

ERODING COAST — A SERIOUS ENVIRONMENTAL PROBLEM

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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 Gerritsen 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	0.1-0.2	10-20
NORTHEAST	TRINCOMALEE	210	40	0.2	10-0
	MULLATTIVU	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

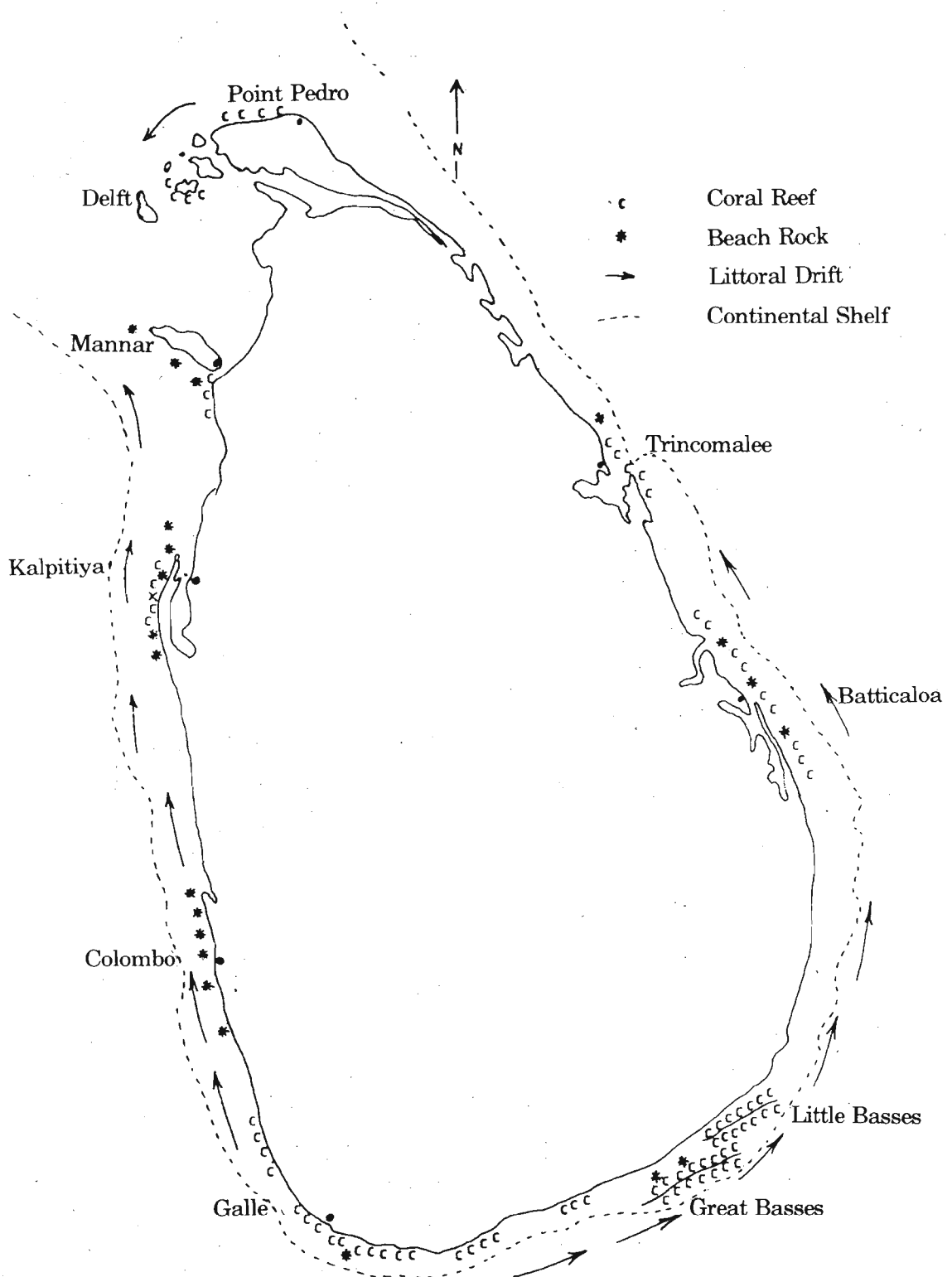
This is a climatic factor as opposed to the other natural factors that are primarily geological. In Sri Lanka coastal erosion is severe in the two monsoon seasons as strong winds provide more energy to the waves. During the south-west monsoon period of the May-September months intense erosion occurs 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 m³ 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 relatively 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*

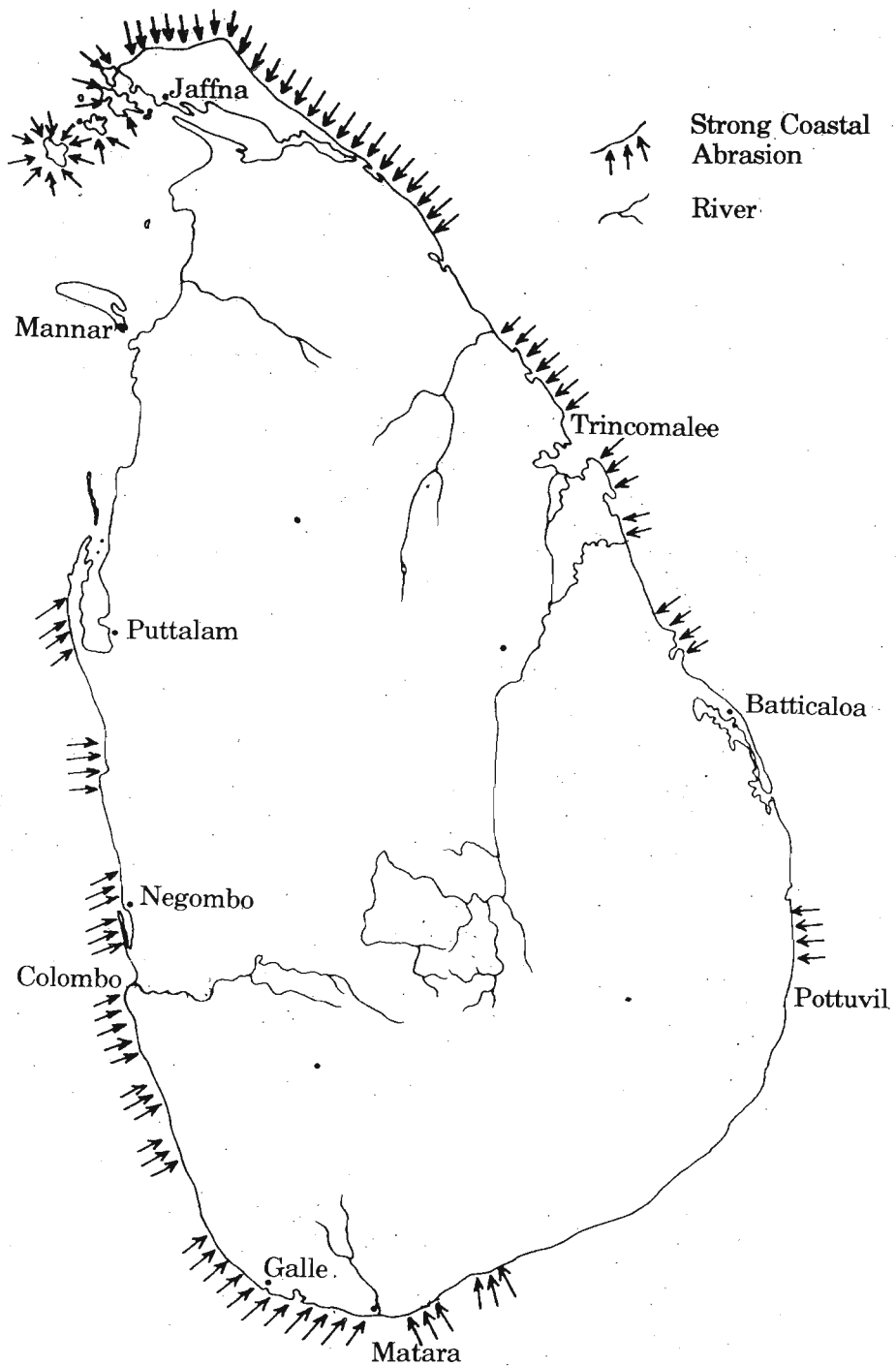
Both field and laboratory studies have shown that sea level rises and coastal erosion are generally correlated. Even the 'Small States Conference on Sea Level Rise' of Nov. 14-18, 1989 was mainly focussed on the sea level rises expected in the next hundred years. Although various predictions indicate 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, occurring 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.

MAGNITUDE 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.

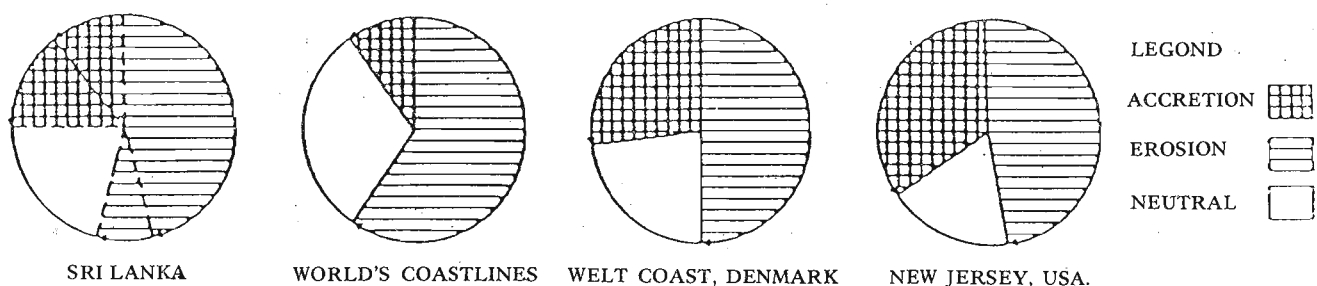


Fig.1. Graph Depicting Coastal Erosion in Sri Lanka, Denmark, New Jersey (US) and the World.
(Source: Coast Conservation Dept. 1985 Master Plan)

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.

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BENEFITS FROM THE FOREST*

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Introduction

A forest may be defined as an extensive stretch of land covered with a rather tall and dense tree growth. Forestry, in its broadest sense, is the science and art of raising and/or managing forests. The trees in a forest need not necessarily have sprung up there by natural means; in fact, many forests in the world today are either wholly man-made (called forest plantations) or are natural forests that have been modified to a greater or lesser extent by man.

In many countries, including Sri Lanka, land which has had no forest cover in the recent past is planted up with forest species. This practice is called afforestation. If the land on which a forest plantation is raised had earlier contained a forest cover, then the practice is called reforestation. Reforestation is practised extensively in Sri Lanka.

There are other terms that are used when referring to forests. "Scrub" is a type of open woodland where there are no tall trees. "Jungle" is an Indian word adapted for use in English, and it generally refers to a whole range of tree and shrub growth with a suggestion of wildness for which the term "bush" is used in Australia and throughout Africa.

We know from observations that an area which is left bare is always subject to colonisation by plants. What species of plants colonise the area will depend firstly on what propagules reach the area by dispersal from plants outside it. It will also depend on climatic and soil factors in relation to the tolerance limits of the species whose

propagules reach the area. The colony of plants so established is not stable. The plants exert an influence on the habitat e.g. organic material accumulates due to the death and decay of the plants. The effect of these changes is generally to improve the soil conditions and the micro-climate. Under the changed conditions new plants which had earlier found the area inhospitable get established and the original colonisers get gradually displaced. This process of change is called plant succession. It could be observed everywhere, even in one's own garden if left unattended. Eventually, if left to nature, shrubs and, later, trees could colonise the area. The process of succession leads finally to the establishment of a stable climax community. The climax community that develops in an area is, therefore, the highest expression of the factors of climate and soil that influence vegetation. In most areas of the world the stable climax ecosystem is forest, and at one time, before modern man's drastic impact on natural vegetation, most of the land area of the world was actually covered by forest. Much of this has now been cleared for shifting cultivation, organised agriculture, providing raw materials for industry and so on.

From what has been stated above it is clear that in any area there is an interaction between the organisms on the one hand and the soil and climate on the other. A climax forest is then the stable ecosystem that develops in an area. In such an ecosystem the biotic factors (trees, shrubs, herbs, animals and micro-organisms including those in the soil) are in equilibrium with one another and with the abiotic factors, the climate and soil. If the climax ecosystem in an area is destroyed and the area left to nature, the

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process of succession will start again leading eventually, perhaps after many decades or even a few centuries, to the climax.

The widely held concept in countries like Sri Lanka two or three decades ago was that forests represent unutilised land and a storehouse of timber. If either land or timber was required the forest was cleared. The situation has changed dramatically in the past few decades, and considerable concern is now being expressed at the large scale destruction of forests that is taking place worldwide. Whereas earlier one spoke only of what one could get out of the forest by way of timber and other products, it is now recognised that forests have an equally important role to play in ameliorating the human environment. Forests therefore have two distinct functions in relation to man. These could in short be described as the productive and protective functions.

Protection and production appear to be conflicting interests; one demands that the forest be conserved and the other that it be exploited. Then again, for production to go on, on a sustained basis, one must ensure that removal does not exceed growth. All these factors and many more have to be resolved in the scientific management of forests which is an intricate exercise demanding a knowledge of numerous disciplines like botany (growth, flowering and fruiting), soil science (soil preferences of different species), zoology (effect of insects and other animals on the trees and on timber in use), engineering (forest roads and buildings), economics (many forest projects have to be justified on economic grounds), and so on. Now perhaps one understands why forestry is defined as the science and art of managing forests. The management must be done in such a way that man derives the optimum benefit on a sustained basis.

With regard to production, timber is the principal product of the forest. It is a material of the utmost importance to man and is today used for wide ranging purposes such as the manufacture of paper and rayon, for building construction work, and for transmission and telegraph poles. Besides timber, there are numerous other products that are derived from the forest. These include lac (an important industry in India), medicinal

products (eg. Aralu, Bulu, Nelli, Weniwelgeta, etc.), turpentine (from *Pinus*), beedi leaves (from *Diospyros melanoxylon*), etc. These are collectively called minor forest produce.

Indirect Benefits

Forests exert a profound effect on the environment, generally making it more congenial to man. These are the protective benefits from the forest. Conserving forests is necessary also for preserving the indigenous gene pool represented by the natural vegetation of a country.

Forests and Rainfall

As has been stated earlier, climate and soil are important environmental factors that determine the type of forest that develops in a given area. But the forest also interacts with the climate and soil and modifies these factors.

The factors that cause the south-west and north-east monsoons which are the major determinants of the rainfall regime of the island are located far away from the country, and the presence or absence of forests can have no effect on them. However, forests could influence precipitation in the following ways :

- (a) Evapotranspiration and the upward movement of a warm, moist air current occurs in the forest as a result of solar radiation. When this air rises well above the forest canopy and is cooled in the upper atmosphere it can no longer retain the water it was able to carry as vapour when it was warm, and the vapour then condenses and falls as rain. This is called convectional rain.
- (b) The relative humidity in a forest is usually much higher than outside. This is due to the greater evaporation and transpiration within the forest and the restricted air movement as a result of which humid air tends to remain *in situ*. If there is a big difference between day and night temperatures as is the case in the months January and February, particularly in the Dry Zone, the moist air that is trapped in the forest

during the day cools at night and this results in the condensation of water vapour which drips from the leaves and flows down the stems to add moisture to the soil (occult precipitation).

- (e) When moisture laden winds blow over mountain ranges they are deflected upwards into the cooler altitudes where moisture condenses and comes down as rain. If the mountain ranges are forest-clad, the winds are deflected to a greater height because of the presence of the forest canopy and this results in a greater cooling effect and consequent increased moisture condensation.

Forests have a profound effect in reducing wind velocity and so rendering wind-swept areas more hospitable. Hence it is a common forestry practice to raise forest plantations in the form of shelterbelts in areas devoid of forests and subjected to strong winds. Shelterbelts of Eucalyptus and other species have been raised by the Forest Department in the wind-swept Dry Patanas in Keppitipola (at one time called Palugama), between Welimada and Nuwara Eliya, and at Harasbadde (near Ragala) to serve as windbreaks. Windbreaks of forest plantations are raised in the form of belts more or less at right angles to the general wind direction. A single row of trees is inadequate to serve as an effective windbreak. At least three rows are required; the middle row consisting of trees with high crowns, and the two lateral rows of shorter, low-branching trees.

A windbreak slows down the velocity of winds on the leeward side up to a distance of about 20 times the height of the break. Over extensive areas, therefore, it is necessary to have a series of parallel windbreaks.

A forest soil generally differs appreciably in its physical features from the soil in an open area. It generally has a crumb structure and a high water-holding capacity; there is a constant input of organic matter in the form of litter and other decomposing plant and animal remains. There is also a rich microflora and microfauna. The soil of a forest generally acts as a sponge taking up rain water when available in quantity and releasing it gradually afterwards.

What happens during heavy rain in a forest? At first the leaves and branches get wet and a fair quantity of water is used up in this. With continued rain the water reaches the ground as stem flow (down the stems of the trees) and as drip from the leaves. The impact of the rain fall on the soil surface is therefore much less severe than if the rain were to fall directly on the soil as in a deforested area. Moreover, the soil in a forest is protected by a more or less thick layer of leaf litter which is absent in an open area. Having reached the surface of the mineral soil, the water is then readily absorbed by it. As the soil gets saturated, the water percolates downwards to the water table. When there is a prolonged period of rain the water table rises, and the water in the soil, moving laterally, emerges as springs. Even in rainless periods the soil is moist because of its high water holding capacity and there is a reasonable dry weather flow in the water courses. When there is heavy rainfall in a forest, even if there is surface run off, the water is found to be clear and silt-free.

In an area that is deforested the rain drops strike the soil surface directly, and, in consequence, the spongy, crumb structure of the soil is soon destroyed. This process is accelerated because of the reduced input of organic matter. Hence, a good part of the rainfall in a deforested area flows along the surface as run off and it carries with it the top soil causing sheet and gully erosion. The silt and other soil particles that are carried by the force of the flowing water ultimately get deposited in the beds of rivers. This occurs as the carrying power of the water drops due to a slowing down of the rate of flow.

This deposition, occurring year after year, causes a raising of the river beds and consequently an increase in the incidence and intensity of floods. At the other extreme, during rainless periods, the soil which had retained only a small fraction of the rain water received during the preceding wet weather, soon dries up and the dry weather flow of springs is reduced to a trickle or disappears altogether. So with extensive deforestation, the intensity and frequency of floods increase during the rainy periods and the drought conditions become acute during the rainless months. This effect of forests on the water regime of the soil and on the environment in general is more impor-

tant than an increase in the rainfall that forests could bring about.

Conservation of the Gene Pool

Another benefit of considerable importance is the preservation of the gene pool (sum total of the genetic material) represented by the flora of a country. This is of special importance in Sri Lanka where about a quarter of the flowering plants are *endemic* to the country i.e. they are species that are found only in Sri Lanka. Unless suitable extents of natural forests are preserved without exploitation, there is the very real danger of extinction of some of the endemic species, and hence the loss forever of the genetic material (represented by these species) that has evolved over millions of years. This applies to animals too. For this reason, the Forest Department has demarcated certain natural forest areas in the major bioclimatic zones of the island and declared them as special reserves under UNESCO's Man and Biosphere Programme. One of these is the Sinharaja Reserve where timber felling which had been done in about a quarter of the 22,000 acre Reserve has now ceased.

Direct Benefits

Supply of wood which is the main product of the forest is the principal direct benefit man derives from forests. Wood is one of the oldest construction materials known to man and it still continues to be widely used. Wood is light in relation to its strength and as a result of this, quite large sizes can be handled manually. It is also comparatively easy to work with simple tools, and it can be used for virtually any construction work. Wood is also used for a variety of other purposes such as the manufacture of rayon, fibre board and particle board. It is therefore easily the most important and useful product obtained from the forest.

In Sri Lanka about five million cu. ft. of timber (fuelwood excluded) are extracted from the state

forests annually. Wood is used in its natural form by sawing or by peeling into veneer or is chipped and reconstructed into particle board. Wooden poles are put to many uses ; transmission and telegraph poles, fence posts, and as a construction material in rural housing. One of the most important uses of wood in Sri Lanka as well as in other developing countries is as a domestic fuel.

Besides wood there is a host of other products that could be obtained from the forest. These are collectively called minor forest products.

Minor Forest Products

There are numerous products besides timber that are obtained from the forest, and some of these are of considerable commercial importance.

Wattle extract for tanning leather is a product obtained from *Acacia mollissima*. This species is grown in the Kandapola area, but except for some trials that were carried out, no commercial extraction has yet being done. Species of mangroves and *Cassia auriculata* (Ranawara) also produce tanning material.

Various types of essential oils are distilled from forest species like *Eucalyptus* spp., cypress, *Pinus*, etc. Oleoresins suitable for use as an incense are obtained from *Canarium zeylanicum* (Kekuna) by tapping the bark. Gums could be obtained from quite a few species. Trees of the family Dipterocarpaceae yield resins that can be used for making French Polish, varnish and similar products.

A number of products (bark, fruits, stems etc.) used in Ayurvedic medicine are collected from the forest. Beedi manufacture is an important industry in Sri Lanka. The wrappers used are the leaves of *Diospyros melanoxylon* — a species which is found in Sri Lanka but not in adequate quantity to make commercial exploitation possible.

SOME HYDROLOGICAL ASPECTS OF THE KNUCKLES REGION

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&

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Introduction

Knuckles region is the mountain mass which lies north-east of Kandy and separated from the rest of the Central mountains by Dumbara Valley. The main parts of this region are made up of Knuckles mountain range stretching from Laggala in the north-west to Medamahanuwara in the south-east. There are several high peaks along the length of this range, namely Gombaniya (6248') the highest, Knuckles (6112'), Kehelpothdoruwegala (6016'), Kirigalpotta (5403'), Dumbangala (5385'), Kalupahana (5341'), Dotulagala (5164'), Wamarapugala (5110'), Telambugala (4368'), and Laggala (4342'), —(Cooray, 1956).

The Knuckles range acts as an effective barrier to both monsoonal winds. Western slopes receive a heavy rainfall with the South-west monsoon and during the North-east monsoon from October to January the whole area receives a very heavy rainfall accompanied by strong winds. The Knuckles region can be identified as the second highest rainfall area in the Mahaweli basin. There are several perennial streams originating from the Knuckles range and it forms a very important catchment area for Mahaweli Ganga Basin. Kalu Ganga in the north, Heen Ganga in the north-east and Hulu Ganga in the south of this region are important tributaries which contribute perennial waters to Mahaweli and its reservoirs.

The gross area of the the Mahaweli Development Scheme is 2.5 million ha. which is approximately 55% of the dry zone and 39% of the total area

of the country. The non availability of irrigation water in the quantities needed and the under-utilisation of power station capacities resulting from the reduced dry season water flow and erosion caused siltation of reservoirs will seriously undermine the viability of such an important Irrigation Project. Therefore it is important to look into the hydrological regime of this region and take necessary steps to conserve the forest vegetation in order to minimise erosion, maintain dry season flow and availability of water in the reservoirs year around. Now it has been identified that the area above 3500 feet contour and the continuous forest area even below this, which makes the total extent around 22,000 ha. in the Knuckles range (Sketch I) is critical for conservation of the watershed and genetic resources of the region. These areas have to be declared as a forest reserve to provide legal status to afford better protection as an important watershed in the Mahaweli basin.

Geology and Soils

The rocks of the region belong to the Metamorphic Group and are predominantly quartzites, quartz schists and gneisses. Among the rock types commonly found in the region are Garnet — biotite — graphite gneisses, Garnet — sillimanite — granite schists and gneisses Crystalline limestone, Charnockites. (Cooray, 1956). The soils in the region are mostly lateritic soils derived in situ from the metamorphic parent rock. They are generally well drained and deep except in places associated with steep terrain. The forest soils are

mostly dark brown with considerable humus accumulation in the wet montane forest zone (Rosayro, 1958).

Catchment Areas and Drainage Pattern

The main features of the drainage and catchment areas are shown in sketch II. There are several rivers draining the Knuckles region. They are :

(a) Kalu Ganga, which drains the northern section of the region flows in the direction of south to north. This forms the chief headwater stream of the Amban Ganga which is one of the major tributaries of the Mahaweli Ganga. The drainage basin of Kalu Ganga is confined mainly to the montane zone of the Knuckles region, generally over 4000' elevation. Halmini Oya and Karamana Oya form major tributaries of this river. Wamarapugala — Kalupahana ridge from the east, Selvakanda plateau from south and south-west and Kirigalpotta from the west demarcate the boundary of the Kalu ganga catchment, which covers approximately around 30% of the total area of the Knuckles region.

(b) Heen ganga drains the eastern section of the region and flows in the direction south to north-east. The main stream of this river is Maha Oya of which the upper reaches is known as Karambakkitiya Oya. Head waters of Meemare Oya which is also a tributary of Heen ganga originate from Kalupahana ridge and it is separated from Kalu ganga by a distance of only 500 yards. Kalu ganga originates from the western slope of Kalupahana ridge and Meemare Oya from the eastern slope of the ridge. Other tributaries of Heen Ganga are Kakaliwatta Oya and Rawana Oya. Ridges of Kalupahana, Knuckles, Dumbanagala and peaks of Laggala and Kehelpothdoruwegala mark the boundary of the Heen Ganga catchment. These areas also cover approximately around 30% of the area of the Knuckles region.

(c) Head waters of Hulu Ganga are a number of small streams including Kota Ganga and Hini Oya. These streams drain the western face of the Knuckles region and flow in the general direction

of South-west. The main ridge of mountains Kirigalpotta, Gombaniya and Knuckles running NW-SE forms the northern and eastern boundary of the drainage area of tributaries of Hulu Ganga. This drainage area covers about 35% of the total area of the region.

(d) Teligam Oya is another small stream originating from the Knuckles range. This forms the headwaters of Kambarawa Ganga which is a tributary of Amban Ganga.

The streams which originate from the main Knuckles range generally over 3500 feet elevation within the wet montane forests, are perennial and other streams which originate at lower elevations are seasonal.

Hydrological Importance of the Knuckles region

The Knuckles region has been identified as one of the most critical watersheds which requires immediate attention. The first interim report of the Land Commission of 1985 has specifically identified the Knuckles region as one of the major source regions of water for river systems in this country and the report recommends formulation of a Watershed Management Master Plan which should pay special attention to the conservation of stream source areas of Knuckles range and other identified areas. Hydrological importance of the Knuckles region can be discussed under the following headings :

(a) *High Intensity Rains and the Steep Terrain.*

The rainfall distribution in the region exhibits a marked seasonal variation. Western slopes receive a heavy rainfall between May and August with the South-west monsoon. During the North-east monsoon from October to January northern slopes receive more rain but the whole region receives a very heavy rainfall accompanied by strong winds. Generally, these rains are of high intensities with a capacity to cause serious erosion problems. The mean annual rainfall of three major catchment areas in the region are given below (Madduma Bandara, 1985) :

Table 1

River Catchment	Mean Annual Rainfall (m.m.)	Mean no. of Rainy Days per Year
Hulu Ganga	3031.9	183
Kalu Ganga	2724.6	184
Heen Ganga	4281.9	184

In 1971, Madduma Bandara identified five hydrological regions of the Upper Mahaweli Basin based on the relationship between mean annual flood and the catchment area (sketch III). This classification provided an indicator of the rainfall and stream flow of the region. According to this classification, the Knuckles region comes under the category of Hydrological type 2 which is the second rainiest region in the Mahaweli Basin. Mean annual rainfall at gauging stations such as St. Martins (4470 m.m.) in the Knuckles range comes second only to Watawala, the rainiest part of the country.

As indicated earlier, the topography of the region is a rugged hill mass rising up to 6248 feet MSL forming a very steep terrain. This steep terrain together with high intensity rains makes the Knuckles region one of the most critical watersheds in the country.

The relationship of factors controlling soil erosion has been identified as :

A = RKSTCP	A = Soil loss
(Universal Soil	R = Rainfall factor
loss Equation)	K = Soil erodability factor
	S.T = Slope length and
	gradient factor
	C = Vegetative factor
	P = Soil conservation

Among these factors affecting soil erosion we have very little or absolutely no control over factors such as rainfall, soil erodibility and slope. Only factors that we can alter are vegetation and soil conservation which we can consider together as land use. Therefore it is evident that in the face of high erosive rains and very steep terrain in

the Knuckles region the only solution to the problem of erosion is a suitable land use system to protect the soil from erosive rains.

(b) As a Catchment Area of Victoria Reservoir

The useful storage capacity of Victoria reservoir is 698 MCM which could provide 210 MW of Hydro electric power and irrigation requirements for the development of 70,000 ha. of new lands in systems B and C. The total drainage area of the reservoir upstream of Victoria falls is 1891 sq.kilometres of which Hulu Ganga catchment forms approximately around 9%. As indicated earlier, the drainage area of this river in the Knuckles region together with heavy rainfall provides a significant contribution to the waters of the Victoria reservoir. Hence it is important to protect the source areas of waters of Hulu Ganga in order to reduce siltating of the reservoir and maintain the requirements of water for irrigation and hydropower, particularly in the dry season.

(c) As a Catchment Area of the Proposed Reservoirs under the Mahaweli Project

Now that most of the work on the accelerated Mahaweli Programme has been completed, there are still a number of projects in the Mahaweli Development proposals which can be taken up for development. Two proposed Projects which associate with the Knuckles watershed are :

(a) Kalu Ganga Project : Irrigation and Hydropower Project, — Reservoir capacity 208,000 ac ft.

(b) Heen Ganga Multi-purpose Project : — Irrigation and Hydropower Project

When these projects are completed, the Knuckles region will form the major catchment area of the proposed two reservoirs.

Some Hydrological Aspects of Major River Basins in the Knuckles Region

Hydrology Division of the Irrigation Department had maintained stream gauging stations at Telde-niya, Uduwelwala and Wellewela to collect stream flow data from Hulu Ganga, Heen Ganga

and Kalu Ganga respectively. Stream flow data had been collected from these gauging stations only for a few years and are not functional at present.

(A) A summary of hydrological data collected from these stations is given below :

Table 2

Stream and Station	Catchment Area (km ²)	Mean ann. Runoff (m.m.)	Mean ann. Runoff rainfall ratio	Mean ann. Runoff (mcm)*
1. Hulu Ganga (Teldeniya)	160.58	1481.58	48.86	237.91
2. Kalu Ganga (Wellewala)	194.25	1636.77	60.07	317.94
3. Heen Ganga (Uduwelwala)	115.25	2357.88	55.06	271.75

Source : Some Aspects of the Hydrology of the Upper Mahaweli Basin — Madduma Bandara, 1985.

* Calculated by the Author (M C M — Million Cubic Metres)

Please see Table 1 for rainfall data.

Following observations were made from the data given above:

(a) Among the three catchments, Kalu Ganga has the largest catchment area out of which about 35—40% lies within the Knuckles region.

(b) Kalu Ganga carries the maximum volume of water among the three rivers originating from the Knuckles region.

(c) Greater Run off — Rainfall ratio indicates a relatively poor vegetative cover in the Kalu Ganga basin.

(B) Kalu Ganga gauging station at Wellewela was functional from 1960 — 72. The data from this station was obtained from the Hydrology Division

of the Irrigation Department and the following observations were made after analysing the data :

(a) Runoff — rainfall ratios calculated from annual values are considered as an indicator of land degradation. Runoff — rainfall ratio for the 10 year period from 1960 — 70 exhibits a gradual increase which is a clear indication of the land degradation in the upper catchment areas of Kalu Ganga within this period (Table 4). However, the annual stream flow during the period has ranged between 49% — 73% of the annual rainfall. (Mean annual value was around 60%).

(b) There is a marked seasonal variation in the stream flow with a maximum of 92.4 million cubic metres (MCM) in January and a minimum of 1.93 MCM in August (Table 3). Wet flow (October—April) contributed about 93.5% of the total flow, and the dry flow contribution (May) was only 6.5% of the total. This variation in stream flow and extremely high Runoff — rainfall ratios from December — February can be attributed to degradation of land in the catchment and high north—east monsoonal rains during the period of low evapotranspiration. Evapotranspiration during this period is significantly low due to the low temperature and sunshine hours at high altitudes in the Knuckles range. However, if the forest vegetation in source areas of water is protected and enriched, the dry flow can be significantly improved as a result of increased infiltration capacities of soils in the catchment area [Chunkao (1986), Coleman (1953)].

Recommendations

I — The Knuckles region is one of the most critical watersheds in Sri Lanka which requires immediate steps for conservation of soil and water and other environmental conditions. As indicated, a considerable amount of degradation has already taken place in this region and further degradation may lead to serious environmental and irrigation problems. Hence it is suggested that immediate steps should be taken to conserve the forests in the Knuckles region.

II — Appropriate soil conservation methods should be adopted in all arable lands including

tea plantations in the higher altitudes particularly over 3500 feet MSL. Strict implementation of the -Soil Conservation Act within the critical areas of the Knuckles region is necessary to achieve this objective.

III — Some action has to be taken to control indiscriminate felling in the privately owned

forests in higher altitudes (over 3500 feet MSL) of this region.

IV — Finally, it is recommended that hydrological studies be carried out in this region to develop a better understanding of the distribution and disposal of water and process of soil erosion in the Knuckles watersheds.

Table 3
Kalu Ganga
Mean Monthly Data — Runoff and Rainfall

Month	Mean Rainfall (M.M.)	Mean Rainfall (M.C.M.)	Mean Runoff (M.C.M)	Runoff as a % of Total	Runoff/Rainfall Ratio
January	413.33	80.29	92.40	28	1.15
February	307.39	59.71	60.65	18	1.02
March	136.30	26.48	24.20	7	0.91
April	211.96	41.17	18.53	6	0.45
May	94.31	18.32	11.90	4	0.65
June	82.58	16.04	3.34	1	0.21
July	79.12	15.37	2.24	0.7	0.15
August	109.58	21.29	1.93	0.6	0.09
September	114.38	22.22	1.98	0.6	0.09
October	293.34	56.98	6.13	2	0.11
November	431.22	83.76	30.53	9	0.36
December	479.09	93.06	75.50	23	0.81

% to annual rainfall

— 60

% evapotranspiration

— 40

Wet flow %

— 93.5 (October — April)

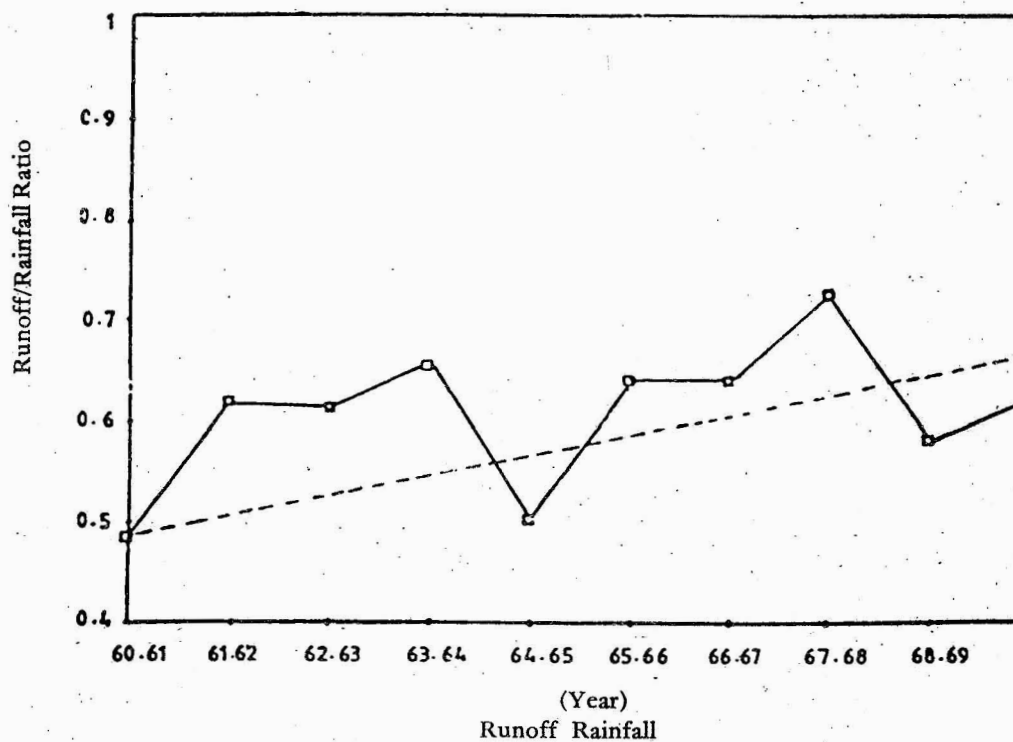
Dry flow %

— 6.5 (May — September)

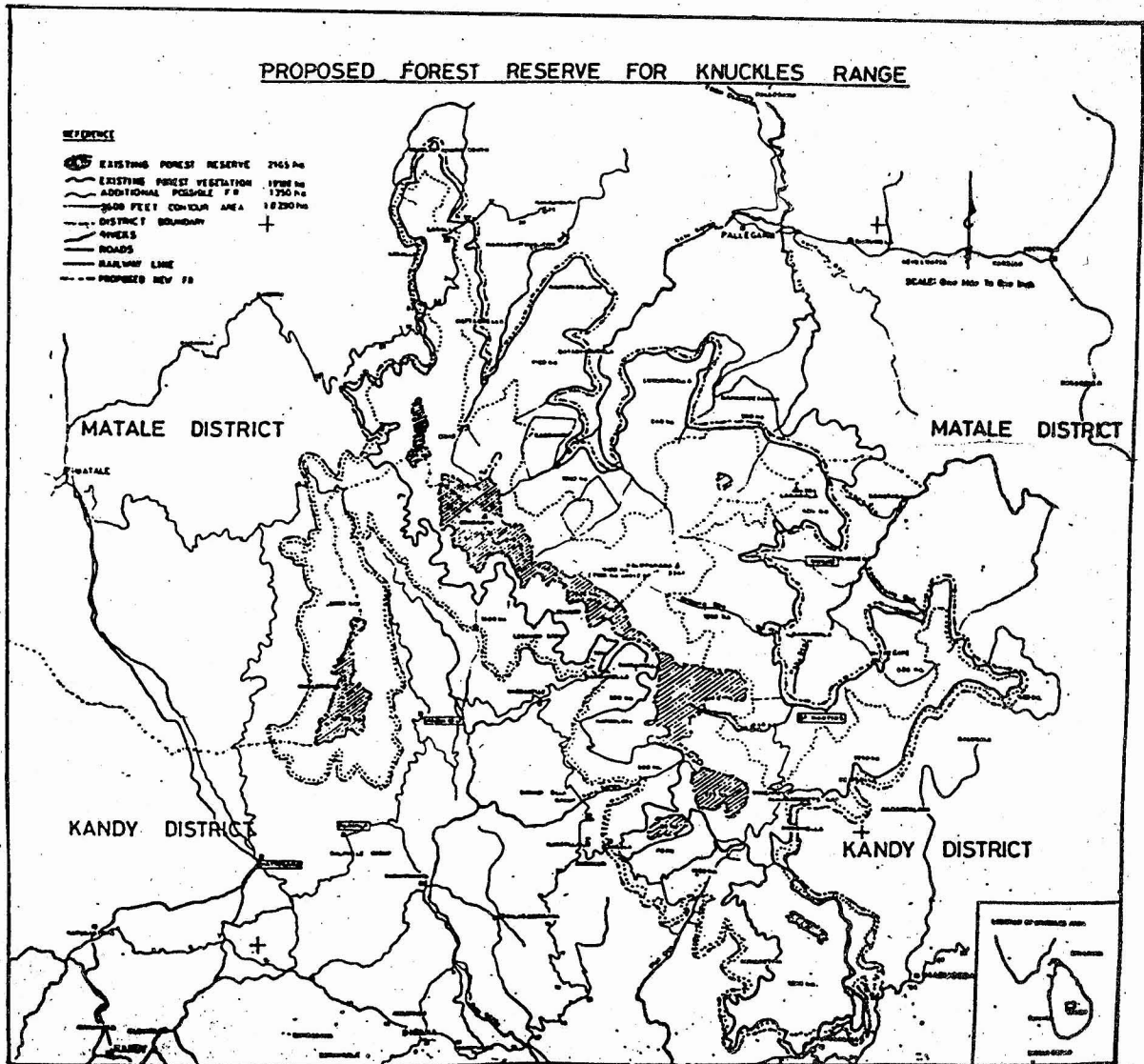
Table 4
Runoff Rainfall Ratio – Kalu Ganga

Year	Rainfall (M.M.)	Rainfall (MCM)	Runoff Volume (MCM)	Runoff/Rainfall Ratio
60-61	2377.17	461.77	225.16	0.49
61-62	3232.90	627.99	390.46	0.62
62-63	3342.38	649.26	399.68	0.62
63-64	3145.52	611.02	403.90	0.66
64-65	2325.62	451.75	228.63	0.51
65-66	2340.36	454.61	293.32	0.65
66-67	2308.60	448.45	288.93	0.64
67-68	2744.71	533.16	389.40	0.73
68-69	2613.68	507.71	298.26	0.59
69-70	3094.99	601.20	375.50	0.62

Runoff/Rainfall Ratio – Kalu Ganga

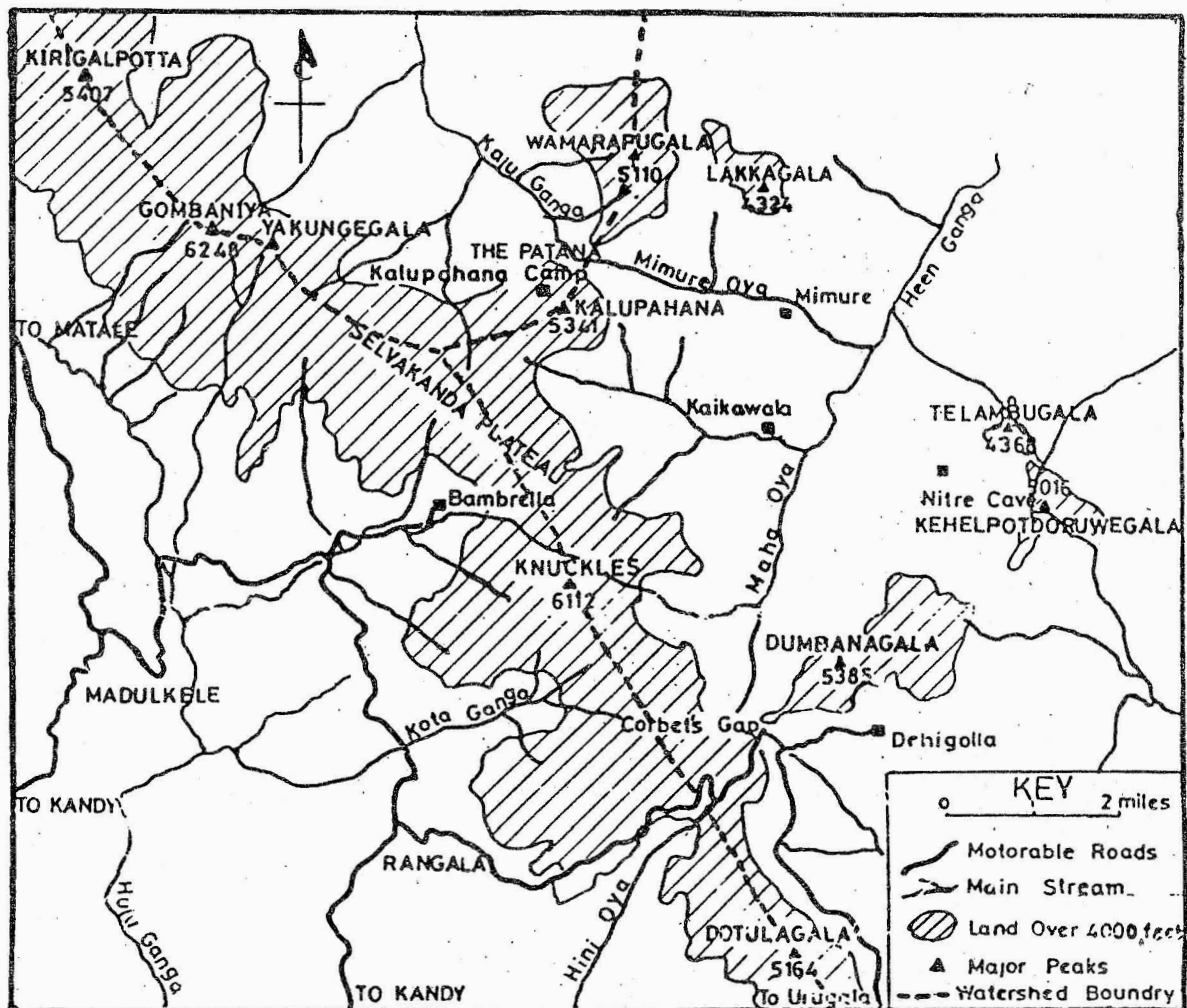


Sketch I



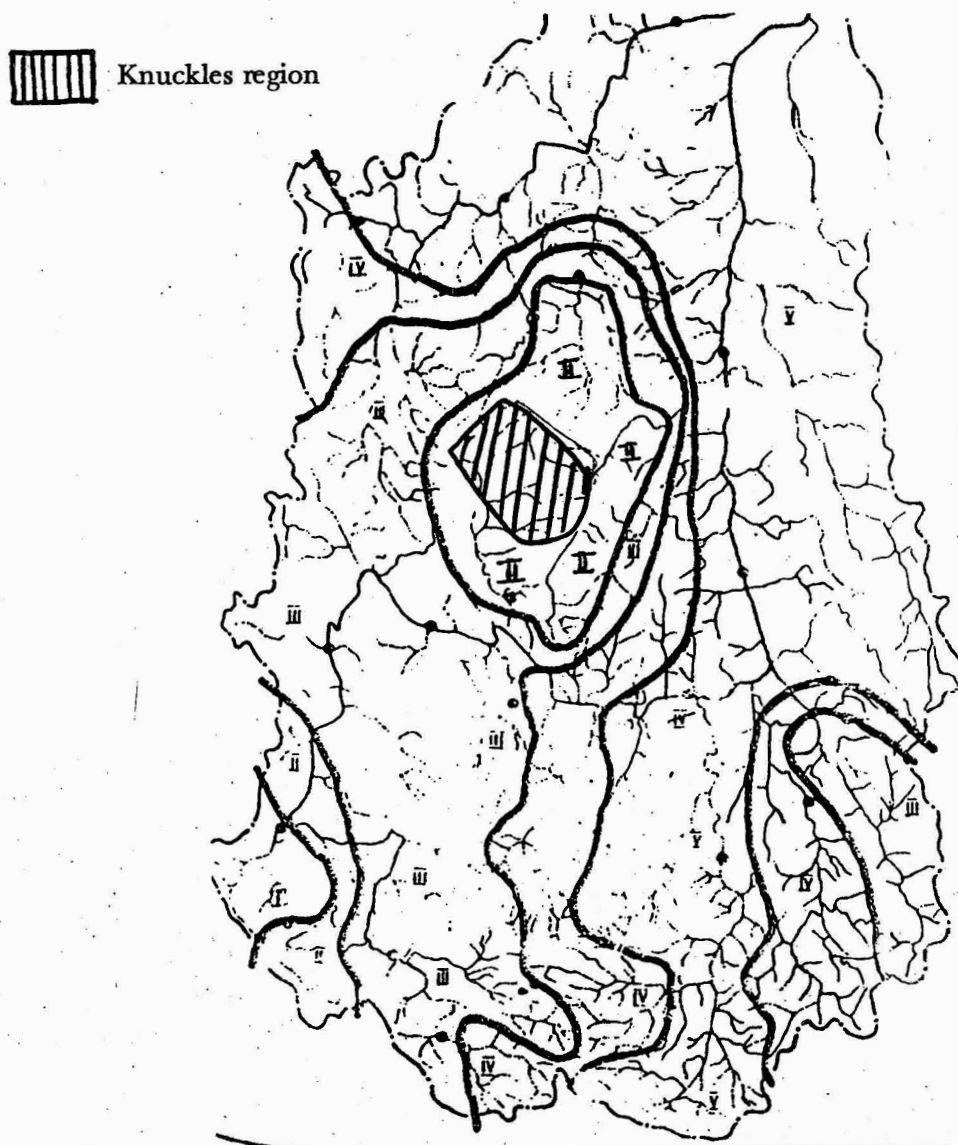
Sketch II

SKETCH MAP OF THE KNUCKLES REGION
SHOWING MAJOR CATCHMANT AREAS



Sketch III

Division of Upper Mahaweli Basin in to Hydrological Regions



Source : Madduma Bandara (1985)

HORTON PLAINS — SOME ASPECTS OF ITS VEGETATION AND ECOLOGY

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Situated in the angle between the western and central ridges of the main mountain massif of Sri Lanka is a plateau of undulating land well known as the Horton Plains. Its average elevation is 2150 m. above sea level. From its Western and North-Eastern ends arise two mountains; the more spectacular 2392 m. tall Kirigalpotta and the less prominent 2206 m. tall Totapolakanda. The southern boundary of this land is a steep escarpment overlooking Balangoda.

Based upon its location 6° 45' north of the equator and its average annual temperature of about 17°C, Horton Plains is subject to a tropical montane climate. The mean monthly temperatures show little variation here, but daily means fluctuate quite widely, particularly during late January, February and early March, when day temperatures reach 25°C and night temperatures close to or below 0°C. Consequently, night frost is a common feature at this time of the year when its climate may be aptly described as 'every day a summer and every night a winter' as suggested by T.C. Whitmore in his book 'Tropical Rain Forests of the Far East'. Other climatic factors include a mean annual rainfall over 2000 cm, very high humidity, frequent cloud cover which limits the amount of sunlight reaching plants and high winds during late August to early October. The interaction of all these climatic features, over many thousands of years has given rise to the vegetation of Horton Plains as seen today. What

intrigues one most about this vegetation is that it is neither completely forest nor completely grassland, but a mosaic of both, each occupying about 50% of the land area. What is even more puzzling is that forests are limited to upper slopes and hill crests while grasslands occupy lower slopes and valleys; both vegetation types appear not to invade each other and a sharp boundary exists between them. This forest-grassland vegetation, though common to the area, is best manifest in the Horton Plains.

The vegetation, climate and some of the larger animals like the bear monkeys and birds are among the obvious features that cannot be missed in Horton Plains. What is not obvious or tangible is the threefold integration of vegetation, environment and animals; in other words the ecosystem of Horton Plains, how it functions and its importance to Sri Lanka. Let us examine some of these features briefly.

In height, the forest in Horton Plains varies between 10–15 m and 1–1.5 m on the summits of Kirigalpotta and Totapolakanda where one looks down on the 'forest'. In appearance most do not have straight stems or buttresses (stilt roots may sometimes be present); they are low branched, twisted and branched, so much so that Mr. W.R.H. Perera, the former Conservator of Forests in the island, reports that they resemble 'giant bonsai of Japanese tree culture'. On the

whole the leaves of these taller trees are small and show drought resistant features such as hairs or a thick waxy layer on their surfaces. Where the forest is wind swept, the canopy is more or less continuous without any characteristic emergent trees. Beneath the tree layer, shrubs and herbaceous forms abound and in them the leaves are relatively large. Other plants that predominate are the epiphytes growing on the tree trunks and branches, and epiphyllous forms growing on leaf surfaces. Among these plants are orchids, balsams, ferns, mosses, liverworts and lichens. Some of them even grow on rocks, decaying wood or directly on the forest floor. The major factor that determines their growth is the high moisture content.

Plants in this forest belong to either families almost entirely restricted to the tropics and subtropics (e.g. Clusiaceae, the mountain *Keena* family; Myrtaceae, the Guava or Eucalyptus family; Melastomataceae, the *Osbeckia* or *Bowitiya* family etc.) and those common to temperate countries (e.g. Ericaceae, the *Rhododendron* family; Vacciniaceae, *Vaccinium* and *Gaultheria* family; Magnoliaceae, the *Michelia* or Wanasapu family etc.) The absence of plants belonging to the Fagaceae or Oak family and those of the Conifers which are present in mountain forests of the region, is particularly interesting.

Beneath the trees, the treelet and shrub layer is dominated by a single species of plant, viz., *Strobilanthes* or Nelu. This species blooms only once in its life time, after which the plants die. No one knows for sure how long the life span of a single plant is; 4–8 years is the common belief. Most of these plants being of the same age bloom together, imparting to the forest undergrowth a striking mauve colour. The dying *Strobilanthes* though unsightly, permits light to filter through between the decomposing stems, stimulating the growth of herbaceous balsams and *Coleus* on the forest floor. These are short lived species and complete their life cycle before *Strobilanthes* seeds germinate and subsequently establish. When the *Strobilanthes* begins to grow, the ground layer of the forest takes on a carpet like

appearance. Apart from *Strobilanthes*, members of the Rubiaceae, the coffee family, are abundant in the undergrowth. Among the non-flowering plants, primitive members of the ferns such as *Psilotum* and *Lycopodium* (related species of kuda-hedeya and maha-hedeya) and their advanced members such as the filmy ferns, and numerous mosses such as *Frullania*, *Bazzania* and *Sphagnum* are present either as epiphytes or terrestrial forms. In clear flowing unpolluted streams that arise from the forest, the only species of fresh water red algae in Sri Lanka, namely *Batrachospermum* may be seen.

The soil underlying the forest vegetation is equally dynamic and has its own flora and fauna. Bacteria and fungi abound in the soil flora and the existence of the latter is only evident when some of them produce their fruiting bodies or the familiar mushrooms which are of various forms, sizes and colours.

In the grassland, the dominant component is the 1–1.5 m tall tussock grass *Chrysopogon zeylanicum*. Scattered among this grass are a few shrubs and stunted trees; four among them are the familiar red flowered *Rhododendron zeylanicum*, the small white flowered *Gaultheria* sp., whose crushed leaves emanate a wintegino-like aroma and the yellow or white flowered *Anaphalis* spp., whose stems and leaves are covered with cottony white hairs. In the shade and protection of the grass, numerous herbaceous plants with delicate but beautiful flowers may be seen. Where streams flow through or moisture is high in the shallow valleys of the grassland the dwarf bamboo, *Chimonobambusa densifolia*, may be seen growing luxuriantly.

Thus, in the forest and grassland of Horton Plains, different types of plants, ranging in size and shape, exhibiting various degrees of complexity grow in micro-habitats well suited to each of them. This diversity of plants, apart from other features, tells the story of evolution itself.

Complexity and diversity of animals and plants impart a dynamic equilibrium to fragile ecosystems such as the Horton Plains. Such systems are

therefore relatively stable provided they are not subject to man's influence or major natural catastrophes like earthquakes etc. The forest in Horton Plains is not merely a stand of trees; but trees provide micro-habitats for the rest in this system. One might surmise that shrubs and herbs do not contribute to the well being of the trees; no, they benefit each other. Shrubs and herbs maintain a suitable ground cover, protect the soil, retain high humidity and provide a suitable soil temperature to facilitate the growth of tree seedlings as well as their mature individuals.

Among the applied uses of Horton Plains, four may be considered important and presented here. They are its contribution to the country's (1) education, (2) hydrology, (3) gene pool conservation and (4) future agriculture.

(1) Education: Like all natural vegetation types, Horton Plains is a valuable resource for teaching. With the diversity of plant and animal life in it, students of Botany, Zoology and Ecology in particular could be made to understand various aspects of these subjects. In the class room, students must depend entirely on the teachers' descriptive ability and enthusiasm as well as their own imagination. Whereas in the field, the student sees nature for himself and the reality, thus giving the student ample opportunities to develop an inquiring and perceiving mind. Ecosystems like Horton Plains are yet under-utilised for purposes of education but their potential for it is enormous.

(2) Hydrology : Horton Plains serves as a part of the catchment area or watershed for the Mahaweli river. From the Western and Northern sides of the plains tributaries of the Agra Oya and Nanu Oya respectively, and on its East those of both the Uma Oya and Badulu Oya all originate eventually finding their way to the Mahaweli river. In addition, uppermost tributaries of the Udawalawe river, including the Belihulu Oya originate on the Southern side of the plains near Baker's falls and World's End. The natural montane forests of Horton Plains are well adapted to capture, retain and release precipitation

falling on them, unlike the Tea estates that surround it. The multi-layers of trees, climbers and epiphytes growing on tree trunks, branches and surfaces have the ability to intercept the rain. Once these surfaces are fully saturated water is slowly released to the soil where it is first absorbed by the leaf litter and humus. After this, any excess water will infiltrate the soil. Only when all these surfaces are fully saturated will surface runoff begin. Thus, every part of this complex ecosystem acts as a reservoir of water. More complex the vegetation, greater its potential as a water shed. The epiphytic lichen, moss, liverwort and fern flora in these forests play an important role in the capture of water. According to Prof. D. Mueller-Dombois, an ecologist at the University of Hawaii, these plants have the ability to comb out water from the mist that hangs and settles on these forests at night, particularly during the dry seasons. This, to some extent ensures dry weather flow in the streams that originate from Horton Plains. No grassland or monoculture Tea, *Pinus* or cash crop has a rich lichen, moss, liverwort and fern flora as the natural forest. Consequently, these simple vegetation types do not equal natural forests as efficient catchment areas and watersheds.

(3) Gene Pool Collection : The vegetation of Horton Plains is a collection of plants with many future potential uses in the fields of horticulture, agriculture and medicine. It is to ecosystems like Horton Plains that one would return to, to find suitable plant material for crop diversification.

Even today several plant collectors from overseas Botanic Gardens have collected plants from habitats such as Horton Plains and grown them in their own Botanic gardens for horticultural purposes. Among these plants are species of *Strobilanthes*, *Exacum* and *Gordonia*, all of whose flowers are exceptionally beautiful and attractive. Similarly, other species are of medicinal value (*Rubia* and *Lycopodium*) and yet others of food value.

(4) Future Agriculture : Apart from the value of potential agricultural plants in the vegeta-

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tion of Horton Plains, the forest as a whole gives one an indication as to what man might achieve in artificial or man made multicropping systems of these mountains. Examining details of how the natural forest is structured and how it functions will certainly shed light useful to agriculture at similar elevations and climate. The efficiency with which these natural forests function are time tested. Can we not study them and see whether this knowledge could be applied to future agricultural systems? Horton Plains with forest and grassland side by side certainly serves as a valuable model for future agriculture.

Last it must be mentioned that the Horton Plains ecosystem is changing. As far back as 1978 Mr. W. R. H. Perera, who was referred to earlier in this article, reported that the trees of Horton Plains are dying. In various parts of the world 'Die Back' of forests have been documented and

the causal factors for this phenomenon are being researched upon. In the case of Horton Plains one does not know what factors triggered this 'Die Back'. Are they man induced or natural? If natural, were the present grasslands, whose origin is believed to be due to natural causes, a result of similar conditions that prevailed several thousand years back? Would the present forests be replaced by grasslands? If the factors are man made is it a warning that man has gone too far in destroying the natural environment? **Whatever** it be, the fact remains that the vegetation of Horton Plains is changing. Just as much as the rolling landscape, silence and vastness of the plateau and beauty of the forest-grassland ecosystem draws man to itself, the current changes disturb and worry the ecologist who asks 'What is the future of this forest-grassland ecosystem of Horton Plains?'. Will generations to come see it as we see it today or would it be quite different?

NATURAL VEGETATION TYPES OF SRI LANKA

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According to the most recent estimate of the Survey Department, the natural vegetation of Sri Lanka covers 24.9 per cent of the land area. It comprises different vegetation types which can be described in various ways. However, the following classification according to the climatic zones is widely used. (Table I). In addition, there are other plant communities such as grasslands, Savannah forests, Mangroves and other coastal communities which are not peculiar to any climatic zone.

Table 1

Different Vegetation Types of Sri Lanka according to
Climatic Zones

Vegetation Type	Climatic Zone
Tropical Wet Evergreen forests/ Tropical Rain forests.	Wet Zone
Tropical Montane forests	Wet Zone
Intermediate Zone forests	Intermediate Zone
Dry mixed Evergreen forests	Dry Zone
Tropical Thorn forests	Arid Zone

Tropical Wet Evergreen Forests/Tropical Rain Forests

This forest type is the climax vegetation of the wet zone occurring in the South — Western sector of the country. It extends from coast to the mid elevations of about 1500 m. This area receives an

annual rainfall of 2500 mm. — 5000 mm. with no moisture deficit period. The mean temperature is about 28°C. The area is humid, with relative humidity varying from 75% — 85%. The soil type is the Red, Yellow Podzolic.

Rain forests are complex vegetation structures. The vegetation is dense and well packed growing luxuriantly under the favourable climatic conditions. The plant density of this forest type is very high. A great diversity of species and a high proportion of endemics have been reported from the Tropical Wet Evergreen Forests.

Vertical stratification is very distinctive. The tallest trees or the emergents are scattered and do not form a continuous canopy. The main species are *Dipterocarpus zeylanicus* (Hora), *Dipterocarpus hispidus* (Bu—Hora) and *Shorea* which may reach a height of 45 m. The canopy well packed with tree crowns may reach 25–30m. in height. The dominant canopy species are the *Mesua nagassarum* (Batu—na), *Chaetocarpus castanocarpus* (Hedawaka), *Anisophyllea cinnamomoides* (Welipiyanne), *Myristica dactyloides* (Malaboda) and *Shorea* species. The sub canopy and the understorey layers are prominent below the canopy.

Below the understorey is the layer of shrubs, treelets and saplings. The ground is covered with many species of mosses, ferns, and herbs. The woody climbers twine around trees and climb up to the canopy. Epiphytic orchids and ferns are common at all levels of the vertical structure.

Among the large trees, columnar tree boles are typical. Branching (when present) begins quite high while a considerable number of species are unbranched. The large trees are supported by plank buttresses specially because of the shallow root systems. Some species have even developed stilt roots for support. Another noteworthy feature of the rain forest is the driptips of the leaves. This elongated leaf may probably be an adaptation to drain off the excess moisture which constantly collects on the leaf surface. Flowers and fruits arise directly from the main trunk or branches. This phenomenon known as 'cauliflory' is peculiar to rain forests. Young leaves develop bright colours for protection from harmful

turbid in some protected areas viz Sinharaja, Hiniduma Kande and Kanneliya.

Tropical Montane Forests

This forest type occurs in the South — West slopes of the mountain ranges above 1500 m. in the wet Zone. This area also receives an annual rainfall of 2500 mm. — 5000 mm. with no moisture deficit period. The mean temperature is about 20° with occurrence of frost frequently in higher peaks.

The vertical structure of this vegetation type is less prominent with a low number of strata. The trees are of much smaller stature reaching only

Table 2
Extents of Forests in Sri Lanka

Vegetation type	Percentage Forested with respect to the Total Land Area in each Zone	Percentage Forested with respect to the Land Area of the whole Island
Tropical Wet Evergreen Forests/Tropical Rain Forests	9.1	1.45
Tropical Montane Forests	17.8	1.54
Intermediate Zone Forests	1	Negligible
Dry Mixed Evergreen Forests	30.3	21.97

radiation. The nutrients of rain forests are mainly accumulated in the biomass. The shallow root systems are well adapted to absorb nutrients released to the soil by decomposition of organic matter and weathering. A symbiotic association between tree roots and fungi referred to as mycorrhizae further facilitates nutrient absorption. This rapid cycling ultimately leads to impoverishment of forest soil.

Although once extensive, this forest has presently been reduced to 1.45 per cent of the land area of the whole island. (Table 2). It still exists undis-

about 13 m. in height at canopy level. The appearance of trees is twisted and gnarled particularly at the branches. Dense, spreading crowns of the canopy trees are flat topped. Leaves of many tree species are leathery and very small. The main tree species of the plant community are *Elaeocarpus glandulifer* (Thittha veralu), *Elaeocarpus serratus* (Honda—Veralu), *Mastixia tetrandra* (Diya—Thaliya), *Michelia nilagirica* (Sapu) and *Calophyllum walkeri* (Batu—keena).

Below the canopy layer are the small tree species *Cinnamon* sp. (Kurundu) and *Rhododendron*

arboreum (Maha-Ratmal). The dense undergrowth comprises shrubs viz. *Psychotria nigra*, *Strobilanthes* sp. and hill bamboos. Epiphytes, orchids and lichens are in abundance. The lichen, *Usnea barbata* commonly known as "Old man's beard" hangs down from the branches of trees. The ground layer consists of many herbs.

This vegetation type occupies only 1.54% of the total land area at present. The protected areas of Hakgala, Horton plains and Adams peak ranges are well known for Tropical Montane Forests.

Dry Mixed Evergreen Forests

This forest type is the climax vegetation of the plains of the dry zone which covers about 2/3rd of the island. The mean annual rainfall of this area varies from 1250 mm. – 1900 mm. The North-East monsoon brings rain from October to January with a pronounced dry period from June to September. The soil type is reddish brown earth.

The forest canopy is open and inferior in height. Vertical stratification is absent. Emergent dominants rise about 3 m. above the canopy level. Most of the emergents are deciduous comprising, *Chloroxylon swietenia* (Burutha), *Vitex pinnata* (Milla), *Berrya cordifolia* (Halmilla) and *Adina cordifolia* (Kon). The canopy consists mainly of evergreen species reaching a height of 20 – 25 m. Common canopy species are *Drypetes sepiaria* (Wira), *Berrya cordifolia* (Halmilla) and *Diospyros ebenum* (Kaluwara). The forest gets an evergreen appearance even when the other species have shed leaves mainly because of *Drypetes sepiaria* (Wira).

Most of the plant species exhibit xeromorphic adaptations. Epiphytes, and mosses are absent in this plant community. The forest soils are relatively rich in plant nutrients.

Although this plant community is the most extensive of the natural vegetation types in Sri Lanka it is fast dwindling. The present extent is 21.9% of the total land area.

Tropical Thorn Forests

It is the typical vegetation of the arid areas in the North-West and South-East sectors of the island. The annual rainfall is less than 1250 mm. mainly deriving from the North-East monsoon. A long moisture deficit period of 4–7 months is experienced from March to September.

The forest is a low, open, thorny scrub with isolated trees. All the species exhibit thick leaves, thorns and other xeromorphic adaptations. The common species are *Carissa spinarum* (Heen karamba) *Zisypus* sp. (Eraminiya), *Acacia* sp. and *Dichrostachys cinera* (Andara). The tree species are stunted. The main tree species of this plant community are *Salvadora persica* (Maliththan), *Manilkara hexandara* (Palu) and *Drypetes sepiaria* (Wira).

Thorn forests can be found in the coastal areas of Mannar and Hambantota districts.

Intermediate Zone Forests

These semi evergreen forests are the climax vegetation in the low and mid country intermediate zone. The species composition of this plant community is somewhere between the wet evergreen forests and the dry mixed evergreen forests. The common tree species are *Melia Dubia*, *Filicium decipiens* (Pihimbiya), *Bombax ceiba*, *Artocarpus lakoocha* (Kanagona), *Mangifera zeylanica* (Etamba) etc. These natural forests have virtually disappeared to negligible proportions below 1% of the total land area. Degraded patches of forests can still be found at Barigoda in Kurunegala and Daragoda in Moneragala districts.

Tropical Savannah Forests

These forests are found on the eastern slopes of the central hills. They are dominated by grasses while trees are scattered. Grasses are tall and may reach about 2 m. in height. Fires break out frequently in this plant community as the grasses

are highly inflammable. The dominant grass species is *Imperata cylindrica* (Illuk). Trees are stunted and may reach a height of 7 m. The tree species are fire resistant comprising mainly of *Careya arborea* (Kahata), *Terminalia belerica* (Bulu), *Terminalia chebula* (Aralu) and *Phyllanthus embelica* (Nelli). Patches of this forest type can still be found in Mahiyangana, Bibile and Welleya areas.

Grasslands

Grasslands can be found in all climatic regions. However it does not form a true climax in any of these regions. Of the grasslands, the most extensive and the best known are the patana grasslands, occurring in the wet zone. These are two types, the dry patanas and the wet patanas. Dry patana grasslands are extensive and distributed between 500–1500 m. The surface of the soil is dry, enhancing periodical fires. The dominant grass species are the *Cymbopogon na* (Mana) *Themeda tremula* and *Imperata cylindrica* (Iluk). The wet patana grasslands are smaller in extent, occurring at high elevations above 1500 m. At high elevations, the penetration of solar radiation is quite low through the clouds overcasting the sky. Wet patanas are frequently subject to strong winds and ground frost. The soils are wet and water logged. The organic matter accumulates in soil making it blackish in colour as the decomposition is minimal. The dominant grass species are *Chrysopogon zeylanicus*, *Arundinella villosa* and *Pollinia* sp. *Rhododendron arboreum* (Maharatmal) and several herb species are scattered in the grassland. An endemic bamboo, *Arundinaria densifolia* (Bata) colonises the permanently wet sections. The best known wet patana grassland is at Horton plains.

The other wet zone grasslands, Thalawa and Kekilla fernlands can be described as low country grasslands occurring below 1500 m. This vegetation is the result of soil impoverishment following forest clearing, shifting cultivation and regular burning. Thalawa grasslands can be found in Galle and Kalutara districts. Kekilla fernlands are

dominated by the fern *Dicranopteris linearis* (Kekilla). These can be found in Ratnapura and Kalutara districts.

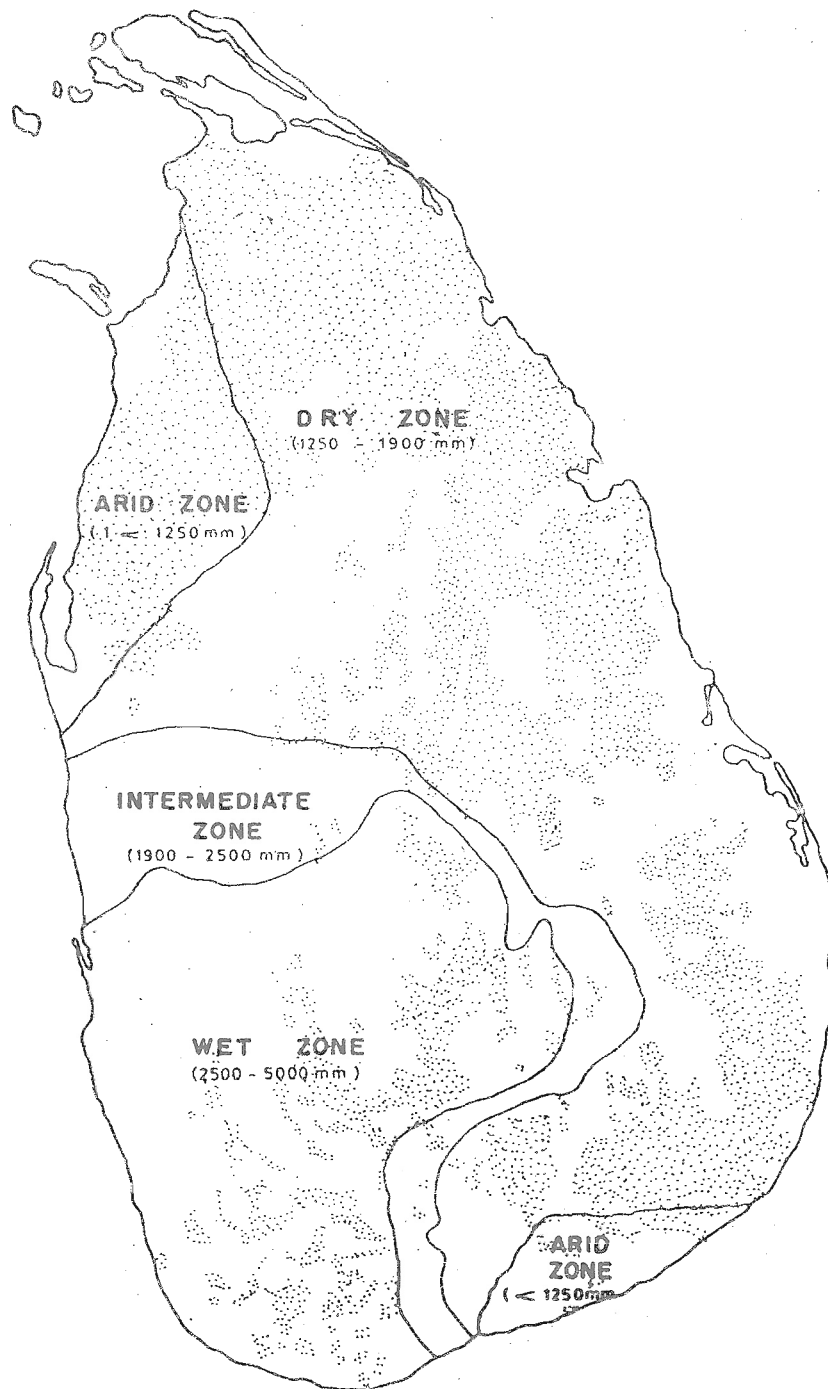
The dry zone grassland types are the dry Damana and wet Villu. Damana grasslands also are the result of forest clearing and burning. These can be found in Polonnaruwa, Manampitiya and Gāloya areas. Wet Villus occur in wetlands in the beds of abandoned reservoirs, large water holes and the flood plains of rivers, notably the Mahaweli Ganga. The period and the extent of flooding determines the ecology of the Villu system. Soil is saturated with water. The plant community comprises, grasses, hydrophytes and trees. The grass species of *Cyanodon dactylon*, *Panicum repens* and *Brachiaria* species dominate the grassland.

Mangrove Forests

Mangrove forests occur along sheltered, inter-tidal coast lines in association with lagoons and mouths of rivers, where the areas are subjected to frequent inundations with saline water. The special community is governed by edaphic factors. Sri Lankan mangroves are less diverse and poorly developed. None of the mangrove species is endemic. This plant community consists of true mangroves and mangrove associates. True mangrove species are *Rhizophora*, *Bruguiera*, *Avicennia*, *Xylocarpus*, *Ceriops* etc. Mangrove associates comprise *Cerbera manghas* (Kaduru), *Acanthus ilicifolius*, *Sonneratia alba* (Kerala) etc.

In the areas where mangroves grow, the soils get water logged resulting in poor aeration. The salinity level of water is usually high, fluctuating periodically. To counteract these drastic conditions mangroves have developed special adaptations. Special roots are developed to provide anchorage as mangroves live on a loose substratum. These special root types are the prop roots arising from the branches and stiltroots arising from the main stem. Excess salt is removed through the salt secreting glands. Xeromorphic adaptations are common to all mangroves to

FOREST COVER AND CLIMATIC ZONES OF
SRI LANKA



avoid water loss through transpiration. The cuticle of leaves is thick with extensive water storage tissues inside. Many species develop air breathing roots or pneumatophores growing upwards from the soil surface. Exchange of air takes place through the openings of the roots. Viviparity is exhibited by many mangroves to meet the hostile conditions of the environment. The seed germinates while the fruit is attached to the mother plant. The young seedling with the well developed hypocotyl dislodges from the parent plant and floats on the water until it gets a foot hold in the soil. Mangroves are best represented in Negombo and Batticaloa lagoons.

Coastal Community

There are several coastal communities in Sri Lanka viz. Sea shore community, Sand dunes, Sea grass beds and Salt marsh vegetation. Only the sea shore community will be described here as it is the most extensive of the coastal communities. This vegetation type is found above the high tidal level of the seashore. Four zones can

be distinguished which are,

- (i) the bare area with no vegetation
- (ii) zone with low creeping vegetation
- (iii) zone of lowshrubs and littoral woodland
- (iv) creeping zone vegetation which binds the sand particles with spreading root systems.

Species like *Ipomoea pescaprae* (Binthamburu) and *Spinifex littorus* (Maha-Rawana-Ravula) dominate this zone. The low shrub zone is dominated by shrubs and herbs such as *Clerodendron inerme* and *Crotolaria retusa*. Littoral woodland comprises species like *Pandanus* (Wettakeiyya), *Calophyllum enophyllum* (Domba), *Barringtonia speciosa* (Mudilla), *Phoenix zeylanica* (Indi palm) and *Terminalia catappa* (Kottamba). This community is presently confined to a few patches on the coast.

Science Update

GLOBAL WARMING AND SRI LANKA

T. SABARATNAM

Editorial Staff

"Ceylon Daily News"

Carl Sagan, a world-renowned US astronomer and science populariser, says global warming is "In a way the most serious, the most difficult of the environmental problems. Responding to it requires the greatest change in how we think of the world".

Global warming is now world's number one worry. It is specially so for the littoral states and island nations like Sri Lanka. These countries may lose their low lying coastal areas due to a rise in the sea level besides suffering from climatic changes and other ill effects.

Global warming is the outcome of man's own activities. He is furiously burning fossil fuels and is cutting down the forests at a frenzied rate. He is also releasing into the atmosphere a variety of gases which are disturbing the natural balance that had prevailed for centuries since the birth of planet earth.

The worst of all these is the upsetting of the carbon dioxide cycle. There is carbon dioxide in the atmosphere. The concentration of this non-poisonous gas is 0.03 per cent by volume. This concentration is maintained by the process of constant addition and removal, one balancing the other. Carbon dioxide is added to the atmosphere by the breathing of living organisms, by the decay of organic matter and by burning. It is removed by the plants which use the carbon in it to synthesise carbohydrates and by the oceans and other water bodies which dissolve it.

Since the industrial revolution, man has been using the fossil fuels — coal, natural gas and oil

(which had been stored in the bowels of the earth) at an increasing rate. This has resulted in releasing more carbon dioxide than during earlier years. In addition, man has been felling trees and forests as never before. Thus, while releasing larger quantities of carbon dioxide, he is reducing the source which removes it.

The increase in the atmospheric concentration of carbon dioxide has been measured by scientists and meteorologists. They say that in 1860 when Industrial Revolution had not begun, the atmospheric concentration of carbon dioxide was 290 parts per million. But in 1958 it was 310 parts per million and in 1985 the figure was 340 parts per million. This shows that the concentration of carbon dioxide is rising at the rate of 0.7 parts per million every year. The rate of growth of the concentration is rising continuously.

Carbon dioxide has the property of absorbing and retaining sun's heat radiation. The sun emits energy through heat radiation and a small percentage of it falls on the earth surface. The earth absorbs that heat and radiates most of it back into space. Carbon dioxide which forms a shield over the earth traps some of the heat and helps keep the earth warm. As the concentration of the carbon dioxide rises, the quantity of the heat trapped will also rise—thus causing the earth's temperature to rise.

Carbon dioxide is not the sole gas that causes global warming. Methane, a gas released during the decay of organic matter, sulphur dioxide and nitrous oxide which are released during the burning of coal and petroleum products and

chlorofluorocarbon, the man-made industrial gas used in refrigeration, aerosols and in the manufacture of foam rubber are the other culprits.

Chlorofluorocarbon (CFCs) plays another role also. It destroys the ozone layer, a layer which floats about 15 kilometres above sea level and shields the earth from sun's ultra-violet rays. Scientists say that wide holes have been formed over the south and north poles which allow ultra-violet rays to reach earth surface. These rays are harmful to living organisms and in man, they cause skin cancer. These rays also add to the heating of the earth.

Scientists have estimated the extent of the heating of the earth surface. They say that in the next 40 years, that is, in the year 2030 A.D., the average temperature will rise by 2 degrees Celsius. and by 2090 A.D. the rise will be 4 degrees Celsius.

When the temperature rises, the ocean waters will expand and the polar ice caps and glaciers will melt thus increasing the volume of the ocean waters. The resulting rise has been calculated at 18 centimetres above the pre-industrial level by the year 2030 A.D. and another 40 centimetres by the year 2090 A.D.

Prof. K. D. Arudpragasam, chairman, Central Environmental Authority, says: "The world is taking this sea-level rise very seriously. But we in Sri Lanka have not approached it with the required seriousness".

The world has taken the matter very seriously. Our tiny neighbour Maldives hosted an international conference on global warming in 1989 where a declaration called the Male Declaration was adopted. The declaration urged all island nations to formulate a common program to monitor the sea level rise and to develop projects to counter that. It also urged all nations to mount a campaign of afforestation.

For Maldives, the danger is greater than for Sri Lanka. Most of the islands that form the island

chain of Maldives will sink if the water level rises. Prof. Arudpragasam says that Sri Lanka too would suffer severely.

He warns that the entire coast will be eaten up. The southern and the west coasts would suffer most and all those areas where the water would enter are highly populated. He says: "all coastal areas which are 20 centimetres above mean sea level will go under water; coastal railway line and parts of Galle road will be washed away; many parts of Colombo city will go under water; and backing of river discharge and intrusion of salt water will cause heavy damage."

Prof. Arudpragasam also warns of severe effect on monsoon winds and the sea currents generated by them. He adds that changes in monsoonal patterns and intensity, changes in distribution of agro-climatic boundaries and changes in soil moisture conditions, with attendant changes in plant growth pattern and vegetable cover should be anticipated.

"I am going to take these things seriously and am going to set up a core group to study the problem and suggest ways and means of tackling them", he says.

The task of the core group will include: assessment of the impact; development of the outlines of possible response strategies; liaison with small states and regional states; alerting the government and its agencies.

The global temperature rise will also have other effects on the world: climatic patterns may change; plant growth may be affected. These are also bound to affect Sri Lanka.

Scientists studying coral reefs around the caribbean islands, Jamaica, the Bahamas, Puerto Rico, the Caymans, the Florida Keys etc. say that the sensitive corals have begun sending the first biological signals of global warming. The corals are suffering extensive bleaching and possible death from high water temperatures. Coral reefs are

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made up of colonies of small animals that live in symbiosis with microscopic algae that give the coral its colour and nutrition. The algae are sensitive to extremes in water salinity, temperature, sedimentation, pollution and variations in light intensity. If the world's reefs begin dying, the economic consequences will be incalculable. Some 109 countries around the globe, including Sri Lanka, have reef systems which support marine life.

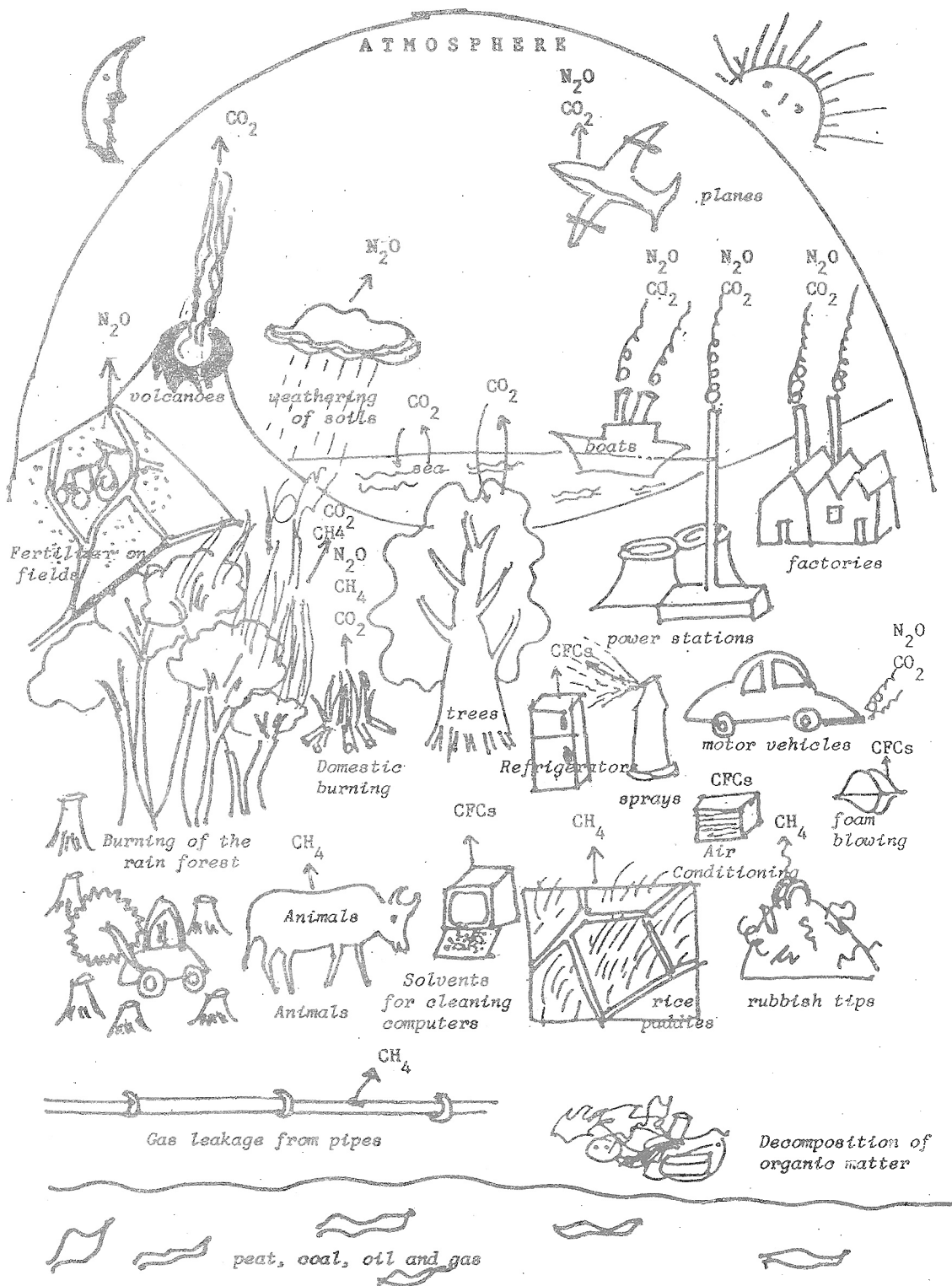
Sagan feels that science and technology can solve the growing environmental crisis and earlier this year speaking at a conference of American business he suggested the setting up of a special research institute to undertake this task. He suggested three areas for intense research : more efficient burning of fossil fuels, alternate energy sources and massive reforestation on a global scale.

On the first he said that almost a third of carbon dioxide release is from motor vehicles and adds : "Why do we drive cars that get less than 10 kilometres per litre. We could reduce the amount of carbon dioxide from that source by two-thirds".

Of the alternate energy sources he says : "The paragon of these alternatives is solar power. It converts sunlight into electricity or into hot water, producing no polluting gases, no greenhouse gases and no radioactive waste. Such systems are within hailing distance of being competitive".

On massive reforestation he says : "Growing trees take carbon dioxide out of the atmosphere. They are a kind of anti-greenhouse machines. We plant forests; carbon dioxide gets taken out of the atmosphere".

SOURCES OF GLOBAL WARMING



"REVOLUTIONARY" NEW GENE TRANSFER METHOD DEVELOPED

NALAKA GUNAWARDENE

Science Correspondent

The "Island"

A Canadian research team headed by an expatriate Sri Lankan scientist claims to have developed a simple and fast method to transfer plant genes.

It has been described as a discovery "that could revolutionise genetic engineering" and accelerate the improvement of a broad range of crops.

In 1989, the same research team, working at the Department of Crop Science in the University of Guelph in Ontario, Canada, won international recognition for developing what they called "*artificial seeds*" — dry plant cells that grow into genetically identical plants. These were produced using tissue culture methods.

"Artificial seeds" technique has already stirred excitement in plant breeding circles because it offers a simple and easy way to multiply rare plants.

Artificial seeds could also prove helpful in saving endangered species of plants, and enable horticulturists to exchange plant genetic material without fear of spreading plant disease.

"This (technique) will be particularly beneficial to developing countries, whose plant quarantine regulations are not so strict. The dried seeds, produced in sterile laboratory conditions, will not harbour disease-causative micro organisms," said Dr. Tissa Senaratna, the Sri Lankan plant physiologist heading the Guelph research team.

The team has now demonstrated an apparently simple method to insert a desired single gene into

artificial seeds — by simply putting the seeds into water containing that gene!

As the seed soaks up moisture, it would pull the gene inside and adopt it. The gene's characteristics will be expressed in the plant that grows from the treated seed.

Dr. Senaratna calls it "*the surfboard phenomenon*", drawing an analogy to a surfer riding the crest of a wave.

"It's very simple," he quipped. "I think it surprised everybody."

It certainly did surprise the first audience of scientists to hear his ideas and the results of his experiments at the International Tissue and Cell Culture Congress in Amsterdam last summer.

The process of gene transferring is crucial to gene splicing, one of the most prominent applications in genetic engineering since 1973. Gene transferring has enabled scientists to produce some of the marvels of molecular biology, such as human insulin produced by bacteria, plants that grow their own herbicides, growth hormones that increase milk production in cows etc.

Similarly, with such gene transference, it is possible to develop new characteristics in plants selectively and immediately. This contrasts with the time-consuming, imprecise method of cross-breeding practised for centuries.

Gene transfer systems so far involved one of three

basic techniques : bacteria, micro-injection or ballistic.

The bacteria approach involves several steps: loading the desirable gene onto a bacteria; having the bacteria penetrate a cell of the target plant or bacteria; then having them dump that genetic load into the cell and having the cell adapt them into its genetic code.

So far, the bacteria approach has only worked with dicotyledons, such as beans, and not monocotyledons, such as wheat. Canada's agriculture features far more monocotyledon crops than dicotyledons, so any genetic engineering technique that works for monocotyledons will be of "immediate and particular interest to Canada's plant breeders," noted one Canadian newspaper which highlighted the development.

In the micro injection technique of gene transfer, microscopic surgical instruments, (such as a needle) are used to insert a gene into a plant. And in the ballistic approach, it involves loading the genes on tiny pellets that are literally blasted into a cell with a .22 calibre rifle.

Dr. Senaratna says his new approach depends on two factors.

First, the cell membrane has to open. That is *not* normal for ordinary cells, but does happen briefly with artificial seeds, both when they are drying down to become artificial seeds, and again when those dry seeds are moistened to develop into plants.

Second, the gene-carrying water has to move across that open membrane into the seed.

This is why the method would not work with ordinary cells. Ordinary cells have a membrane that acts like a skin to hold its components in place. This membrane does not open up, even briefly, like those in artificial seeds.

Dr. Senaratna, while satisfied with their progress

so far, stresses that much more remains to be done.

To begin with, the artificial seed technique has so far been only tried and proven on a few species of plants — alfalfa, geraniums, microspores involved in canola-breeding programmes and embryos from black spruce trees.

Dr. Senaratna is confident that the artificial seeds technique will eventually work for many more species, including wheat. "But we haven't got around to trying it yet."

If the artificial seed technique works on a given plant, then the new genetic engineering system should also work. There too, more work remains to be done to determine whether it will work for a broad range of genes.

The Guelph experiments were done with the GUS gene — glucuronidase, a popular "marker gene" that yields an easy-to-see blue colour.

Dr. Senaratna's team, which included Drs. Bryan McKersie, Ken Kasha and Doug Procunier, had their first success with gene transfers in early 1990.

"We literally jumped up and down with joy, shouted and hollered when we saw it worked," Dr. Senaratna recalled.

The team has been going through exciting times since the artificial seeds breakthrough the previous year. Using soy bean and a few other crops, they produced thousands of dry "seeds" from a single plant. Unlike natural seeds — the product of sexual reproduction in plants — "artificial" seeds were produced using tissue culture.

In tissue culture, researchers fiddle with individual cells taken from any part of a plant, inducing them to develop just like fertilised eggs. With the addition of proper nutrients and hormones, these cells ultimately develop like a "seed".

Tissue culture has been tried on many food crops, horticultural and forest tree species. It enables scientists to produce a large number of young plants without having to depend on naturally occurring plant reproduction.

However, no one had previously been able to dry these "seeds" from their test tubes, to make packaging and transport easier. Precisely this is what was achieved with "artificial seeds".

Once dried, "artificial seeds" can be packed into a seed coating using various nutrients. This protects the seeds from mechanical damage. Seeds can also be coated with substances which will imbibe water at a faster rate, giving them extra initial vigour — an edge over ordinary seeds.

When conditions are right, artificial seeds can germinate just like normal seeds. However, says Dr. Senaratna, they take "a few days longer" to grow.

Dr. Senaratna, now perfecting his gene transfer

technique, believes that the animal kingdom might find some uses of his research with plants. For example, he notes that sperms can be frozen; he thinks that sperms may be dried, just as they were able to dry plant seeds.

If that proves possible, the new gene-transferring technique might work for animals and birds as well.

That, in turn, leads Dr. Senaratna to ideas already being explored by another researcher at Guelph. Dr. Jim Squires in the Department of Animal and Poultry Science has just begun experiments to test his idea that sperm cells could be a simple, easy and cheap way to accomplish genetic engineering.

But that is another story.

* * *

(An earlier version of this article appeared in *The Island* in December 1990; it has since been edited and parts re-written).

SOME SRI LANKAN PLANTS AND THEIR MEDICINAL USES

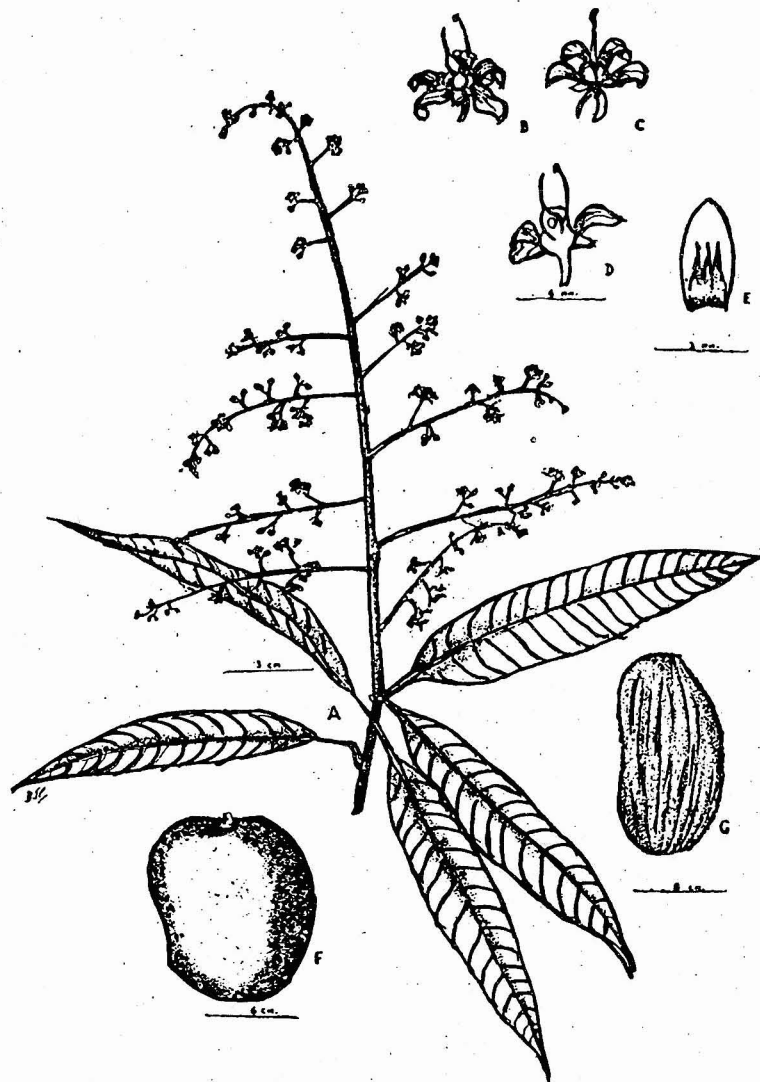
Mangifera indica Linn. — ANACARDICAEAE

Figure . *Mangifera indica*. A, branch with flower panicle. B, hermaphrodite flower showing a single stamen, ovary and staminodes. C, male flower with a single stamen and tumid staminodes. D, longitudinal section of a hermaphrodite flower. E, petal showing 3 ridges inside. F, fruit. G, seed.

Engl. Mango; *Sinh.* Amba; *Tam.* Adishelarayam, Ambiram, Amiram, Iradam, Kachakkar, Kilimukuma, Kogilosavam, Kokku, Maa, Madi, Madududam, Manga, Magandam, Malai, Mamagam, Mandi, Manmadamganai, Mattiyagandam, Mirudalagam, Omai, Palashiratta, Palerbatti, Pigubandu, Shedaram, Shegaram, Shudam, Shulli, Tema, Tevam, Tidalam; *Hindi* *Am. Sans.* Alipriya, Amra, Atisairrabha, Bhramarapriya, Bhringabhishta, Chukralatamra, Chuta, Chutaka, Gandhabandhu, Kamanga, Kamaphala, Kamarasa, Kamasara, Kamavallabha, Kamayudha, Kameshta, Keshavayudha, Kireshta, Kokilananda, Kokilavasa, Kokilotsava, Koshi, Madadhya, Madhavadruma, Madhuduta, Madhukara, Madhuli, Madhvasa, Madirasakha, Mahanda, Manjari, Manmathalaya, Manmathavasa, Manodna, Modhakhya, Mrishalaka, Nilakapitha, Nriyapapriya, Parapushtamahotsava, Phalashreshtha, Phalotpatti, Pikapriya, Pikaraga, Pikavallabha, Priyambu, Rasala, Sahakara, Shatpadatilhi, Shareshta, Shukrapriya, Sidhuras, Sripriya, Sumadana, Vanotsura, Vasantadru, Vasantaduta.

A large, spreading tree, about 15–20 m. in height with a rough grooved bark and glabrous stems and branches; leaves simple, alternate, crowded at the ends of branches, 12–40 cm. long, 4.5–13 cm. broad, oblong or oblong-lanceolate, acute or acuminate, glabrous, shining, entire, margins undulate, base narrowed, petioles 1.7–4 cm. long; flowers small, yellowish green, polygamous, monoecious with a pungent odour, arranged in large, many-flowered, pubescent panicles longer than leaves, pedicles short, thick and jointed; bracts small, ovate, pubescent, deciduous; calyx 4- or 5-partite, segments 1.5–2 mm. long, 1–1.5 mm. broad, ovate, imbricate and pubescent; petals 4 or 5, sometimes more being doubled, free, 2.5 mm. long, 1.5 mm. broad, oblong, subacute, reflexed, glabrous with 3 orange-coloured ridges on the inner face; disk fleshy, 5-lobed, alternate with petals; stamens 1–5 inserted inside between disk-lobes or on them, one, sometimes 2 fertile, others sterile slender tipped with a small gland, filament subulate, anther purple; ovary superior, sessile,

1-locular, oblique, glabrous with a pendulous ovule from a basal or lateral funicle, style lateral, stigma simple; fruit a large fleshy resinous drupe, 7.5–20 cm. long with a compressed, fibrous stone inside; seed large, exalbuminous, ovoid-oblong, compressed, testa papery with plano-convex, often unequal and lobed cotyledons.

Flowers in October and fruits in April and May.

ILLUSTRATIONS. Rheede, Hort. Mal. 4: pls. 1 & 2, 1678–1703; Beddome, Flor. Sylvat. pl. 162. 1868–1873; Gaertner, Fruct. 2: pl. 100; Curtis, Bot. Mag. pl. 4510; Kirtikar and Basu, Indian Med. Pl., pl. 274. 1933.

DISTRIBUTION. Occurs in the Himalayas, Sikkim, Khasia, along Western Ghats, Burma and Ceylon. It is cultivated in South Africa and tropical America. In Ceylon, it is grown as a cultivated plant in almost every village garden though it is not a native of Ceylon.

India. Sikkim. T. Thomson, 1857; Dehra Dun, Dimri 34, March 1926; Chota Nagpore, Clarke 14089 A, April 1871; Pen. Ind. Or. Herb. Wight 548, Kew Distribution 1868–8. Ceylon. Eastern Prov., Batticaloa, Thwaites C. P. 1256; Nevill, March 1885; Central Prov., Ambagamuwa Thwaites C.P. 2614; Peradeniya, Bot. Gard., Jayaweera 603, March 1951.

COMPOSITION. The leaves of this tree contain euxanthin acid, euxanthon, hippuric and benzoic acids, mangiferin and mangin while the bark contains tannin and the exudation from it yields resin and gum. The fruits, too, yield a resin which is said to contain mangiferene, mangiferic acid, resinol and maniferol. The fruits which are consumed contain saccharose, levulose, dextrose and citric, tartaric and malic acids in addition to vitamins A, B and C, ascorbic acid and carotene. The seeds possess a fixed oil with oleostearin, starch, gallic acid and tannin.

USES. The juice of the leaves of this tree is given for bleeding dysentery, while an infusion of the

young leaves is prescribed for chronic diseases of the lungs, coughs and asthma. An infusion or expressed juice of the bark is used in menorrhagia, leucorrhoea, bleeding piles and haemorrhages of the lungs and intestines. A cold infusion of the

barks of *Mangifera indica*, *Syzygium cumini* and *Terminalia arjuna* with bees' honey is given for bleeding from internal organs. A decoction of the dry flowers is used with beneficial effects on diarrhoea, chronic dysentery and gleet.

Anacardium occidentale Linn. — ANACARDIACEAE

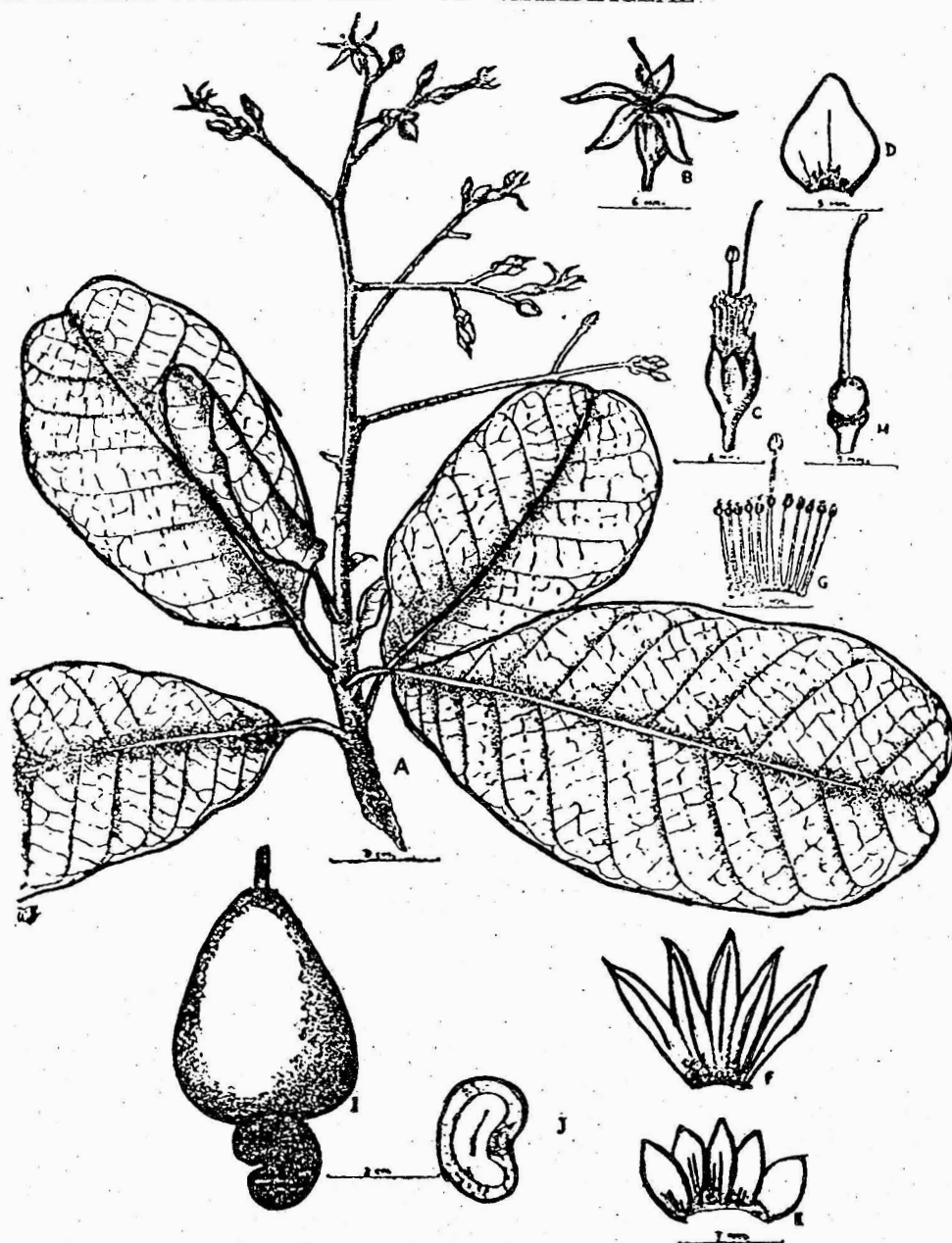


Figure . *Anacardium occidentale*. A, branch with leaves and flowers. B, external view of a flower. C, flower with the corolla removed. D, bract. E, sepals. F, petals. G, stamens with one longer than the others. H, pistil consisting of an ovary with a hairy apex and lateral style. I, nut borne on a swollen pedicel. J, longitudinal section of nut showing the pericarp and one cotyledon.

Engl. Cashew Nut ; *Sinh.* Kaju ; *Tam.* Andima, Kallarma, Kottaimundiri, Mundiri, Saram, Sigidima, Tirigai, Uttumabalam ; *Hindi* Kaju ; *Sans.* Agnikrita, Arushkara, Guchhapushpa, Kajutaka, Parvati, Prithagabija, Sophara, Sophahara, Srigdhapitaphala, Upapushpika, Vrittapatra.

A medium-sized tree with crooked trunk and terete, glabrous branches ; leaves simple alternate, coriaceous, 8.5–24 cm. long, 5.8–14.5 cm. broad, oblong, obovate or elliptic, rounded, or somewhat retuse at apex, glabrous, firmly reticulately veined, base cuneate, margin wavy, lateral veins 10–15 pairs, prominent beneath ; petioles 1–2.5 cm. long ; flowers small, regular, polygamous in terminal, bracteate panicles longer than leaves, peduncles lengthening with age ; bracts 6–8 mm. long and as broad, broadly ovate, acute, puberulous outside and glabrous within, soon deciduous ; sepals 5 or 6, imbricate, 4–5.5 mm. long, 1–2.7 mm. broad, lanceolate or ovate, puberulous outside ; petals 5 or 6, linear-lanceolate, imbricate, incurved, greenish yellow with a red blotch in the middle, 12–12.5 mm. long, 2 mm. broad, deflexed from the middle, puberulous outside ; stamens 7–10, fused at the base round the ovary, one larger than the others and exerted beyond the recurved petals or all equal, filaments of shorter stamens, 3.5–4 mm. long and that of the long stamen 8.5 mm. long, hairy at the base ; ovary obcordate, 2 mm. long with a hairy apex, 1-locular, glabrous, attenuated into a somewhat lateral style 7.5–8 mm. long ; nut reniform 2.5 cm. long on a swollen, fleshy, yellow or red pedicel, pericarp cellular, full of acrid oil, seed reniform, ascending, exalbuminous, testa membranous, cotyledons semilunar with a milky taste.

Flowers in November, and January to March.

ILLUSTRATIONS. Griffith, *Notul.* 4 : *pl.* 656, *f.* 3 *euf* ; *Beddome*, *Flor. Sylvat.* *pl.* 163. 1868–1873. ; Kirtikar and Basu, *Indian Med. Pl.* *pl.* 275. 1933 ; *Herb. Peradeniya*, drawing.

DISTRIBUTION. A native of tropical America, now naturalized and cultivated in the hotter parts

of India and Ceylon. In Ceylon, it is commonly found in village gardens and waste lands along the sandy western coast of the Island and in the dry zone.

India. Nilghiris, *Schmid* ; *Pen. Ind. Or. Herb. Wight* 549, *Kew Distribution* 1866–7 ; *Bot. Gard. Calcutta*, cultivated, *Pierre*, 1863. **Ceylon.** Peradeniya, *Bot. Gard.*, cultivated *J. M. Silva* 195, April 1928 ; *Jayaweera* 253, Dec. 1957. **S. Andamans.** *Heinig* 432, March 1901 ; *Car Nicobar, King's Collector*, Feb. 1893. **Brazil.** *Bot. Gard.*, *Baker* 65, June 1908.

COMPOSITION. The pericarp of the nut of this tree contains a toxic principle, cardol, anacardol, cardanol and anacardic acid. The kernels yield a fixed oil which contains linolic, palmitic, stearic and lignoceric acids and sitosterin. The exudation from the bark is a mixture of gum-arabic and bassorin.

USES. A decoction of the bark of this tree is used as a remedy for diarrhoea, syphilitic swellings of joints and for diabetes. The juice of the ripe receptacle is recommended for scurvy, uterine troubles and dropsy. The oil of the pericarp is useful as an anaesthetic in leprosy and psoriasis. It is a powerful vesicant, vermicide and insecticide. The non-toxic phenol, cardanol, separated from the oil, is used in the insulation of the ignition system in aeroplane engines. The kernel of the fruit is used extensively in the confectionary trade. The oil extracted is a mechanical and chemical antidote for irritant poisons.

In Goa, an alcoholic beverage is prepared from the ripe receptacles. The bark is used as a gargle in the treatment of aphthae, while the root is employed as a purgative in Africa. A cough remedy is prepared for children by infusing the young shoot and leaves in water. In the Congo, the bark is used as an arrow poison and the oral administration of the tincture of the bark is supposed to lower blood sugar level.