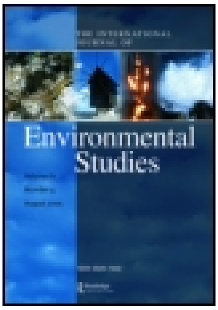

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ENVIRONMENTAL IMPACT OF MINING, EROSION AND SEDIMENTATION IN SRI LANKA

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Erosion and sedimentation have a devastating effect on the environment of Sri Lanka. The Central Highlands with very steep slopes and a radial network of rivers that begin in these mountainous regions cause major erosional hazards, often resulting in disastrous landslides.

Mining, particularly gem mining, has been responsible for serious problems of soil erosion and river siltation. A large number of illegal mines leave mine spoils resulting in damage to nearby paddy fields, crops, rivers and streams. Extensive sand mining in some rivers has lead to the collapse of river banks, destabilising structures such as bridges and causing influx of salt water.

Landslides and coastal erosion are other factors that have had a negative impact on the environment in Sri Lanka.

Keywords: Mining; erosion; sedimentation; Sri Lanka.

INTRODUCTION

Land degradation mostly by the influence of man induced activities, is one of the most serious environmental problems of Sri Lanka. Significant loss of agricultural productivity has resulted due to high rates of soil erosion and accompanying siltation, flooding and salinization, landslides and also due to mining.

It has been observed that significant land degradation had commenced during the past 150 years after the advent of commercial plantation agriculture[1]. The forest cover which stood at 70 percent in the year 1900 has now dwindled to less than 25 percent and the process is continuing unabated. In watershed areas of the hill country of Sri Lanka, where the forests are most essential, the estimated forest cover is now only 9 percent.

The earlier studies of Joachim and Pandithasekera[2] had highlighted the seriousness of soil loss in some parts of Sri Lanka, notably in the Mahaweli catchment, where a figure of 115 tons/hectare was recorded for soil loss. More recent estimates as reported in Natural Resources of Sri Lanka[1] indicate an average sediment load of 15 million tons for the period 1952–1982 for the upper Mahaweli watershed.

The serious environmental implications of establishing plantation agriculture on steep slopes of the central highlands of the country without any consideration for the geomorphological features has, in many ways, contributed very significantly to the land degradation problems of the central Sri Lanka. Tobacco cultivation has been particularly implicated for this environmental degradation in several areas and one study, TAMS/USAID[3] has reported a soil loss of 45–60 percent on slopes in lands under tobacco cultivation in the mid country.

Recent mining activities, mostly for gemstones and sand have also contributed significantly to the environmental degradation of some parts of Sri Lanka. With increasing population, and rapid industrialisation, competition for land resources has also increased resulting in a heavy and adverse impact on the physical environment.

This paper highlights the processes responsible for this environmental degradation and the adverse impacts on the physical and social environment of Sri Lanka.

THE PHYSIOGRAPHY OF SRI LANKA

Geologically and physically Sri Lanka is a southern continuation of India and separated from each other by the shallow Palk Strait and Gulf of Mannar. On the basis of height and slope characterisation, the Island is divided into three main morphological regions[4].

a. The coastal lowlands with elevation from sea level to 305 m with a few isolated inselbergs. The slopes in the coastal belt range from 0° to 15°. The striking feature of the lowlands is that they are very narrow, particularly in the southern margin of the Island where the width could be as small as 3.2 km. Towards the west however, the coastal lowlands become wider with the widest parts being seen in the north west (Figure 1).
b. The uplands with elevations ranging from 305 m to 915 m consisting of ridge and valley topography and highly dissected plateaus. These areas comprise of narrow "amphitheatres" and domes occupying nearly three tenths of the Island. The average degree of slope varies from 10° to 35° along the upland ridges depending on the lithology and structure.

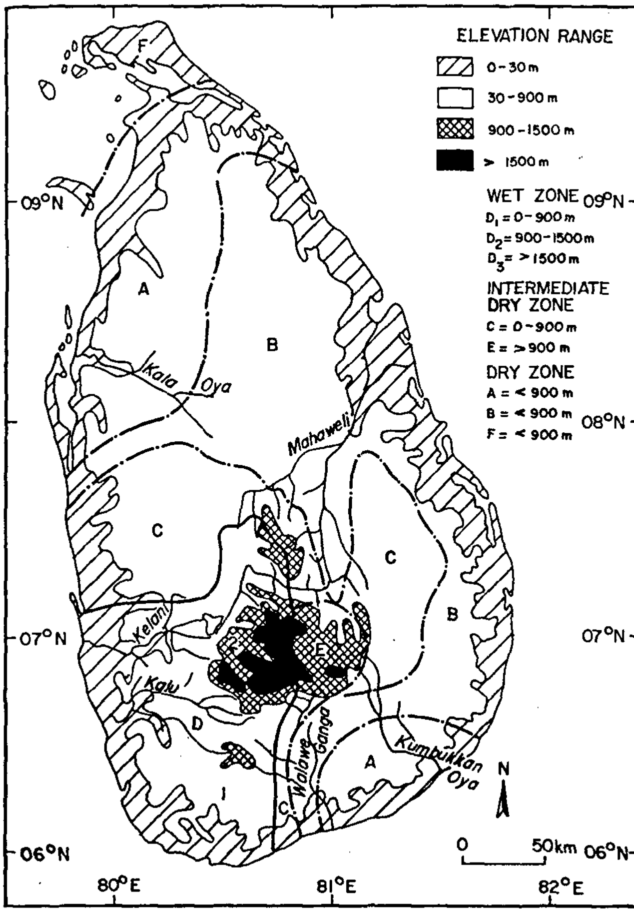

FIGURE 1 Physiographic features of Sri Lanka.

c. The highlands comprising of a series of well defined high plains and plateaus rimmed with mountain peaks and ridges. Their elevations range from 915 m to 2420 m and these highlands characterise the central parts of Sri Lanka. These morphological features are not continuous and are separated from the intervening dissected lower plateaus and uplands by steep escarpments and deep valleys. Two distinct highland mountain massifs—knuckles Massif (2035 m), north east of Kandy and Rakwana Massif (1488 m) south west of Sri Lanka occur detached from the main central highland area proper by the deeply eroded valleys carved out by the head streams of the Mahaweli and Kelani rivers.

1. The Drainage Network

The majority of the rivers of Sri Lanka originate from the central hill country. The heavy annual rainfall received by these central highlands ensures a steady supply of water to these rivers which radiate out in all directions. This radial pattern of drainage is characteristic of the geography of Sri Lanka (Figure 1). Over 90 percent of the land area of the country is covered by 103 natural river basins, the largest of which is the Mahaweli river basin. This covers about 16 percent of the island and is a major source of irrigation water to the Dry Zone. The river systems that supply water to the Dry Zone are only seasonal while the relatively smaller coastal basins do not make a significant contribution to the water supplies.

The Mahaweli Ganga (335 km), which is by far the largest and longest river system in Sri Lanka, is longer than the combined length of any other two rivers of the country. The river originates at altitudes of over 1,340 m above seal level with one of its major tributaries, Kotmale Oya, having its source at an altitude of 2,250 m above sea level. The Mahaweli Ganga with its perennial source of water and its vast catchment has been extensively developed for its hydropower potential. The steep gradients of the river, encountered during its course at main locations, have been used to harness hydroelectricity by the construction of several dams across the river at Kotmale, Victoria, Randenigala, Rantambe, and Maduru Oya. These reservoirs impound vast areas, and with the creation of a network of canals, major irrigation and settlement schemes have been developed. The Mahaweli basin spreads across all major ecological zones of Sri Lanka spanning the country's three climatic zones, namely the Dry, Intermediate, and Wet Zones.

ENVIRONMENTAL IMPACT OF GEM MINING

Sri Lanka is well known for its vast gem potential. Of the 5 percent foreign exchange earned by the mineral industry of Sri Lanka, 60 percent is contributed by the gem minerals. Gem mining is, therefore, common in several parts of Sri Lanka, most notably in the South western sector.

It has been estimated that there are approximately 10,000–15,000 gem pits that operate legally in the Island, while an equal number are illegal. The environmental problems associated with gem mining are of major concern and these include:-

a. damage to natural vegetative cover, plantations, and rice fields
b. degradation of the land and health hazards

c. damage to man-made structures
d. damage to stream and river banks
e. destruction of fauna
f. sedimentation and water pollution (Figure 2)

(Rupasinghe and Cooray)[5]

The haphazard digging of pits in search of gems without giving due consideration to the physical environment has resulted in serious damage to the landscape (Figure 3).

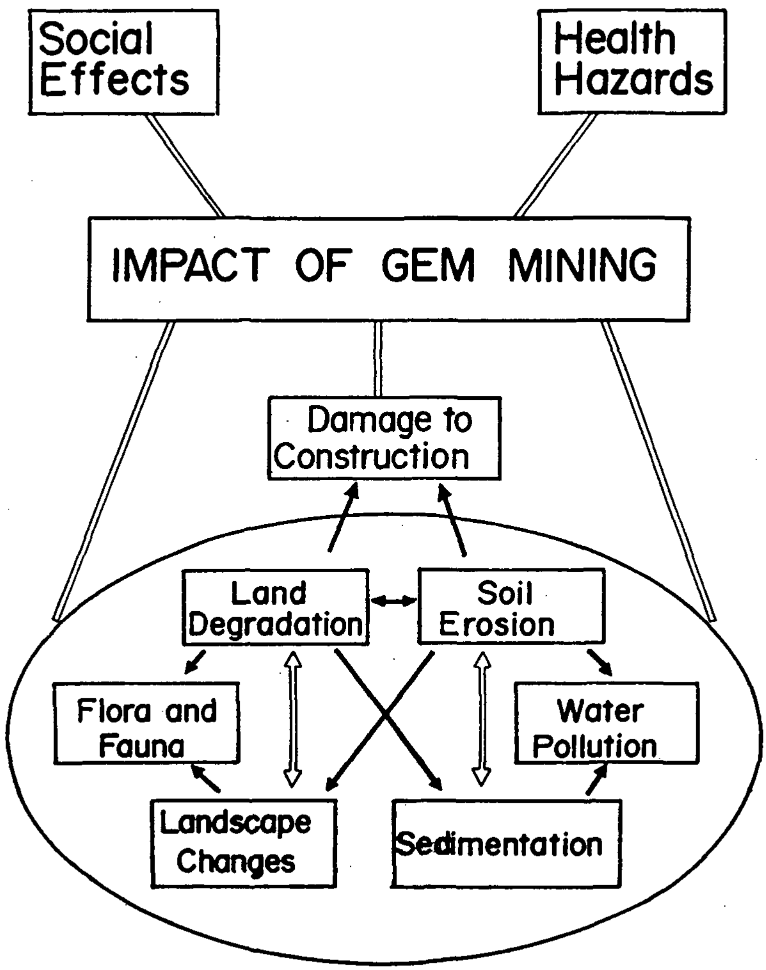

FIGURE 2 Schematic diagram showing environmental impact of gem mining.[5]

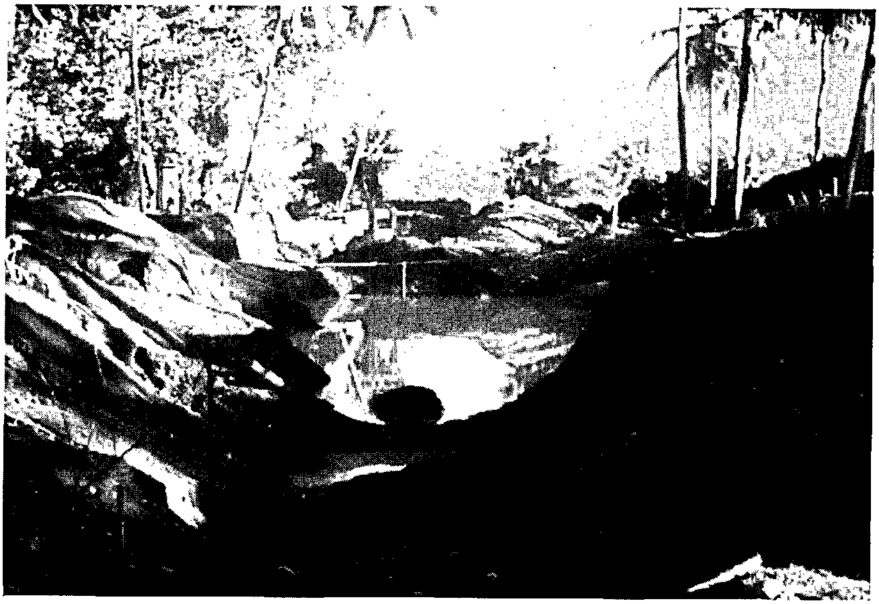

FIGURE 3 Destruction of landscape due to gem mining.

In a detailed study of the environmental impact of gem mining in the Ratnapura district, the main gem producing region of Sri Lanka, de Silva[6] has made quantitative estimates on the soil extracted from a gem mine (Figure 4). It has also been found that nearly half the legal miners and probably all illegal miners leave their soil heaps around the mines (Figure 5). Further, the unfilled gem pits form ideal breeding grounds for mosquitoes and studies have indeed revealed an increase in the incidence of malaria in the gem mining regions. The soil heaps around the gem pits are easily transported with the rains causing damage to the nearby lands and flora. The rains and floodwater also carry the sand, silt and clay to the nearby streams, rivers and low-lying areas or rice fields causing problems of sedimentation. The deposition of sediments apart from blocking streams and canals also destroys fish-spawning grounds. Heavy sediment deposition raises the stream beds thereby reducing the capacity of rivers to absorb flood waters (Figure 6).

The removal of the vegetation cover on river banks causes their collapse into the stream and such cases are found in abundance in the main gem mining areas.

Gem mining by tunnelling under roads, houses, canals and culverts cause extensive damage to man-made structures (Figure 7). In spite of the existence of environmental laws pertaining to gem mining, such activities still persist in several parts of Sri Lanka.

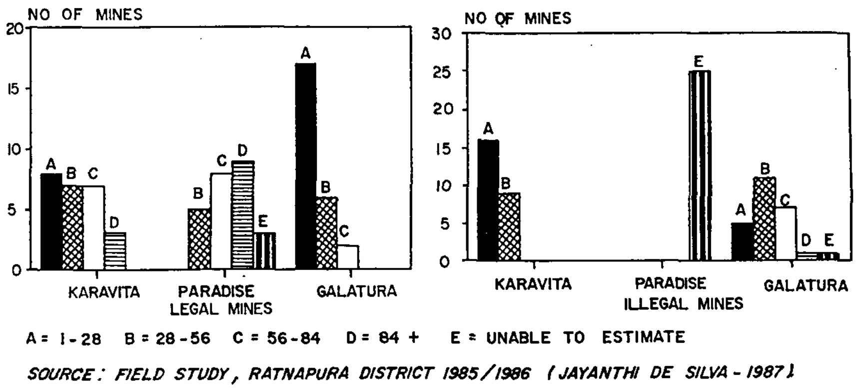

FIGURE 4 Annual soil extraction from average gem mine (cubic meters).[6]

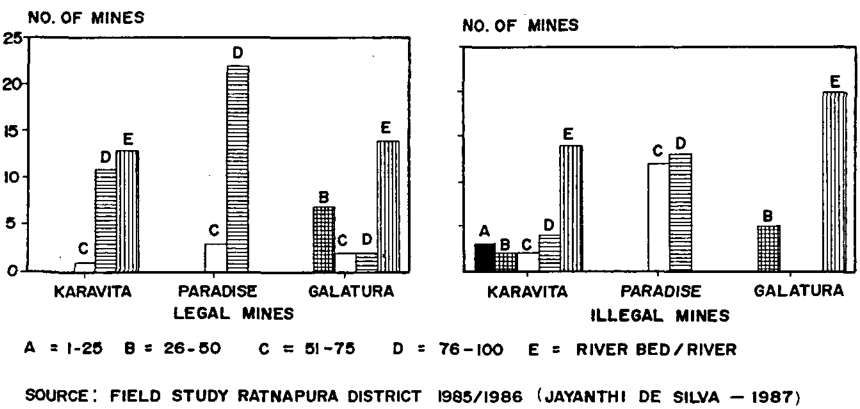

FIGURE 5 The proportion of excavated soils that remain as soil heaps around gem pits.[6]

SEDIMENTATION OF RESERVOIRS

Due to the rapid deforestation, reservoirs are subjected to sedimentation resulting in problems of management of land and water resources. The watershed of River Mahaweli, the longest in Sri Lanka, above the Victoria dam extends over 1893 km^2 covering a large part of the hill country. Figure 8 illustrates the different environments associated with sedimentation in the Victoria reservoir area. This hydroelectric project included:

a. The Victoria dam 122 m high and with a concrete arch and measuring 507 m along the crest

FIGURE 6 Sedimentation of water bodies caused by gem mining.

FIGURE 7 Damage to man-made structures by gem mining.

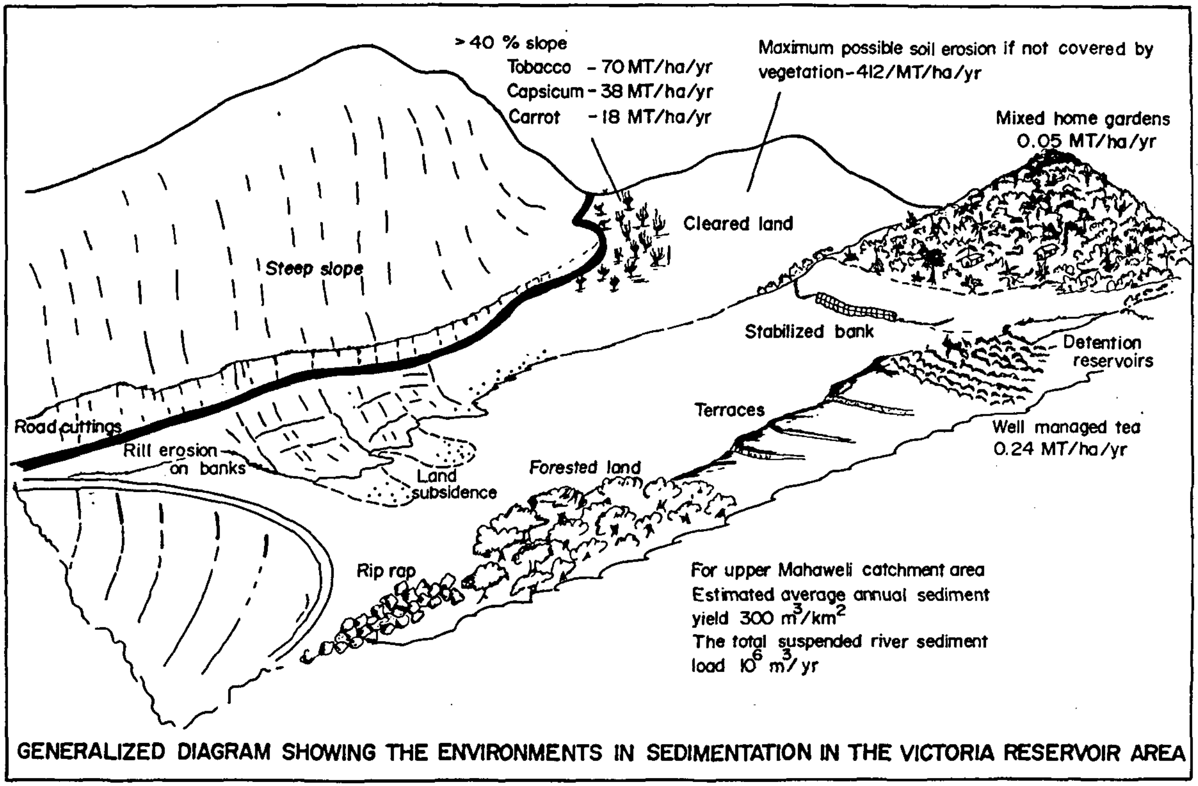

FIGURE 8 Diagram showing soil erosion around the Victoria Reservoir, Sri Lanka.[9]

b. A power tunnel of length 5.7 km
c. A power station with three 70 mw machines with provision for 3 more 70 mw machines
d. A transbasin canal, additional reservoirs and development of irrigated agriculture

In general, the landuse pattern of the catchment is tea at higher elevation, intensive arable farming in the middle slopes, tobacco, rice and vegetables in the valley bottoms. Studies have shown that the soil loss associated with tobacco, carrot and capsicum (chillies) in the middle slopes was significantly high, the measured values of soil loss being tobacco—70 MT/ha; carrot—18 MT/ha and capsicum—38 MT/ha. The soil loss in these environments was therefore higher than the tolerance limit of 9 MT/ha. It has become extremely necessary therefore to practice intensive soil conservation practices to minimise soil erosion.

In the Polgolla reservoir used as a pond accumulating sediments from the upper Mahaweli catchment, just 12 years after commissioning, almost 44 percent of its capacity was silted up, illustrating the magnitude of the problem of soil loss in the hilly slopes of Sri Lanka. As explained by Anderson,[7] the sediment yield of a drainage basin depends on three sets of variables.

a. Natural watershed characteristics
b. Nature of storms
c. Land use

On account of its ability to moderate or amplify the effects of topographic and geologic factors, landuse has the greatest affect on sediment yield. It has been observed that steep sloped watersheds with abundant forest cover yield significantly less sediments than the flatter basins under pasture cultivation. Rainfall also has a much lesser effect on forested areas than on open land[8].

In view of the destabilising effect of the underlying soil and geology. construction stages of the urbanisation process give rise to a marked enhancement of sedimentation. This feature has been very clearly seen in the regions where large hydroelectric schemes and reservoirs have been constructed. The construction of new roads, buildings, power lines etc. have all contributed to the removal of the vegetative cover and the destabilising of the slopes resulting in drastic increases of sediment yields. This is particularly severe in cases where the construction sites are located close to stream channels, as emplified by the newly constructed road along the periphery of the Victoria reservoir. Large quantities of easily transported materials such as sand, clay, loose rock, all find their way into the reservoir thereby increasing the siltation problems. Table I illustrates the soil loss in some lands under different cultivations[9].

TABLE I Soil loss in some lands under different cultivations in Sri Lanka[9].

Management	Soil	Soil Loss MT/ha
I. Mid country Wet Zone (located around Peradeniya)		
(a) Old seedling tea with no conservation practices	Ultisol	40.0
(b) Well managed clonal tea planted on the contours with lateral drains at 30' intervals	Ultisol	00.24
(c) Mixed home gardens with assortment of tree crops with heavy canopy	Ultisol	00.05
II. Up country wet zone (Talawakele)		
(a) Bare clean weeded one year old clonal tea	Ultisol	52.6
(b) One year old clonal tea with Gautamala grass mulch	Ultisol	00.07
III. Mid country intermediate zone (Hanguranketa)		
(a) Tobacco with no conservation practices	Utisol	70.0
(b) Capsicum with no conservation practices	Utisol	38.00
(c) Carrot with no conservation practices	Utisol	18.00
IV. Low country dry zone (Maha Illuppallama)		
(a) Sorghum/Pigeon pea with much 1500 kg/ha	Alfisol	3.90
(b) Sorghum/Pigeon pea clean cultivation	Alfisol	21.30
(c) Cotton clean cultivation	Alfisol	22.30
(d) Cotton with mulch 3500 kg/ha	Alfisol	2.00

LANDSLIDES AND THEIR ENVIRONMENTAL IMPACT

Landslides are common in the hill country of Sri Lanka, generally considered to be land over 300 m above mean sea level. Steep slopes, generally devoid of vegetation are conducive to landslides and these are abundant in the Central hills of Sri Lanka. It has however been found that the rates of occurrences of landslides have increased over the years and even in relatively lower elevations landslides take place. Apart from the geological conditions other factors such as climate, forest cover, anthropogenic influences, also play a major role in the process of landslides.

The environmental impacts of landslides in Sri Lanka have often been severe with loss of life and serious damage to property. Table II shows the extent to which this damage has been caused. As noted by Katupotha,[10] the study of landslides in Sri Lanka indicates that their incidence during the past decade (1983–1993) has increased rapidly. These landslides have caused about 223 village areas damaged, 381 deaths and the dislocation of 1370 families. According to Katupotha,[10] the acceleration of present landslide hazards and related environmental degradation is due to inadequate consideration of

TABLE II Villages and destitute families affected by landslides during the period 1983–1993 in Sri Lanka[10].

District	Number of Affected Villages	Destitute Families	Deaths
Kegalle	52	346	290
Kandy	11	40	4
Matale	26	275	14
Kurunegala	5	25	3
Badulla	45	562	6
Ratnapura	69	106	35
Kalutara	10	3	18
Nuwara Eliya	5	Not known	11
Total	223	1370	381

Source: Katupotha 1994.[10]

geological and structural factors during constructional activities, poor land use, removal of vegetation and interference with natural water flow.

In early June 1988, ironically on World Environment Day, Sri Lanka had experienced perhaps its worst landslide damage, which caused over 300 deaths. Madduma Bandara[11] notes that in the Kegalle District AGA Division of Galigamuwa alone 167 people died. It had been estimated that the cost of rehabilitating the "environmental refugees" was estimated at about 120 million rupees at 1988 prices.

Dahanayake[12] recommends some hints for living with such landslides.

i. Avoid excavations/road constructions on ancient/dormant landslides which may be currently inactive having attained equilibrium to due abutment against a river bank or hillock or due to overgrown vegetation. The dormant landslides are characterized by irregular drainage patterns and hummocky topography and could be easily identified with little experience even on air photographs.
ii. The fracture systems in underlying rock presently covered with soil and/or vegetation should not be exposed to running water particularly in hilly terrains with histories of landslides.
iii. The wanton destruction of forests and setting of fire by hooligans to patana grasses on hill slopes of the Central Highlands should be stopped perhaps by an awareness programme or by stringent legislation. The denudation of such regions will expose the underlying joints to water percolation that could eventually cause block slides.
iv. The constructions on hill slopes should only be allowed after proper geological and engineering investigations.

v. Proper drainage should be maintained particularly in densely populated areas with histories of landslides. There should be regular monitoring of drainage channels so as not to clog them. Overflowing drains on unstable terrains could trigger landslides with destruction to life and property in populated areas.
vi. Minor landslides could be prevented by construction of suitable retaining structures on stable bedrock against unstable slopes.
vii. Large trees should not be grown on slopes/roadcuttings or embankments bordering roads or home gardens. The root systems could pierce through the fractures of underlying rocks destabilizing and causing the displacement of rock and soil debris. Such occurrences are common mostly in town areas. These slopes would remain stable when overgrown with grass.

The state of the nature maps on former landslides, and landslide prone surface deposits are of great use in landslide mapping. Integration of Factor Maps into a Landslide Hazard Map (Figure 9) is often attempted so as to incorporate several sources of information onto one map[13].

COASTAL EROSION

Sri Lanka is an island and coastal erosion is, as expected, an environmental problem. It has been shown that although beaches are receding in most parts of the island, the impact of coast erosion is most pronounced in the western and southwestern coasts, where there is a rapid increase in urbanisation.

It has been estimated that along the coastal segment from the North West to the South East extending 685 km about 175,000–285,000 sq. m. of coastal land are lost annually through erosion[1].

Coastal erosion is of particular concern for Sri Lanka in view of the fact that about 75 percent of the graded hotels in Sri Lanka are located in coastal areas. It is of interest to note that the majority of these hotels have less than a 15 m setback between buildings and the water line. The economic significance of coastal erosion for Sri Lanka is therefore very significant. Figure 10 illustrates the comparison of coastal erosion of Sri Lanka with that of some other countries[14].

Anthropogenic influences have a marked effect on coastal erosion in Sri Lanka. Among these are sand mining from rivers (Table III) and beaches, coral mining and destruction of reefs, removal of mangroves and other coastal vegetation, siting of buildings and other structures at critical locations close to the beaches (Table IV).

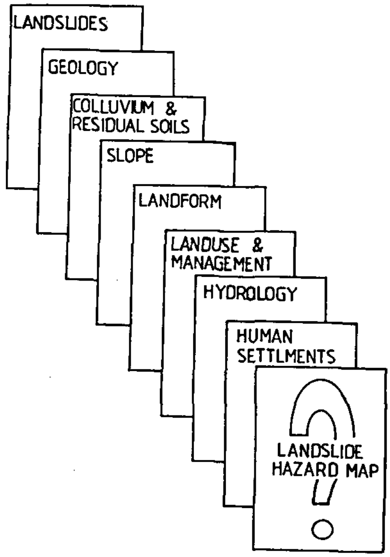

FIGURE 9 Integration of Factor Maps into a Landslide Hazard Map[13].

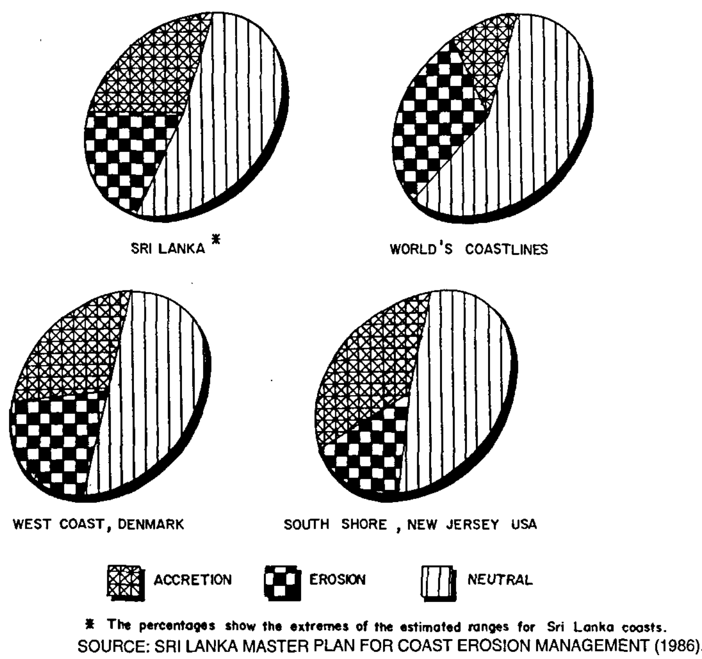

FIGURE 10 Erosion and accretion along the coasts of selected countries[14].

TABLE III Data on sand mining from some major rivers in Sri Lanka.

Namer of River	Number of Landing Sites	Number of Cubes* Removed in 1984	Total
Kelani Ganga	181	222,771	43
Maha Oya	61	111,720	21
Gin Ganga	2	79,445	15
Kalu Ganga	67	46,667	9
Deduru Oya	2	22,896	4
Gin Ganga	41	21,561	4
Nilwala Ganga	7	2,005	1
Subtotal	363	507,866	97

Note: a cube = 100 cubic feet or approximately 3 cubic meters.
Source: CCD Internal Report No.1: A census of the exploitation of sand seashell resources in the Coastal Zone of Sri Lanka (1984).

TABLE IV Activities contributing to coastal erosion in Sri Lanka[4].

Causal Agent	Process	Effect	Examples
Beach sand mining	Reduction of sand in beach maintenance system posing possible treats to renewal	Increased erosion	Panadura, Lunawa, Angulana, Palliyawatta
River sand mining	Reduction of sand in beach maintenance system posing possible threats to renewal	Increased erosion of adjacent beaches, erosion of river banks	Kalu Ganga, Kelani Ganga, Maha Oya
Inland coral mining	Conversion of productive land into waterlogged areas	Development of inland waste dumps and abandoned pits, reduction of coastal stability by creation of low-lying areas	Akurala, Kahawa, Ahangama, Midigama
Collection of coral from beaches	Reduction of beach nourishment material	Increased erosion	Ambalangoda to Hikkaduwa, Midigama, Ahangama and Polhena
Reef breaking	Reduction of reef size, creation of gaps in reef	Increased wave energy on beaches resulting in erosion	Ambalangoda to Hikkaduwa, Koggala, Midigama, Polhena, Rekawa, Pasikudah, Kuchchaveli, Nilaveli
Improperly sited groynes, groynes, harbors,	Interference with natural sand transport processes	Erosion in some places, accretion in others	Beruwela Fishery Harbor, Kirinde Fishery Harbor
Improperly sited coastal buildings jetties	Interference with dynamics of coastal processes	Loss of structures, other property due to retreat	Hikkaduwa, Bentota, Beruwela, Negambo
Improper removal of coastal vegetation	Exposed area subject to more rapid rates of wind erosion	Erosion, retreat	Palliyawatte, Koggala, Polhena, Negambo

CONCLUSION

The environmental impacts of soil erosion on steep slopes, gem and sand mining and other anthropogenic influences have been severe with great losses of top soil and beach areas in Sri Lanka. The central hill country of Sri Lanka, particularly the land under agricultural plantations such as tobacco and tea has been subjected to extensive soil losses. These processes have caused siltation problems in hydroelectric reservoirs, resulting in reduction of the efficiency of the reservoirs for power production. River sand and beach sand mining and also coral mining have caused coastal erosion in several parts of Sri Lanka with serious impacts on the human settlements.

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