

EFFECTS OF HILL LAND DEVELOPMENT AND SOIL EROSION ON SEDIMENTATION AND WATER RESOURCES IN MALAYSIA

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ABSTRACT

In Malaysia, water quantity and quality as well as siltation of river beds are closely connected with hill land development, soil erosion and sedimentation. Gradual depletion of developable lowland has resulted in the development of hill land, which located on the upstream of drainage basins, is extremely sensitive to human-induced environmental changes. Even small changes caused by forest clearance could lead to severe damage on natural systems such as flora, fauna, climate, hydrology and soils. Rapid development of the foothills, slopes and hill tops since the 1970s, have resulted in depletion of forest, destruction and deterioration of water catchments, changing micro-climatic elements, endangering of wild life, high rates of soil erosion, increased incidence of landslides and rockfalls, high rates of sedimentation leading to rapid siltation and reduced capacities of rivers leading to increased frequencies and magnitudes of downstream flooding, and the pollution of river water. Much of such negative impacts are also due to the disparate and uncoordinated nature in which a large number of government agencies manage drainage basins. There is a need for all drainage basins to be managed in an integrated manner, in order to control hill land development and the associated impacts.

INTRODUCTION

Malaysia has come a long way since achieving independence from the British in 1957. After more than three-quarters of a century of tin and rubber exploitation, the British left a legacy of development. Townships and urban areas were rapidly developed and by the 1970s, urbanization and industrialization touched most of the country. This pace of frenzied rapid development accelerated during the early years of Prime Minister Mohammad Mahathir's leadership which transformed the country from an agrarian society to one of the most rapidly developing "Tiger economies" of Asia. As a result, land became an increasingly scarce resource many of the developed areas such as Kuala Lumpur, Petaling Jaya, Penang and Johore Baru. In the last ten years, intensification of industrialization, housing and construction, the development of tourism and agriculture, and greater urbanization have led to greater pressures on land. Even land reclamation (in some coastal areas) has not eased the pressures, as demand for land remains high. As such, developers have turned to developing hill land. Currently, many hills and their environs have been developed and many hill projects are in the pipe line. This has led to many environmental problems such as deforestation, decimation of water catchments, destruction of endangered fauna and flora, soil erosion, landslides, water pollution, sedimentation and downstream flooding. Two of the more serious problems are depletion and pollution of water resources and downstream flooding, i.e. the focus of this paper.

Hill land, which is located on the upstream of drainage basins, is extremely sensitive to human-induced environmental changes (Kung, 1985; Chan, 2000a). Even small changes caused by forest clearance could lead to severe damage on natural systems such as flora, fauna, climate, hydrology and soils (Kung, 1987). Rapid development of the foothills, slopes and hill tops since the 1970s, have resulted in depletion of forest, destruction and deterioration of water catchments, changing micro-climatic elements, endangering of wild life, high rates of soil erosion, increased incidence of landslides and rockfalls, high rates of sedimentation leading to rapid siltation and reduced capacities of rivers leading to increased frequencies and magnitudes of downstream flooding (Chan, 1995), and the pollution of river water (Wan Ruslan, 1995; Chan and Wan Ruslan, 1997).

Traditionally, hill land (as upstream stretches of rivers) and rivers are placed under the responsibility of a large number of government departments and agencies in Malaysia, each managing a distinct component with little interaction or co-ordination amongst them (Keizrul, 1999). Hence, management of river basins (which include hill land) is fragmented and this has been recognized as a major weakness hindering effective management (Ahmad Fuad bin Embi, 1999). Hence, there is a need for river basins to be managed in an integrated and holistic manner whereby upstream and downstream activities need to be co-ordinated (He and Kung, 1998).

EFFECTS ON WATER RESOURCES

Malaysia receives an average rainfall of more than 2,000 mm per annum, most of it during the Northeast Monsoon season (Figure 1). Hence, the country has abundant water resources (Keizrul, 1998; Chan, 2000b). Unfortunately, the distribution of rainfall is uneven both over time and space as many states and months often experience dry spells. In addition, water pollution due to a myriad of human activities reduces the total availability of water resources. One of the main sources of pollution is the sediment resulting from erosion of the land surface. In the humid tropics, soil erosion have caused land degradation to occur at an alarming rate (Douglas, 1994; 1996). Human activities influence both the availability of fresh water and the water quality. Rapid development (related to increase in population) especially in residential development even on the smallest of scale, could lead to contamination of underlying or nearby aquifers or surface water (Falkland, 1993).

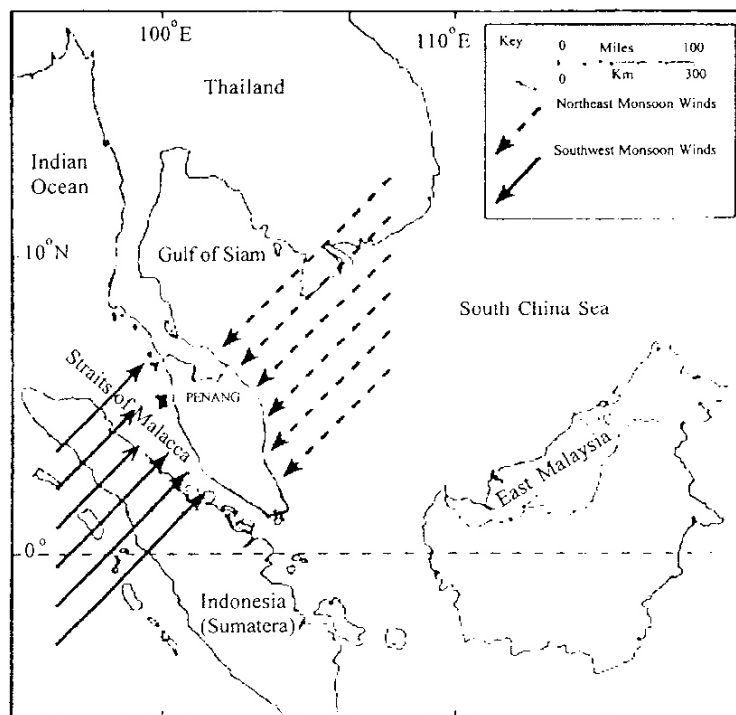


Figure 1. Location of Malaysia and Influence of Monsoon Winds

Wan Ruslan (1995) has shown that hill land clearance by construction activities has caused a lot of erosion on hill slopes. Soil erosion on Penang Hill related to land clearing for agriculture has been described as early as 1938 when Soper (1938) recognises the soil erosion problem as well as ways to manage the problem. Chan (1998) has shown that the rate of soil loss is alarmingly high in steep and hilly areas in the equatorial region. 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 the Penang Hill area) with an average slope of 30 degrees can give rise to a 50-fold increase in surface runoff and a soil loss of between 700 to more than 10,000 tonnes/ha/year. The Department of Environment Malaysia classifies soil erosion rates as follows: (1) low erosion - < 80 tonnes/ha/year; (2) severe erosion - 80 to 150 tonnes/ha/year; and (3) very severe erosion - > 150 tonnes/ha/year. Based on the above classification, it can be seen that the potential soil loss in hill slopes in Malaysia can be extremely high. Even though the above soil loss calculations is based on a worse case scenario (i.e. assuming all vegetation are cleared), it cannot be denied that many hill slopes in urban areas under land pressure (e.g. Penang Island), have very little vegetation left. As such, the soil loss of at least 350 tonnes/ha/year is still at least twice above the very severe category. For example, in the Paya Terubong area in Penang, it is estimated that about 30% of the slopes have been cleared of vegetation. This would give an erosion rate of between 100 to 330 tonnes/ha/year. Daniel and Kulasingam (1974) found that erosion rates in forested and planted (vegetable) areas are $25 \text{ m}^3 \text{ km}^2 \text{ yr}^{-1}$ and $732 \text{ m}^3 \text{ km}^2 \text{ yr}^{-1}$ respectively. This is an increase of more than 29 times. This rate of erosion can have devastating effects on water quality as the volume of generated sediments are extremely high. The lake in Cameron Highlands which used to spot clean clear water is now completely polluted by sedimentation and has to undergo rigorous treatment before it can be used as a source of water supply. This confirms the suspicion that intensive and uncontrolled farming and other physical developments on Cameron Highlands has degraded the quality of its water resources.

Soil loss data collected between June 1995 and June 1996 on Penang island and computed based on the Universal Soil Loss Equation produced a soil loss of about 19,000 tonnes/hectare/year in freshly deforested land with slopes between 20 to 30 degrees (Chan and Wan Ruslan Ismail, 1997). Given the high intensity of equatorial rainfall in Malaysia, the steep terrain and the resulting high rate of soil loss, landslides are the inevitable results. In comparison, soil loss in a forested catchment in the Air Itam water catchment in the Penang hills is only about 0.01 to 1.3 tonnes/hectare/year. Vegetable farming on hill slopes which recorded a soil loss of between 30 to 90 tonnes/hectare/year is already regarded by the authorities with concern.

Soil erosion is also manifested in sedimentation it is helpful to distinguish between on site erosion and downstream effects or off site impacts (Bruijnzeel, 1993). This is because not all the eroded material will enter the drainage network immediately. Sediments that end up in the river will be carried downstream and will be deposited behind debris bars and control structures such as weirs. The increase in sediment concentration associated with land clearing activities pose a great problem to the surface water available for domestic uses. The heavy sediment load pollutes the water and render it unsuitable for public

consumption. The sediment laden water needs to be treated and this usually involves a greater cost which is passed down to the consumers.

One of the greatest problems encountered by river managers is that of sediments (Douglas, 1999). The sediment concentration is one of the main indicator of soil erosion. It only measure the suspended sediment load, where sediment discharge comprises both the wash load (suspended sediment) and the bed load (Dickinson et al., 1990). Land disturbance will increase the amount of erosion (Goh, 1978; Douglas et al., 1992, 1993). Since the load of sediment is the product of sediment concentration and discharge of rivers, any increase in discharge following land disturbance mentioned above as well as the increase in sediment concentration will definitely increase the sediment load and sediment yield measured at a downstream river cross section (Wan Ruslan, 1996).

Measurements taken in the disturbed Sg. Relau catchments yielded sediment yields estimated at $910.5 \text{ t km}^{-2} \text{ year}^{-1}$ and $3,100.6 \text{ t km}^{-2} \text{ year}^{-1}$ at upstream downstream stations respectively. In comparison, the sediment yield measured at Sg. Air Terjun basin (a forested catchment) was only about $101.68 \text{ t km}^{-2} \text{ year}^{-1}$ (Table 1). Elsewhere in the Bukit Kiara Basin, a construction site, Chong (1984) estimated yields about $16,500 \text{ t km}^{-2} \text{ year}^{-1}$ whereas Mykura (1989) found yields about $12,125 \text{ t km}^{-2} \text{ year}^{-1}$ in the Sg. Sering Basin. In the Sg. Jinjang Basin, an urban area, the yields were 2,283 (Balamurugan, 1990). This indicates that development of hill land (in this case deforestation and urbanization) causing diminishing forest cover in the Sg. Relau catchment areas is a significant cause of increased in erosion and sediment yield.

TABLE 1
SEDIMENT YIELD FROM VARIOUS RIVER BASINS IN MALAYSIA

River-Basin	Land Use	Sediment Yield	Source ($\text{ton km}^{-2} \text{ year}^{-1}$)
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 Zuliyadini (1994)
Sg. Relau Basin	Urban	3,101	Wan Ruslan (1995)
Sg. Air Terjun Basin	Forested	472	Wan Ruslan (1995)

Source: Wan Ruslan (Ismail, 1995).

EFFECTS ON WATER YIELD AND DOWNSTREAM FLOODING

One of the effects of hill land development, i.e. land use change from forested to deforested catchments, is in the amount of water yield (Bruijnzeel, 1993; Law et al., 1989). The water yield, however, is not suitable for water consumption since it carries a lot of sediment the cost for treatment is high. Most likely, the increase in water yield also has the effect on increasing the streamflow and runoff, which also has the adverse effect of flooding in downstream segments due to the lowering of channel bed, thus reducing the capacity of the river because of siltation. Many studies have shown the increase in water yield involving the clearing of land upstream. Law et al., (1989) and Abdul Rahim (1990) reported studies in Sg. Tekam Basin and Berembun respectively, involving land use change from forest to plantation and due to logging. Both cases showed an increase in water yield as much as 706 mm (second year) at Sg. Tekam and 175 mm (third year) at Berembun watershed (Table 2). The large increase in water yield in the fourth year (822 mm) was associated with clearfelling in the upper part of the Sg. Tekam catchment (Douglas et al., 1993). The reduced infiltration after conversion of forest resulted in more surface water runoff due to the creation of more impermeable surface combined with the sealing action of rainsplash. This has been shown to exacerbate downstream flooding (Chan, 1995).

Surface water yield increase implies that less water are made available for ground water storage. The storage of water in underground aquifer will be reduced and the effect is normally shown during low flow when the water supply depend solely on underground water. This has some implications for domestic water supply especially during the dry period or low flow supply. The effect of disturbance of land use on water discharge of a catchment especially during low flow exhibits a higher low flow for much forested catchment compared to the most disturbed catchment. Comparison by means of the space-time substitution approach, shows that the total low flow discharge from December 1993 to February 1994 was comparatively higher for undisturbed Sg. Air Terjun catchment which has higher percentage forest cover compared to the lower percentage

forest cover of Sg. Relau catchment. The diminishing forest cover is clearly the main controlling factor in the amount of water storage capabilities of the catchment. The higher discharges at downstream Sg. Relau compared to the upstream station was due to extra water input due to quarrying activity and continuous discharges from urban areas.

TABLE 2
CHANGES IN WATER YIELD IN MALAYSIAN CATCHMENTS FOLLOWING LAND USE CONVERSION

Catchment Name (Type of change)	Catchment Area (km ²)	Mean Annual Rainfall (mm)	Changes in Water Yield mm y ⁻¹			
			Year 1	2	3	4
Sg. Tekam, Pahang (Secondary forest to cocoa plantation)	0.37	1878	+110	+706	+353	+263
Sg. Tekam, Pahang (secondary forest to oil palm [60%] and cocoa [40%])	0.97	1878	+145	+155	+137	+822
Bukit Berembun, Negeri Sembilan (logging [40%] of primary forest)	0.13	2126	+165	+142	+175	+155
Bukit Berembun, Negeri Sembilan (Selective logging of primary forest [30% conservation measures])	0.31	2126	+87	+70	+106	+94

Sources: Law et al., 1989; Abdul Rahim Nik, 1990.

INSTITUTIONAL ISSUES

Hill land and river basins are problematic areas. Currently, there are many government ministries, departments and agencies which have a claim to their management (Keizrul, 1999). It is a case of too many cooks spoiling the soup. Hence, the management of river basins (which include hill land) is not done in an integrated and holistic manner (He et al., 1995; He and Kung, 1998). The divided responsibilities between Federal and State agencies, and often hostilities between them (some states are governed by opposition parties), make matters worse. Hence, there is no formal mechanism to integrate and co-ordinate activities within a river basin. Given that all activities in a river basin will affect the riverine environment and river water quality, proper management of such activities through co-ordinated efforts from planning to enforcement is necessary to ensure that water resources are not polluted and downstream flooding minimized.

Over the years, different government departments are responsible for river conservancy, flood mitigation, water resources, navigation, fisheries, tourism, recreation, maintenance of water quality, research, etc. In addition, some agencies cover areas which impact onto the river system (land use, structural planning, forestry, sewerage, industrial licensing) while others have jurisdiction on the licensing and approval process (Keizrul, 1999). As a result of the involvement of too many different departments, it is inevitable that conflicts often arise. For example, while the Water Supply Department wants to fill up the dams, the Flood Management Agency is desperate to keep the dams half-full. The Forestry Department may be interested in conserving its hill forests but the Tourism Department wants to develop hill areas into hill resorts. This has often led to conflicts and non-cooperation.

CONCLUSIONS

Hill land development in various forms, including logging, land clearing activities for agriculture, illegal squatting, and other human land use in catchment areas are found to affect the hydrological system in terms of increasing the soil erosion, water yield and increase sediment concentration. Many badly eroded hill land areas in Malaysia are largely due to human interference while natural causes such as natural uprooting of trees due to storms are comparatively insignificant. The negative

impacts of hill land development has been shown to seriously pollute the water resources and exacerbate downstream flooding. Hill development can further destroy water catchments, give rise to soil erosion, landslides, sedimentation and other forms of water pollution which exacerbates water stress. When the entire natural hydrological cycle is disrupted, it often culminates in environmental hazards and disasters such as landslides and downstream flooding, events which have become increasingly common in Malaysia in recent years as more and more hill areas are rapidly and haphazardly developed. Despite experiencing an equatorial climate with copious rainfall all year round, Malaysians cannot take water resources for granted. The majority of rivers in Malaysia are already polluted to various degrees. As hill development is accelerated, the water resource base will be further reduced. Malaysia should count itself fortunate that it enjoys plentiful rainfall but it must protect and conserve this vital resource by mitigating its extreme manifestations. Hence, the conservation of hill regions, and the holistic management of river basins through a single empowered agency are necessary steps towards sustainable development.

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