ERODING COAST — A SERIOUS ENVIRONMENTAL PROBLEM

W. N. WILSON,
Department of Geography,
University of Colombo

and

S. N. WICKRAMARATNE,
Department of Geography,
University of Peradeniya.

INTRODUCTION

Environmental problems are a part of the human environment and in all stages of his civilization man had been coping with these problems. Droughts, famines, and epidemics are examples of environmental problems. Coastal erosion experienced by many people living in coastal areas of the world is a similar problem. It is a secular environmental problem compared with catastrophic earth-quakes and floods etc. which are relatively sudden events. This paper examines some aspects of the problem of coastal erosion in Sri Lanka.

First, it is relevant to define some key terms in this context. 'Coast (is) a strip of land of indefinite width (may be several kilometres) that extends from the shore line inland to the first major change in terrain features' (Swan 1983:160). 'Shore' is the area between the highest and the lowest water levels of the sea or a body of water. A beach is a shore area made up of unconsolidated material deposited by fluvial or marine processes. The coastal environment may be defined as the sum total of all related phenomena of the coast. The coastal environment is a very dynamic, geomorphological system which is subject to continual disturbance and change over time and space. Coastal changes can be long-term events probably measurable only in the geological time scale and coastal erosion is a major cause of coastal change.

'Coastal erosion' can be defined as the removal of geological material of the coast by the action of waves. It may be stressed that coastal erosion is a natural phenomenon. However, human factors contribute to aggravate this hazard and therefore, coastal erosion aggravated by man may be taken into account as a 'quasi-natural phenomenon' (see Park 1983:7) which differs from a man-made hazard. Natural erosion of the coast may be looked upon as an evolutionary process, which does not have to be controlled except in very extreme situations. Nevertheless, when coastal erosion is intensified by human activities, it can be mitigated by controlling such factors.

Before the coastal areas of Sri Lanka were densely populated, erosion of the cost-line was primarily due to natural causes. The arrival of the Portuguese in Sri Lanka (1505 A.D.) Mark the beginning of a very intensive utilization of the resources of coastal area by man. In the next centuries the Dutch (1628) and the British (1796) occupied the coastal belt of Sri Lanka which exerted an increasing pressure on the natural resources of these areas. Up to the present our coastal environment has been subject to an ever increasing pressure due to human activities. More than 50% of the population of Sri Lanka live in coastal areas.

COASTAL EROSION STUDIES IN SRI LANKA

Although coastal erosion might have perpetuated since very early times, it attracting Scientific attention has been a recent event. More importantly, coastal erosion has been of national concern only in the last few decades. Therefore, it is pertinent at this point, to look at some work done on the erosion of our coast. As coastal erosion studies

in Sri Lanka are a fairly new trend, there is a dearth of comprehensive literature on this subject. Most of the coastal research done early this century has not been specifically focused on erosion. The written works of Sommerville (1905), Coates (1935), Shepard and Beard (1938) and Wadia (1941), for instance, are descriptive accounts of our coastal land forms, rather than erosion studies. Deraniyagala (1958) attempted to define the Quaternary coast of the island in relation to the Pleistocene epoch. Swan (1964) has analysed 'eustatic changes' (i.e. sea level changes due to climatic and geological factors) of the geological past and of the South-west coast. According to him our south-west coast is a 'polygenetic coast (i.e. a coast that has evolved under the influence of a combination of causes).

Dissanayake (1928), Paranathala (1954) and Kahawita (1954) have analysed coastal erosion of the island from an engineering view point.

Zeper (1964) studied our coastal erosion hazard and made some recommendations. Cooray (1968) made coastal geomorphological studies of the localities of Negombo, Kalpitiya and Mannar. Swan (1974) paid special attention to the coastal erosion problem of the south-western coast.

In the 1980s more coastal studies have been carried out which reflect an increasing awareness on the coastal zone of Sri Lanka. For example, Madduma Bandara (1982), Swan (1983), Katupota (1985), Madduma Bandara *et al.* (1985) and Weerakkody (1985) have made case studies on coastal changes. From among the above work of Wilson (1984) and Weerakkody (1985) was done by applying remote sensing techniques.

Amarasinghe (1971), Gerritsen (1974) and Wickramaratne (1985) have analysed engineering aspects of coastal erosion.

Verstappen's (1987) 'Geomorphological Map of Sri Lanka' depicts the continental shelf of the island and submarine canyons, with areas of strong coastal abrasion.

SPATIALITY OF THE PROBLEM

Sri Lanka's coastline is about 1600 kilometres and this entire length is not uniformly subject to intensive erosion. Swan (1983 op. cit) has attempted to rank sectors of the coast according to erosion intensity and has found that the most severely affected part is the south-western coast. Northern coast is the next most affected area and there are several other localities where coastal erosion is considerable (Madduma Bandara 1982, Swan 1974 and 1983). This problem is least experienced in the north-west and the south-east, and more specifically, these two coastal segments are, rather, accretional environments showing growth of beach. The Colombo-Puttalam main road extends away from the shore-line, as opposed to the Colombo-Hambantota road which often runs very close to the shore, and this observation supports the above statement. A number of scientists have identified the coastline between Kalpitiya and Tangalle as the most eroded segment. Even within this segment, however, there are localities of severe erosion. A number of field evidence documented conform this (Dassanayake 1928, Wadia 1941, Paranathala 1984, Eaton 1961, Swan 1974, and 1983 and Gerristen 1974). According to Paranathala (1954 op.cit.) the localities where severe erosion is taking place are: Negombo, Mt. Lavinia, Beruwala, Hikkaduwa, Ahangama and Weligama.

As for the rate of erosion, Paranathala (1954) and Eaton (1961) have estimated the average rate for Sri Lanka to be 0.3-1.0 metre per year. Madduma Bandara (1982) who surveyed the entire coastline estimated this rate for the island as 1 metre per year. A team of experts of the Danish Hydraulic Institute (see Master Plan 1982) have given more accurate data in this regard as shown in Table 1.

SECTOR	DISTRICT	COASTLINE IN KM	EROSION % OF COAST	EROSION LEVEL M/YR	MCT AREA LOSS 1000 M^3
WEST	PUTTALAM	300	30-40	0.3-0.4	60.120
	GAMPAHA	40	60-70	1.0	35-40
SOUTHWEST	COLOMBO	40	40-50	0.0-0.1	0.5
	KALUTARA	40	70-80	0.1-0.5	10-20
	GALLE	75	70-80	0.3	10-20
SOUTH	MATARA	55	80	0.9-1.0	20-30
	HAMBANTOTA	135	40-50	0.2	20-30
EAST	AMPARAI	110	40-50	0.2	20-25
	BATTICALOA	100	60	01-0.2	10-20
NORTHEAST	TRINCOMALEE	210	40	0.2	10-0
	MULLAITIVU	50	20-30	0.2	0-10
NORTH	JAFFNA	275	60-70	0.3	50-60
	MANNAR	155	60-70	0.3	70-80
ALL COUNTRY		1 565	45-55	0.30-0.35	300-500

Table 1. Some Coastal Erosion Data for Sri Lanka
(Source: Coast Conservation Dept. 1985 Master Plan)

CAUSES OF COASTAL EROSION

Coastal erosion is a function of a number of factors and it is convenient to recognize two principal groups out of them:

1. Natural factors
2. Human factors

1. NATURAL FACTORS

Coastal erosion is a natural process of coastal evolution experienced by many maritime nations. There are numerous natural factors of coastal erosion, some of which are explained below:

(a) Wind Factor

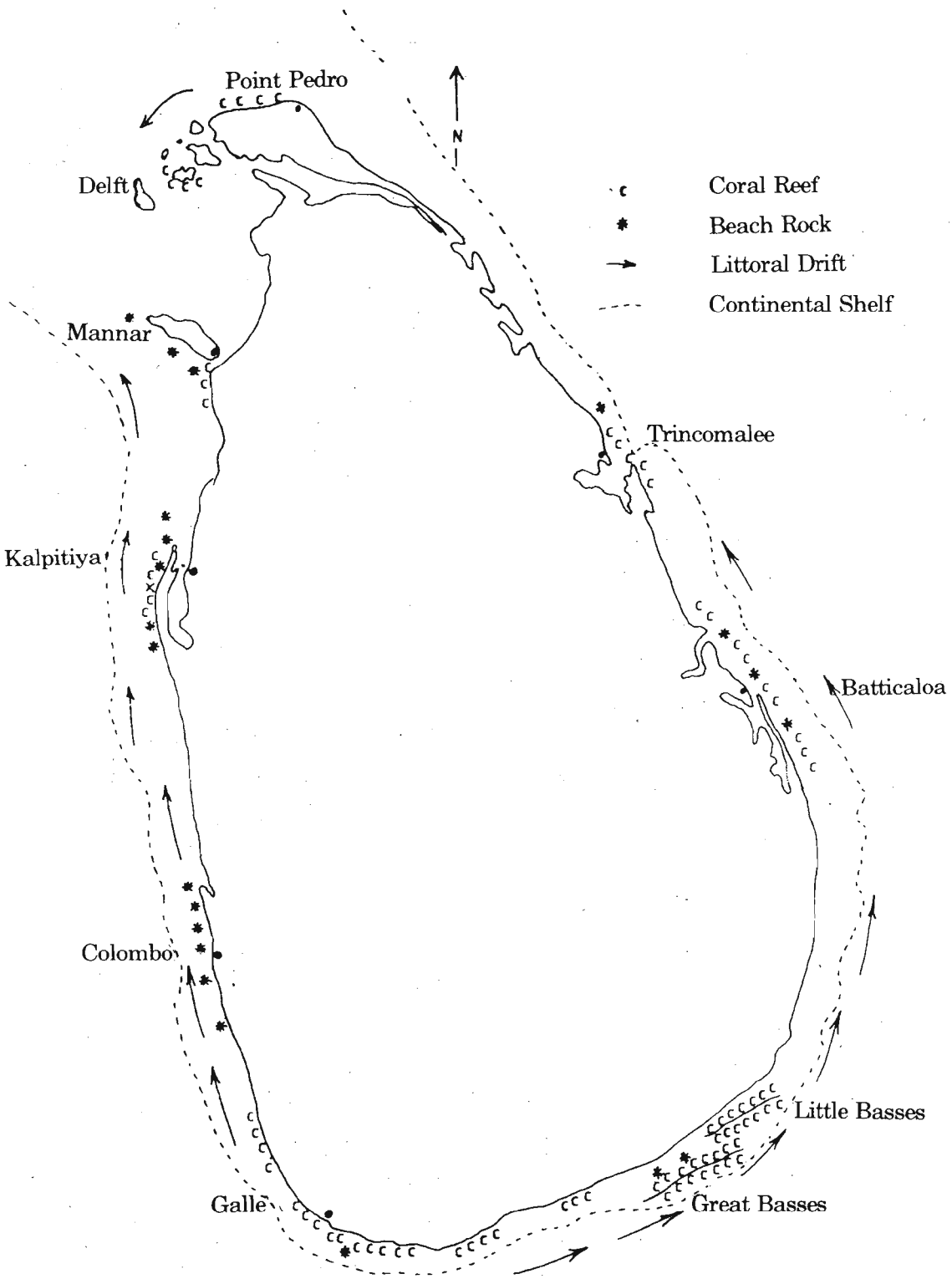
This is a climatic factor as opposed to the other natural factors that are primarily geological. In Sri Lanka coastal erosion is severe in the two monsoon seasons as strong winds provide more energy to the waves. During the south-west monsoon period of the May-September months intense erosion occurs in the south-west. Likewise, erosion is more acute in the north-eastern coastal belt during the north-east monsoon winds of the December — February period.

(b) Orientation

This means the direction of the coast with respect to winds and waves. Orientation of a coast determines the angle of attack of winds and waves and, even influences the movement of littoral drifts. Usually a coast that is more or less perpendicular to the waves and winds is more prone to erosion. Our south-west coast faces winds and waves heading very perpendicular during the south-west monsoon. However, the north-eastern coast is relatively less perpendicular to the attack of north-east monsoon winds and resulting waves.

(c) Littoral Drift

The littoral drift, also known as the longshore drift, is a nearshore current created by the kinetic energy of breaking waves. Therefore, it is more prominent in the monsoon months. In the south-west monsoon season, the south-west monsoon drift moves in a northerly direction transporting eroded material to be deposited north of the points of erosion. Part of this drift moves south too. Similarly, in the north-west monsoon season a less strong littoral drift prevails in the north-east. (Map 1).



Map 1. Map of Sri Lanka Showing the Continental Shelf, Beach Rock Coral Reefs and the Littoral Drift.

(d) Compartmentalization

This means the effect of the irregularities of the coast line due to the presence of bays, lagoons, estuaries, headlands, etc. plus man-made structures such as breakwaters, harbours and groynes. Compartmentalization tends to modify the nearshore circulation, particularly of the littoral drift. As a result eroded materials are intercepted especially behind bars and structures and moreover, new stretches of the coast are open to erosion.

(e) Natural Sand Supply

The natural supply of sand-sized material to the coast is very important for beach development, as it helps determine whether a particular shore environment is depositional or erosional. Sand for the coastal environment is supplied by the fluvial process of rivers. In Sri Lanka there are 103 drainage basins discharging some 44 million m^3 of sand per year (Madduma Bandara *et al.* 1987). If any natural or human factors interfere with this sand supply, the effects will be adverse on our coast-line.

(f) Lithology

The geological foundation of the coastal zone of Sri Lanka is made up of crystalline rocks of the types found inland, together with beach-rock (see p. 13), coral, unconsolidated beach sand, rock debris etc. Nine-tenths of our coast-line is made up of unconsolidated, fluvio-marine sediments and rocky areas are limited. A good portion of the south-eastern coast line which shows high rates of erosion is composed of such unconsolidated material. The presence of coral reefs and beach-rock in the sea near the shore in many parts of Sri Lanka protects the coast from erosion, by acting as barriers that help dissipate the kinetic energy of waves.

(g) Continental Shelf Topography

The island is surrounded by a relativly narrow 'continental shelf' that extends about 7 kilometres towards the ocean. The 100-fathom (about 180 metres) isobath is considered the outer limit of this continental shelf. The continental shelf is wider in the north towards India and much narrower in the south-west, the area most severely affected by erosion (Map 2). It is also narrow between Kokkilai and Trincomalee in the north-east, the coast of which area is also subject to intense erosion. Next, it is narrow in the areas between Potuwil and Kumana of the south-eastern coast, too. However, the coast of this area is not much affected by erosion due to the 'safe' orientation of the coast relative to winds and waves.

(h) Sea Level Changes

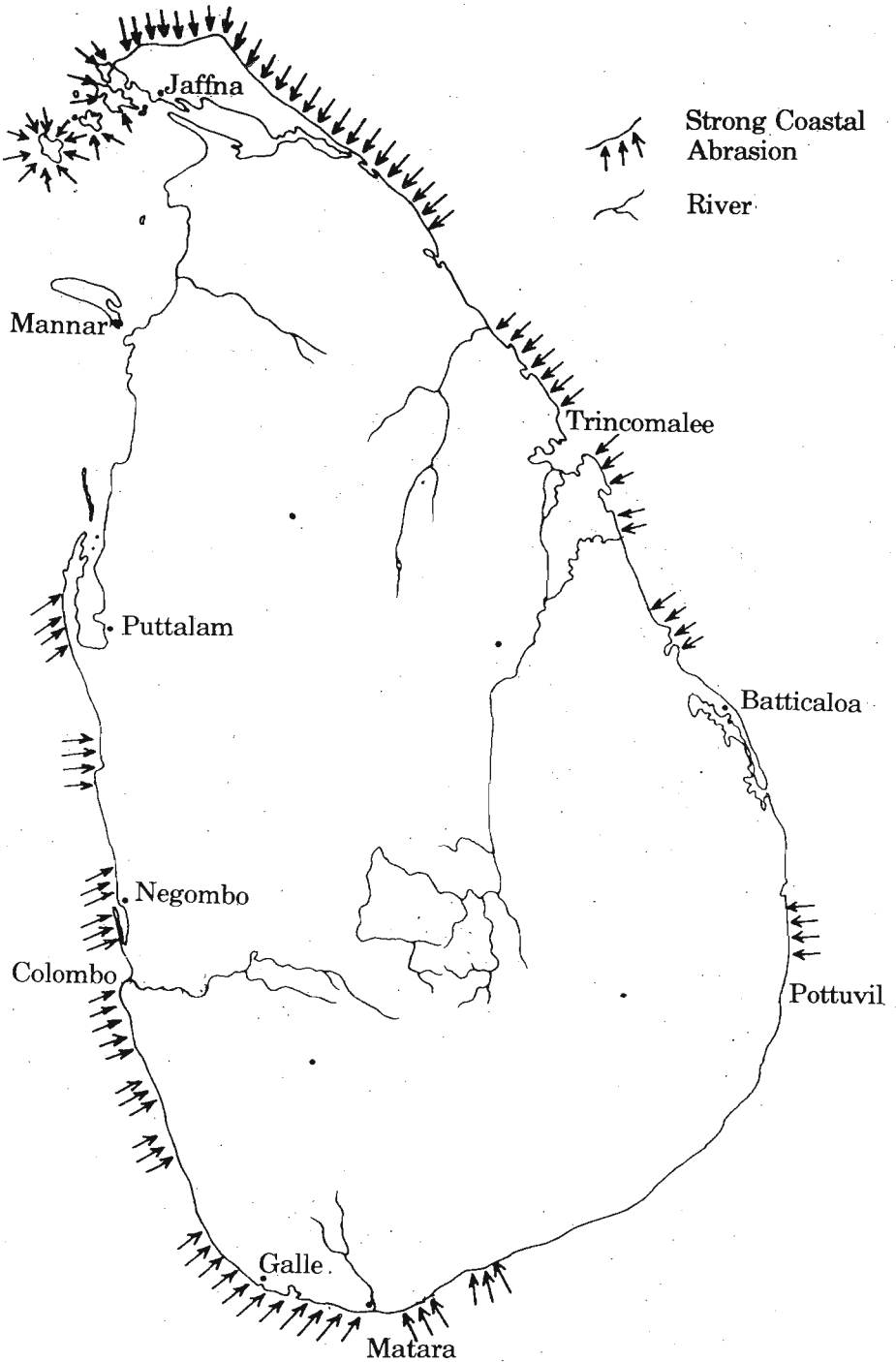
Both field and loboratory studies have shown that sea level rises and coastal erosion are generally correlated. Even the 'Small States Conference on Sea Level Rise' of Nov. 14-18, 1989 was mainly focussed on the sea level rises expected in the next hundred years. Although various predictions indicate a sea level rise ranging from a few millimetres to several centimetres per year, it is not possible to express a definite view on this at present.

2. HUMAN FACTORS

The principal ways in which human activities contribute to coastal erosion in Sri Lanka are discussed next.

(a) Coral Mining

A coral reef is a unique tropical marine ecosystem consisting of a number of animals and plant life forms, in addition to coral polyps. In addition to the many ecological uses of coral reefs, their role in checking coastal erosion is understood. The corals of Sri Lanka, occuring as 'fringing reefs' are found in many parts of the near-shore area. Excessive coral extraction as a source of lime is a serious threat. In 1977, 7000 tons of coral have been extracted and today more than 10,000 tons of coral are extracted annually, mainly from the south-western coast (Wickramaratne, 1985) the area mostly affected by erosion, even without human influence.



Map 2. Map of Sri Lanka Showing Principal Areas of Coastal Erosion.

(b) *Sand Mining*

Commercial sand mining in shore areas as well as in rivers and estuaries contribute to accelerate coastal erosion. Sand mining in rivers and estuaries adversely affect the natural sand supply to the coast, and extraction of beach sand disrupt the natural equilibrium of the shore areas. Usually permits for sand mining are issued by the Coast Conservation Department, and therefore, legal sand mining can be controlled depending on seasonal and regional conditions. However, illicit extraction of sand does a great damage which is difficult to control. In the Kelani Ganga estuary the rate of sand extraction has been estimated to exceed natural replenishment. In the Vallipuram-Ampan area of the Jaffna Peninsula, daily sand removal has been estimated to be 350 tons, which is beyond the safe limits (CCD/USAID/URI 1986).

(c) *Destruction of Beach-Rock*

Some parts of our coast line are protected by the 'beach rock' that occurs more or less parallel to the shore. In some instances it is found adjacent to the shore (e.g. Galle Face, Ahangama) or it is found in the near-shore sea (e.g. Pitipana). Being a geologically recent formation of sand, calcium carbonate and rock debris etc. cemented together, the beach rock forms reefs that harbour a variety of biota like coral reefs. In addition to its ecological importance to fisheries etc., the beach rock protects our coast line from erosion. Yet, blasting of the beach rock, especially to facilitate sea-going vessels has been reported, which is detrimental.

(d) *Construction*

More and more buildings were constructed in the coastal areas, with the expansion of tourism and therefore, retaining walls etc. have been put up on the shore. Not only such constructions are poor in stability, they also deflect winds and hinder free spreading of waves. As a result, waves seeking a new equilibrium erode a new point of the nearby coast. Likewise it is suspected that, breakwaters in harbours obstruct transport of material by the littoral drift and due to this reason some areas of our coastal belt has been left vulnerable to erosion.

(e) *Destruction of Vegetation*

Unlike walls and similar structures built on the coast, coastal vegetation allows movement of wind and waves, although creating some resistance. Even the ground vegetation of the shore composed of such species as *Ipomoea pescaprae* and *Spinifex littoreus* cover the unconsolidated sand, holding the material together. However, such vegetation does not obstruct the free flow of waves on the shore. In coastal lagoons and marshes, the role of mangrove plants in protecting the land is understood. Yet, denudation of coastal areas of vegetation had taken place in many areas.

MAGINITUDE OF THE PROBLEM

Thus far, the areas and causes of coastal erosion of the island has been examined and now, it is necessary to discuss the magnitude of this problem.

The 'Master Plan for Coast Erosion Management' of the Coast Conservation Department (1985) has compared Sri Lanka's coastal erosion problem with that of some other countries (Figure 1). According to this, our erosion problem is generally similar to the same problem of Denmark, New Jersey (USA) and the world. The Master Plan also stated that between 45% — 55% of Sri Lanka's coast line is eroding. In the western, south-western and southern segments of the coast alone, a length of some 340 Kilometres is being eroded.

Although accurate figures of land areas engulfed by the sea cannot be given, the following information may help imagine the dimension of coastal erosion in Sri Lanka. The Alexandria Park of Mattakkuliya which is seen on topographic maps published early this century has been eroded by mid 1950s. A number of near shore islands in the sea (geomorphologically known as 'tombolos') are found in southern Sri Lanka. Sinigama near Hikkaduwa is a good example. Barberyn Island of Beruwala, Pigeon Island of Weligama and Crow Island near Kotuwegoda, Matara are some other examples of tombolos. These islands were originally parts of the mainland, subsequently separated due to the recession of the coast.

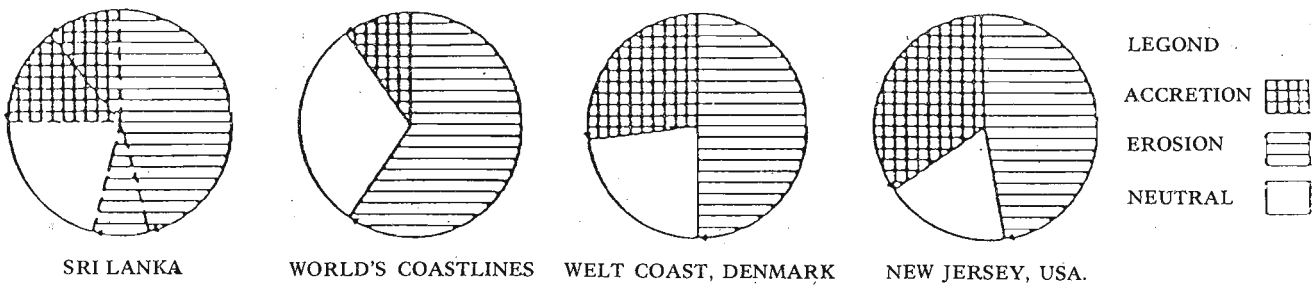


Fig. 1. Graph Depicting Coastal Erosion in Sri Lanka, Denmark, New Jersey (US) and the World. (Source: Coast Conservation Dept. 1985 Master Plan

COASTAL EROSION CONTROL

The enormity of coastal erosion has necessitated erosion control action by the government. The first steps for erosion control of the modern era was taken by the Colombo Port Commission in the late 1930s. The pioneering method adopted was dumping of large boulders in places of erosion. Later in the mid 1960s groynes more or less perpendicular to the shore line were set up to abate erosion. Although these structural measures may have some importance, they were inadequate, as a more comprehensive system was in need. Such a comprehensive system was not formed until the establishment of the Coast Conservation Department in 1978, followed by the Coast conservation Act of 1981. Presently, erosion control is not confined to its engineering aspects alone. Control of sand mining in shore areas as well as in rivers and estuaries and the prohibition of coral extraction are examples of a more comprehensive scheme in practice, in spite of the fact that many practical limitations are experienced in these measures.

As coastal erosion is a natural process, people will have to adapt to this natural phenomenon. Yet, coast conservation measures supported by a good awareness on the coastal environment will allow us to maintain coastal erosion within natural limits without accelerating it.

REFERENCES

AMARASINGHE, S. R. 1971
'Coast Protections in Ceylon'. Draft Report EW/3 LP/Genl vol 11, Port Commission, Colombo.

BRUUN, P. 1962
Sea-level rise as a cause of shore erosion *Journal of water ways and Harbours Division* American Society of Civil Engineers. pp, 117-130.

CCD/USAID/URI 1986
Technical Report (Draft) of 'Workshop on Critical Habitats in the Coastal Zone'.

COAST CONSERVATION DEPARTMENT 1985
Report on Master Plan for Coast Erosion Management.

COASTES, J. S. 1935
'The Geology of Ceylon' *Spolia Zeylanica.* 19(2) Colombo.

COORAY, P. G. 1967
An Introduction to the Geology of Ceylon. Natural Museums, Colombo.

DASSANAYAKE S. W. 1982
Coast Erosion in Ceylon. *Trans. Engn. Assoc. of Ceylon.*

DERANIYAGALA, P. E. P. 1958
The Pleistone of Ceylon. Ceylon National Museums.

EATON, R. O. 1961
Coast Protection and Coastal resource Development in Ceylon. U.S. Operations mission report. 83/31/012/2/10057.

GERRITSEN, F. 1974
Coastal Engineering in Sri Lanka. Report on U.N. Mission. 28/6/1974-3/10/1974 Colombo.

KAHAWITA, D. W. R. 1954
Report on beach study in the vicinity of

Negombo Lagoon. *Transactions of the Engineering Association of Ceylon* (Part 1).

KATUPOTA, J. 1985
Evidence of high sea level during the mid-Holocene on the Southwest Coast of Sri Lanka. Boreas 17,209-213.

MADDUMA BANDARA, C. M. 1982
A Survey of Coastal Zone of Sri Lanka Vol.I, II, and III. Department of Geography, University of Peradeniya. (A Research Report submitted to the Coast Conservation Department.)

MADDUMA BANDARA, C. M. 1985,
WICKRAMAGAMAGE, P.
WILSON, W. N.
WICKRAMARATHNE, S. N.
NELSON, M. D.
Coastal Changes of the Crow Island and its Environs. Department of Geography University of Peradeniya. (Research Report submitted to the Coast Conservation Department).

MADDUMA BANDARA, C. M. 1987
WICKRAMAGAMAGE, P.
WILSON, W. N.
The changes of the Kaluganga estuary and Negombo Lagoon. Department of Geography, University of Peradeniya. (Research Report submitted to the Coast Conservation Department.)

PARK, C. 1985
Environmental Hazards. Macmillan, London p-7.

PARANATHALA, W. E. 1954
Thoughts on the organization and protection of coastal works in Ceylon. Transaction of the Engineering Association of Ceylon. (Part 1).

PEOPLE'S BANK 1984
A Census on the Explanation of Sand and Seashell Resources in the Coastal Zone of Sri Lanka. (Research Report, Coast Conservation Department.)

PEOPLE'S BANK 1985
Coast Conservation Special Report. *Economic Review* Vol. II.

SCHWARTZ M. 1965
Laboratory Study of Sea-Level Rise as a Cause of Shore Line Erosion. *J. Geology* 73(5).

SHEPARD F. P. and BEARD, C.N. 1938
Submarine Canyon Distribution and Longtitudinal Profiles. *Geogr. Review* 28:439-451

SOMMERVILLE, B. T. 1908
The Submerged Plateau Surrounding Ceylon. *Spolia Zeylanica* :78-85

Swan, B. 1965
Coast Erosiòn Principles and a Classification of south-west Ceylon's Beach on the Basis of Their Erosional Stability. *Cey. Geographer* 19:1-14

———— 1974
The Coast Erosion Hazard: South-west Sri Lanka. Univ. of New England, Armidale.

———— 1983
An Introduction to the Coastal Geomorphology of Sri Lanka.

VERSTAPPEN, H. Th. 1987
Sri Lanka Geomorphology, *ITC journal 1987-1*, The Netherlands.

WADIA, D. N. 1941
The Geology of Colombo and its Environs. *Spoloa Zeylanica.* 23(1) Colombo.

WEERAKKODY, U. 1985
Geomorphological Evolution of the South western coast of Sri Lanka. MSc. thesis. ITC, enschede.

WICKRAMARATNE, H. J. M. 1985
Coastal Zone Problems of Sri Lanka: A Historical Perspective. Economic Review 11(2). May 85:

WILSON, W. N. 1984
Terrain analysis using the aerial photo interpretation technique: A case study of the area around Valachchenai in the Northeast of Sri Lanka. M. A. thesis, University of Colombo.

ZEPER, J. 1960
Sea Erosion Studies and Recommendations on Coast Protection in Ceylon. *Bureau for International. Tech. Assistance.* The Hague.