, Dipterocarp forests at 26.6 % (Baharudin Kasran, 1989), and pine forests at 18.49 % (Bo et al., 1989). In general, tropical forests have interception rates between 10 to 35 %. When forests are replaced by rubber plantations, interception rates decrease to about 15 %. For urban areas, there is hardly any interception except by roof tops (which quickens the collection and transport of rain drops into rivers rather than delay them) and the occasional city park.

When comparing the same rainfall events in open areas and forested areas, it was found that interception in rainforests depends on rainfall intensity. For events less than 5 mm, interception rates are high, i.e. between 55 – 100 % but for heavy rainfall events > 30 mm, interception is typically lower but still significant at between 20 – 30 %. Hence, if a river channel's capacity is capable of draining up to 100 mm of rain per hour, any rainfall event above this figure would result in flooding (in the case of an impervious urban area). However, under rainforest cover with interception rates of 20 – 30 %, it would take an event of at least 125 mm per hour to flood the area. However, so far only interception is considered. The forest is also capable of absorbing part of the rain, slowing down the rate in which rain drops reach the river (via trunk flow, obstruction by roots and leaf litter, and increased infiltration). Hence, typically, it would take a much higher rainfall event to flood a forested area. During the dry season, flooding almost never occurs as almost the entire amount of rainwater is retained by the forest and its soil.

(ii) Surface Runoff and Water Yield: Runoff from upstream also has to penetrate the forest before reaching the river, hence increasing lead time. Wetland forests along rivers, estuaries and coastal areas also give runoff from precipitation (which eventually gets into rivers) a place to spread out, serving as natural retention basins. Wetland forests act like sponges soaking and absorbing a lot of water down into the ground and then releasing it slowly over time. Studies in the United States have shown that as much as 2.3 million litres of water is absorbed per hectare, depending on the nature of the soil (Arland-Fye, 2001). Forests hold the water and release it slowly. When forests are cleared or destroyed, all the rainwater gets into rivers at a relatively rapid time, resulting in flash floods. The concentration of water into the main river channel over a much shorter period of time dramatically increases flooding. It is vital for engineers and all scientists to work with natural systems rather than against them. In this respect, the JPS Malaysia has initiated the mandatory Manual for Environmentally Friendly Drainage for all development projects, indicating an all-important change of mindset from conventional engineering approach to a more comprehensive multi-disciplinary approach that taps on the expertise of all disciplines. Studies by the JPS Malaysia have shown that uncontrolled development, indiscriminate land clearing and other human activities can increase the severity of floods, by increasing both the peak discharge and the time of concentration. Studies in the Sg. Tekam basin proved that with clearing of land from jungle to cultivated crops, the initial impact was a 157 % increase in water yield, a four fold increase in sedimentation rates and a 185 % increase in flood peak flow while time to peak increased by 65 %. When crop cover has been established, these parameters declined but were still higher than the pre-clearance stage (Hj Keizrul Abdullah, 1999).

When forests are replaced by impervious surfaces, both the frequency and magnitude of flash floods increase. This is because cities and towns are almost entirely covered with impervious surfaces which increase surface runoff (a major component of floods). Studies conducted by the JPS Malaysia have indicated that when there is an increase in areal imperviousness from zero to 40 %, it would cut the time to peak discharge by about 50 % and increase the discharge magnitude by about 90 %. Elsewhere all studies conducted so far testify to the fact that a change in land use from forest to any other land use would increase runoff, the greatest when forest is replaced by concrete or tarred surfaces (Table 4). Hence, before deforestation, rainwater gets intercepted by the forests, infiltrates into the ground and takes a much longer time to travel to the river. In contrast, urbanization results in rainwater being unable to infiltrate the soil but collects on the roofs and grounds, then runs into gutters and drains that swiftly covey it into the river. Such a large volume of runoff results in the river being unable to cope, hence it floods.

Table 4: Runoff Coefficients for Various Land Covers in Malaysia

Land Cover	% Surface Runoff
City/Urban:	
Cement/Concrete Paths	0.95
City Built-up Area	0.90
Industrial Built-up Area	0.80
Housing Area:	
12 houses/acre	0.85
8-12 houses/acre	0.75
4-8 houses/acre	0.65
4 houses/acre	0.55
Exposed Land	0.75
Parks in Cities (flat)	0.40
Village:	
Rubber Crop	0.45
Virgin Rainforest	0.20
Secondary Rainforest	0.30
Tin Mining Land	0.10

(Sources: Chia and Chang, 1971; Lewis et al, 1975; Fricke and Lewis, 1980; Douglas, 1984)

(iii) Lead Time: Chan (1998b) has studied river systems extensively in Penang Island and found that changing land use from forest to urban has led to a significant reduction of lead time, i.e. the time taken for ran drops to reach the river. In a typical forested catchment, rain drops usually take between one to two hours to reach the main river system, depending on the season and soil saturation. In a typical urban catchment, the lead time is only minutes from the commencement of a rain event. Hence, flood management authorities in Malaysia have often lamented on the short lead time which is insufficient to warn potential victims of impending floods. Loss of natural retention ponds, lakes, forests and wetlands has often been cited as the major causes of reduced lead time (Figure 1). Deforestation activities on hill slopes also reduce channel capacities due to sedimentation and siltation of downstream stretches,. These include housing developments and illegal farming. Chan (1995) examined flooding in Penang and found that hill land development was one of the major contributory factors. Haji Ahmad Jamalluddin bin Shaaban and Chong (1992) discovered that hill development has disturbed hydrological parameters, resulting in the exacerbation of downstream flood peaks and frequency.

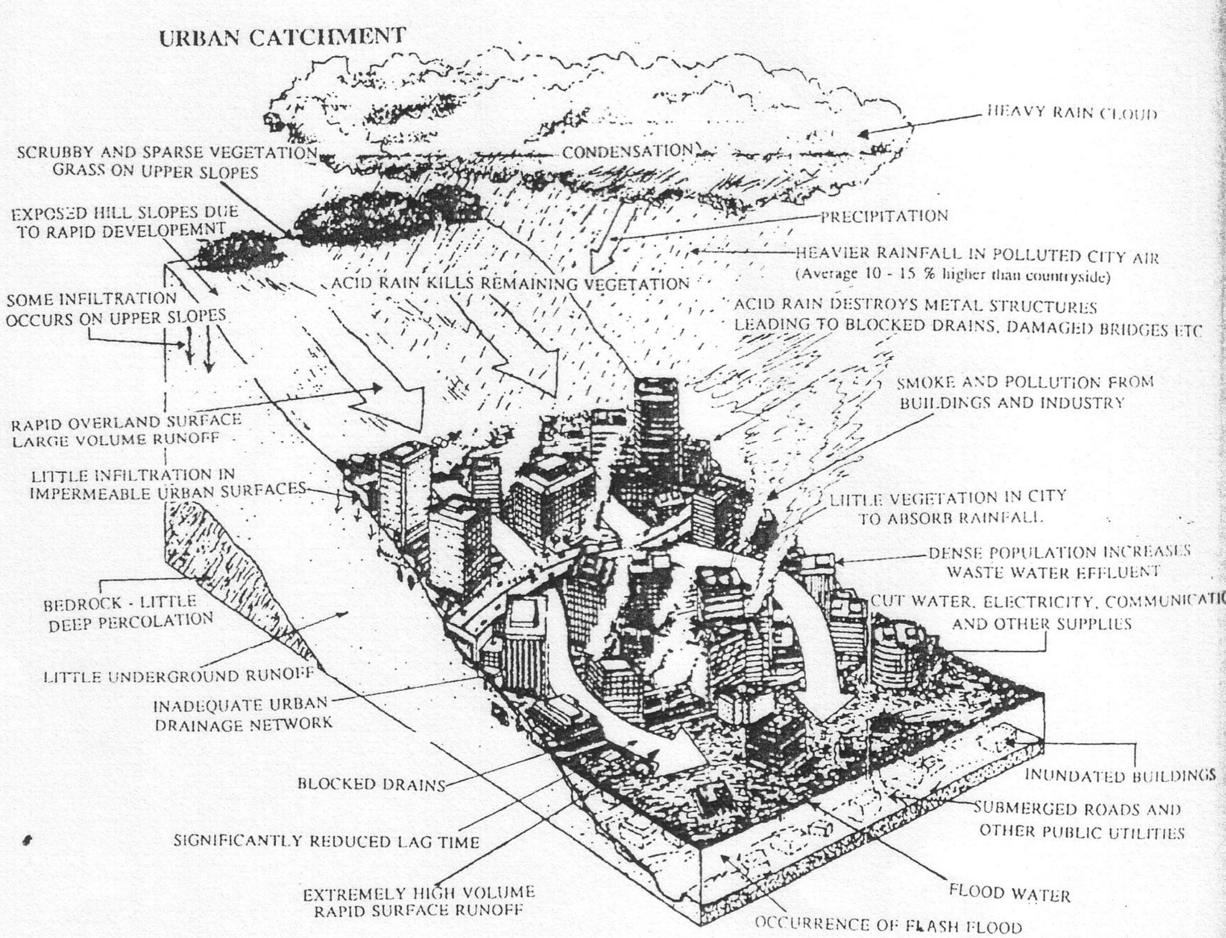

Figure 1: Shortened Lead Time due to Deforestation (No-retention Function) and Impervious Surfaces (Extreme Runoff) in Cities is the Major Cause of Flash Flooding (After: Chan, 1998b).

(iv) Sedimentation: According to Douglas (1999), sedimentation is a major river management issue in all countries and is a global issue. Table 5 shows that conversion of forest to urban can have devastating effects on the volume of sediments entering rivers. The most severe sedimentation occurs during the earthwork stage when the land is laid bare and exposed.

Table 5: Sediment yield from various river basins in Malaysia

River Basin	Land Use	Sediment Yield (ton km^{-2} $year^{-1}$)	Source
Bukit Kiara Basin	Construction	16,500	Chong (1984)
Sg Sering Basin	Logging	12,125	Mykura (1989)
Sg Jinjang Basin	Urban	2,283	Balamurugan (1990)
Sg Relau Basin	Semi-Urban	2,701	Wan Ruslan dan Zullyadini (1994)
Sg Relau Basin	Urban	3,101	Wan Ruslan (1995)
Sg Air Terjun Basin	Forested	472	Wan Ruslan (1995)

(Source: Wan Ruslan Ismail, 1995)

Malaysia is generally a hilly country with more than 60 % of its land classified as hilly. Significantly, these hilly areas also coincide with forests and water catchments, making them very sensitive ecosystems (Chan, 1998). With much of the country being developed now, "developable" flat land is a scarce resource, especially on the west coast of the peninsula. In recent decades, intensification of industrialisation, housing and construction, the development of tourism and agriculture, and greater urbanisation have led to greater pressures on land. Land reclamation has not eased the pressures, as demand for land remains high. As such, developers have turned to the remaining hill land for development. For some reasons, hill land appeals to developers as many hills and their environs are developed. Some prominent examples are Genting Highlands (Casino, recreation and tourism), Cameron Highlands (farming and tourism) and Penang Hill, Bukit Larut and Fraser's Hill (tourism). Many hills have been and are still being logged. Increasingly too, hills and forests are being destroyed for the construction of dams and highways. Yet, many hill projects are in the pipeline. Development of these areas has caused extensive soil erosion, landslides, sedimentation and downstream flooding (Chan and Wan Ruslan Ismail, 1997). This is because hill land is extremely sensitive natural systems comprising living systems (e.g. forests, fauna and other ecosystems) as well as non-living physical systems (e.g. climate, hydrology and soils). Any environmental change to such systems can upset the balance in nature and this can result in adverse consequences, not only on the natural systems but also ultimately on human society. Inevitably, hill land development means cutting down trees as hills are covered by virgin forests in their natural state. Studies have shown that development of hill land can have serious irreversible effects on the drainage basin as a whole as what happens upstream will inevitably affect the surrounding downstream.

Deforestation is closely related to hill development as hills are usually densely forested before they are developed. Topsoil depletion and high erosion rates are caused by deforestation. Goh (1978) discovered that sediment transport between a forested catchment and a semi-developed catchment was 50-300 times greater in the latter. Wan Ruslan Ismail (1995) has shown that deforestation can significantly increase rates of erosion. In Malaysia, erosion rates on exposed slopes are extremely high because of the abundant and intensive rainfall. These studies have shown that the difference between erosion rates in forested and exposed catchments are significant. In an exposed surface, the erosion rate would be much higher depending on the slope and other local factors. In Malaysia, the wet equatorial climate has generates great potentials for accelerated erosion, which in turn contributes to sedimentation and reduction of a river's drainage capacity. This is because of the high erosivity of the high intensity rainfall as well as the steep slopes. Based on the Universal Soil Loss Equation (USLE), it was found that exposed hill slopes in Malaysia with an average slope of 30 degrees could give rise to a soil loss of between 700 to more than 10,000 tonnes/ha/year. The DOE in Malaysia classifies soil erosion rates as follows: (a) low erosion - < 80 tonnes/ha/year; (b) severe erosion - 80 to 150 tonnes/ha/year; and (c) very severe erosion - > 150 tonnes/ha/year

Chan (1998) has demonstrated how rapid development on the hill slopes of the Paya Terubong valley in Penang has given rise to landslides, mud flows, sedimentation of rivers and downstream flooding. Mud flows are a common phenomenon in new housing estates. This is due to the exposed land surfaces during the initial phases of earth works. Several areas in Penang State in which mud flows are common are the Paya Terubong area, the Sg Ara housing area, and the Bt Gambier area. There have been many other instances of landslides, rockfalls and mudslides in Penang, especially in steep sloped areas subject to hill land development. Sediments from developing hill areas have also led to siltation of rivers downstream. In many drainage basins in Penang, a sediment concentration of 10,000 mg/l is not uncommon. Such a level of sedimentation often leads to flash flooding. Levels of sedimentation in some river catchments that have been developed in Penang, such as the Sg Relau catchment and Sg Pinang catchment are high. Amongst the various activities contributing to sedimentation, hill development and associated deforestation are perhaps the main contributors to the high sedimentation rates. Other than flooding, high rates of sedimentation can also pollute river water.

High sedimentation can reduce the capacities of downstream rivers, thus exacerbating flood peaks and frequencies. Thus, high rates of sedimentation can contribute significantly to flooding. This is because rivers are made shallower by the sediments, thereby reducing their capacities to drain away excess discharges. The classic Sg. Tekam study showed that with clearing of land from jungle to cultivated crops, the initial impact was a 157 % increase in water yield, a four fold increase in sedimentation rates and a 185 % increase in flood peak flow while time to peak increased by 65 %. When crop cover has been established, these parameters declined but were still higher than the pre-clearance stage (Hj Keizrul Abdullah, 1999). With respect to catchment runoff, an increase in areal imperviousness from zero to 40 % would cut the time to peak discharge by about 50 % and increase the discharge magnitude by about 90 %. In forested hill regions, rainwater gets intercepted by the vegetation, infiltrates into the ground and takes time to travel to the river, but deforested areas allow rainwater to flow as runoff quickly into rivers. As a result, rivers are unable to cope with this excess loads and flooding occurs. Wan Ruslan Ismail and Ahyaudin Ali (2001) have shown that wetland forests in Malaysia perform functions of sediment retention and natural flood control and regulation.

(v) Loss of Water Retaining Function: Wetlands are described as "lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface of the land or the land is covered by shallow water" (Cowardin et al., 1979). Whatever the definition, wetlands are not "wastelands" for they perform a variety of ecological and hydrological functions, including flood retention (Chan, 2001). Since the 1930s, large tracts of wetlands have been systematically drained and cleared for padi farming in Malaysia. While this has increased food supplies and improved rural livelihood, it also entailed the destruction of large tracts of swamps and wetlands. Destruction of wetlands not only increases floods but also increases the incidence of low flows and water shortages. With the loss of tree cover, the natural reservoir capacity of the trees to store water that might otherwise be lost to evaporation or rush rapidly downstream is lost. Thus arises an apparent paradox: trees increase the total annual flow of a river but reduce peak flow during floods. Trees also help anchor soil that otherwise would wash into the river and so raise the height of river beds and flood levels. It is an irony that after years of draining wetlands and replacing them with farms, there is now a move to "construct" wetlands for flood mitigation and a variety of ecological functions (Abalone, 1988).

It has also been alleged that illegal cutting of forest by logging companies, illegal squatting, illegal farming and other deforestation activities is fairly common. Illegal cutting of forests, including in nature preserves, has occurred throughout the country (The Star, 16 Jan 2002). Residents of two villages near the interior town of Nabawan in Sabah state reported illegal logging activities in a virgin jungle area and have lodged a formal complaint with the Chief Minister's office (in a letter dated Jan 12, 2002). Apparently, the illegal logging had been going on since March 2001, resulting in a substantial area being logged and this has resulted in soil erosion and sedimentation (The Star, 16 Jan 2002). Illegal logging is not surprising, given the high number of applications for logging licences rejected each year. In 2001 alone, the Pahang Forestry

Department rejected more than 50,000 applications from companies and individuals wanting to log timber (The Star, January 15, 2002). Over the years, logging has reduced the amount of forest cover in Malaysia substantially (Table 6). The country was almost completely covered with forest before western colonization at the turn of the 17th Century. Even during British colonial rule from the late 19th century up to independence in 1957, total forest coverage was more than 70 % of the total land area. Logging, agriculture, urbanisation and other human land uses have now reduced the forest coverage to less than 57.5 %. This figure is expected to drop below 50 % as the country develops further and as the pressure on land escalates. Illegal logging operations are one factor behind the environmental degradation that has worsened the flooding.

Table 6: Distribution and Extent of Natural Forests by Major Forest Types in Malaysia, 1995 (million ha) (Source: Hashim bin Saad, 1997)

Region	Land Area	Dipterocarp Forest	Swamp Forest	Mangrove Forest	Plantation Forest	Total Forest	% of Total Land Area
Peninsular Malaysia	13.16	5.38	0.30	0.10	0.07	5.85	44.5
Sabah	7.37	3.83	0.19	0.32	0.11	4.45	60.4
Sarawak	12.33	7.20	1.20	0.20	0.01	8.61	69.8
Malaysia	32.86	16.41	1.69	0.62	0.19	18.91	57.5

CONCLUSIONS

There is no doubt that wetlands are nature's way of controlling floods. They affect the hydrological cycle by intercepting rainfall at the canopy and regulating the flow of rain down branches, trunks and roots before reaching the river. Runoff has to penetrate wetlands before reaching the river, hence increasing lead time. Wetlands along rivers, estuaries and coastal areas also give runoff from precipitation (which eventually gets into rivers) a place to spread out, serving as natural retention basins. Wetlands act like sponges soaking and absorbing a lot of water down into the ground and then releasing it slowly over time. It has also been shown that rapid development in many countries, some over centuries and some over many decades, have systematically destroyed and decimated wetlands (including the lakes which they surround) and this has resulted in increased flooding. Some of the more severe flood in recent decades have been linked by scientists to the replacement of wetlands with agriculture, industrial, urban and other forms of human land use which are incompatible with the environment.

Governments at all levels must now issue emergency orders to monitor and control illegal cutting of highland and lowland rainforests, wetland forests and other riverine vegetation to curb flooding. Research has shown the clear connection between clear cutting and soil loss upstream and the river floods. More forests need protection either via gazettement as Permanent Forest Reserves or as National or State Parks. Currently, many forest reserves under various States have been de-gazetted for logging and other developments. Many are still facing such threats. In addition, secondary forests that have been logged need to be regenerated and re-afforested. There should also be more stringent requirements for logging trails to be paved and better protected against soil erosion and sedimentation. Loggers should be required to "clean up their act" after logging has ceased by carrying out erosion control work rather than leave the exposed forests to attack by the elements. More so, in the area of agriculture, wetland forests need to be protected from encroachment. Shrinking of wetlands has deprived the land of the flood retention function, not forgetting the other ecological functions of wetlands.

A programme of reforestation of deforested areas including wetlands must be implemented. This will not only reduce flooding but in the long run replenish timber supply (when replanted forests are harvested sustainably) and produce carbon sinks in terms of benefits for reduction of CO_2 emissions, as wetland forests are a source of CO_2 sequestration recognized by the IPCC. Putting in place a long term forest conservation plan, including gazettement of forest reserves and national parks will also help reduce flooding significantly as well as having other positive effects. Major lessons can be drawn from the floods of recent years. Though developed countries such as the USA and Japan can see to it that reafforestation of forests and restoration of wetlands proceed smoothly, it may not be so smooth sailing for developing countries like Malaysia and those in South-east Asia who depend on forestry and farming.

Squatters remain a major stumbling block to protect our forests. Illegal occupation of hill slopes, river banks and floodplains by both local and foreign squatters (Chan et al., 2001) must be controlled. Such activities are not only destroying forests but also polluting water and contributing to floods. State governments should direct all levels of local government to strengthen protection of forest resources and to halt forest destruction in development approvals, especially in the area of housing development. All forestry regulations must be rigorously enforced. All construction projects involving forestland should be slapped with a mandatory Macro-EIA, or in the case of extremely sensitive areas, be frozen for a period of time. The 50 ha minimum requirement before an EIA is required should be abolished and replaced by a mandatory EIA when it comes to forest land. At the moment, this EIA requirement is often circumvented by developers who chop areas larger than 50 ha into two or more smaller units (which then do not require an EIA). Whenever use of environmentally sensitive forest land is needed, permission must come from the State Government. Finally, culprits found guilty of violating the law (relating to forest protection) should be severely punished including jail sentences.

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