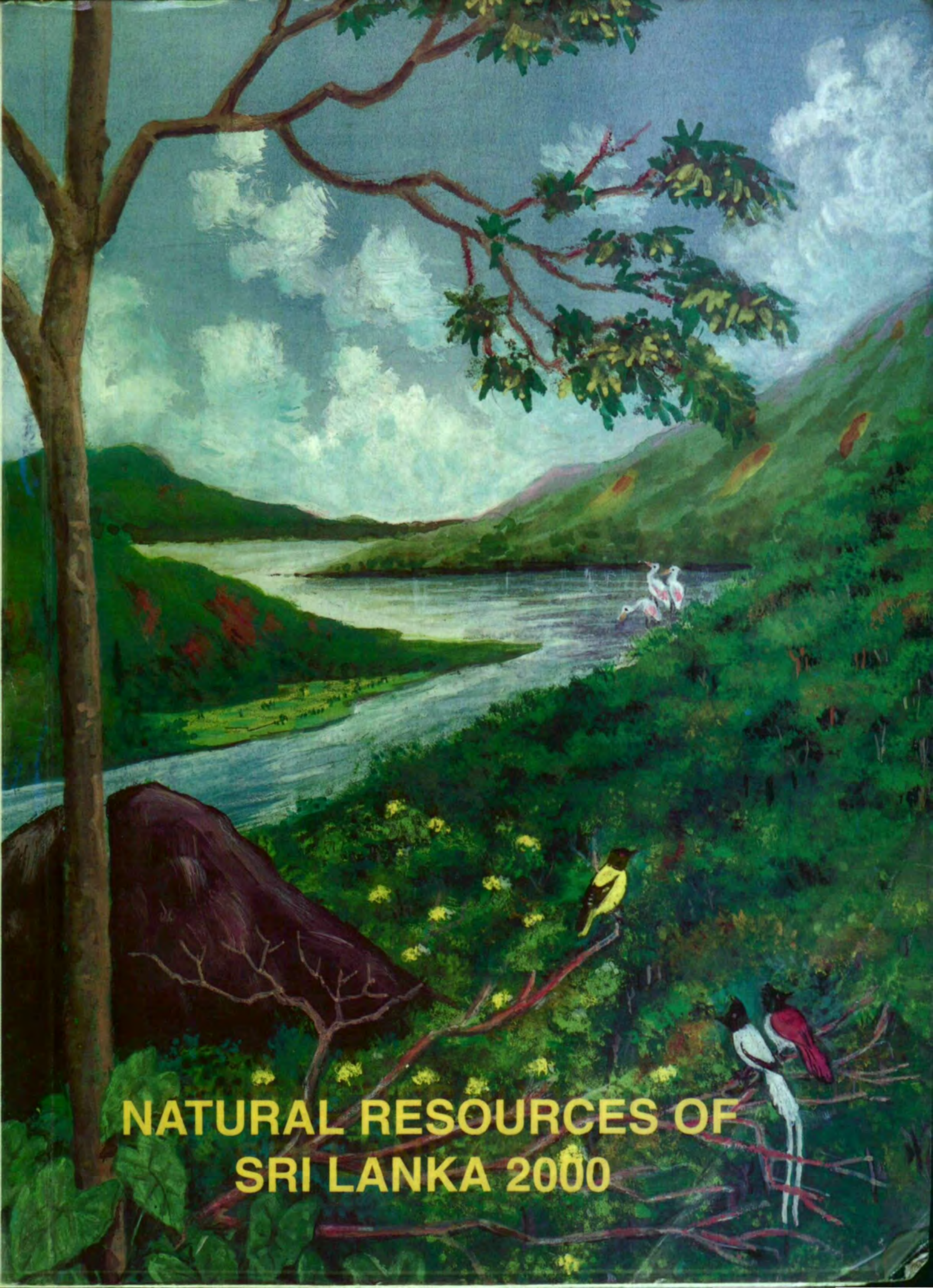

NATURAL RESOURCES OF SRI LANKA 2000

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FOREWORD

In 1991, the Natural Resources Energy and Science Authority (NARESA) of Sri Lanka brought out a publication entitled "Natural Resources of Sri Lanka – Conditions and Trends". This book was the first of its kind that presented a holistic overview of the island's natural resource base, how it was being used and managed and how its potential could be used in the future, to the best advantage of the economy and the people. Edited by Malcolm Baldwin and consisting of several chapters on natural resources written by recognized experts in their relevant disciplines, the book became a standard source of information for scientists, planners, policy makers, students and the general public.

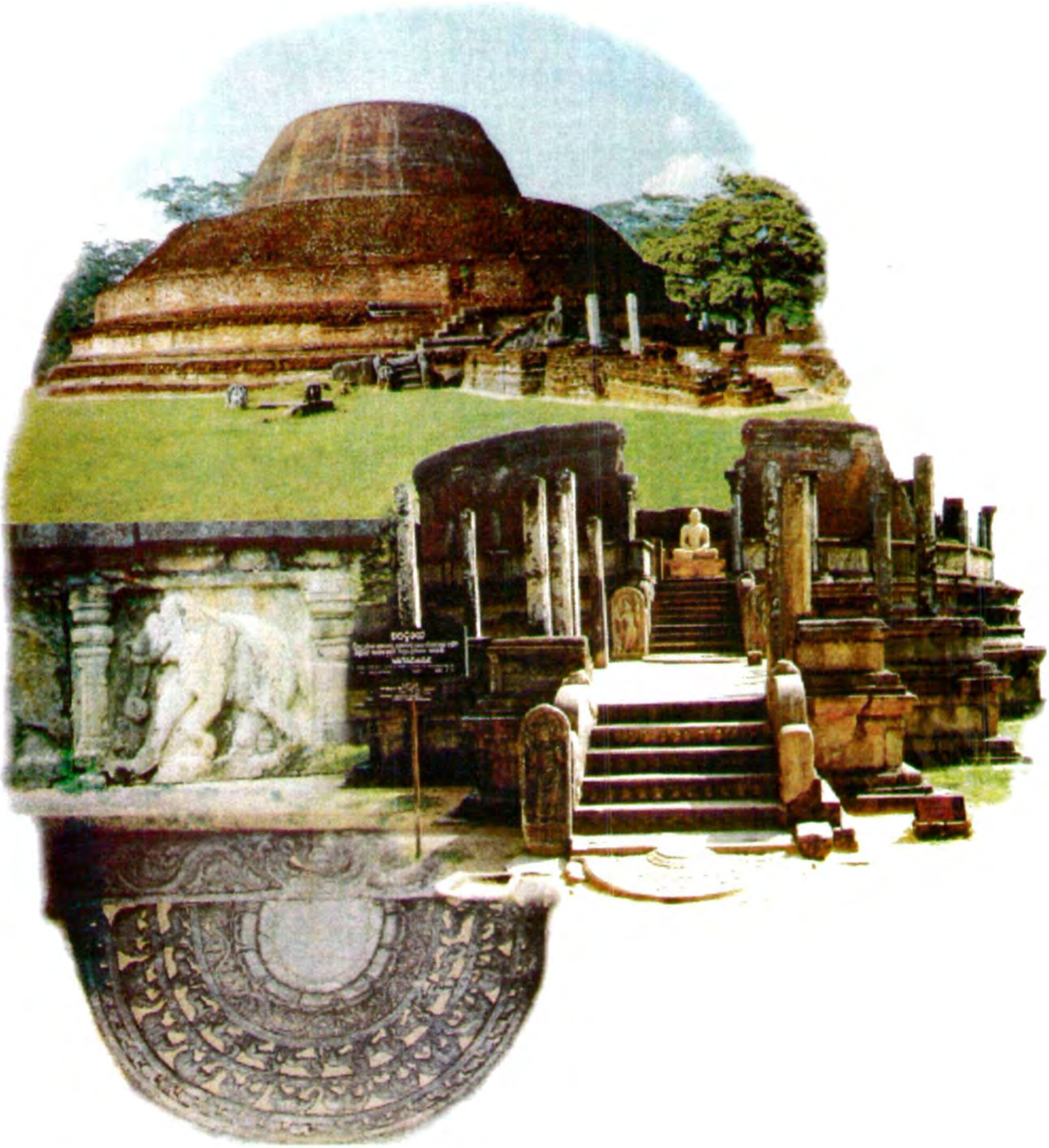
However, time has not stood still in this country, nor have resource use and economic development. Much has taken place in the decade that has passed since the publication of the previous book. Taking note of the pivotal role this book played as a source of authoritative information and mindful of the fact that we have moved into the world of the 21st Century, the Steering Committee on Natural Resources had made a recommendation that the book should be revised and updated. The Board of Management of the NARESA (now National Science Foundation – NSF) had accepted the recommendation and directed that the material be revised, re-written as appropriate and updated. It had been also decided that it should be published in the Year 2000 under the title "Natural Resources of Sri Lanka 2000".

The Steering Committee on Natural Resources of the NARESA appointed an Editorial Board headed by Professor P.G. Cooray, to handle the revision. The Committee and the Editorial Board invited nationally reputed experts to write the relevant chapters. They were required to bring data on all aspects of the resource, its use and management and estimated future potential upto date, as nearly as possible to 1999. Authors were requested, also, to include relevant scientific data and analyses while keeping in mind that the book should still capture the interest and understanding of the student and the general reader.

I am happy to be able to state that the book has achieved all its stated objectives. We are certain that in a milieu of sustainable development which is a *sine qua non* for survival and advancement in the 21st century, this publication will be of critical value to an even greater extent than its predecessor was during the closing decade of the 20th century.

On behalf of the Board of Management of the NSF, I wish to record my deep appreciation for the valuable contributions made by the invited experts, Editorial Board, General Editor, Copy Editors and Editorial Assistants who had worked tirelessly to make this major undertaking a success.

Professor Kapila Dahanayake
Chairman
National Science Foundation (NSF)
26 December 2000



Picture by Chandima Kahandawala.

Our Heritage

INTRODUCTION

K. D. Arulpragasam
National Education Commission

THE ISLAND

Sri Lanka is a tropical island a few kilometers off the southeastern coast of India at 79° 39' - 81° 53' E and 5° 54'-9° 52' N. It lies in the Indian Ocean astride the main international sea routes between the east and the west, which pass immediately southwards of the island. An uninterrupted expanse of ocean extends southwards from Sri Lanka to Antarctica.

Sri Lanka is rated as one of the most beautiful islands on earth. Its natural scenic beauty is its most treasured possession. The climate is equable. A unique feature, for an island the area of which is only 64 000 km^2, is the range of temperature, extending from a daily average of 27° C, in the coastal regions and lowlands, to a daily average of 15°C, in the hill country. This wide range of temperature relates to rapid changes in altitude from sea level to heights of over 2000 m. This transition takes place within a distance of about 150 km. The hill country has a climate that can be described as temperate.

Climate and topography together combine to create a rich variety of scenic vistas and a wide range of ecosystems. These include beautiful bays, coral reefs, estuaries, sandy beaches and dunes in the coastal fringe and tropical rain forests, tea and rubber plantations, majestic mountain views, cascading waterfalls, and a host of unique ecosystems such as Horton Plains, inland. The latter is a plateau that lies at an elevation of over 2000 m. Its southern edge is known as World's End. From here the southern lowlands extend to the coast of the island, beyond which a vast expanse of ocean extends uninterrupted down to Antarctica.

Sri Lanka, known in the past also as *Ceylon, Serendib* and *Taprobane*, was once part of the great southern super-continent called Gondwanaland. When that super-continent broke up and its parts drifted away from each other to form the continents of Antarctica, South America, Africa, Australia, India and the island of Madagascar, Sri Lanka which had been part of the super-continent, trailed along with India to its present position. This aspect of Sri Lanka's geological history gives the island certain unique characteristics of relict fauna and flora. In addition, it also gives Sri Lanka close geological, biological and cultural ties to the Indian sub-continent.

Over 90 per cent of the island is formed of Precambrian rock. Miocene limestone forms the northern Jaffna Peninsula and adjacent islands and part of the northwestern coastal belt, where it is partly overlain by Quaternary deposits. Two small Jurassic deposits are found at Tabbowa and Andigama. Apart from these, alluvial deposits form a fertile cover over the river flood plains of the island.

For most of this century, the physiography of Sri Lanka has been considered as consisting of three main erosion levels (or "peneplains"), separated from each other by escarpments. The most recent view, however, is that there are several major physiographic provinces in the island, with distinct landform assemblages which are related to the island's lithology. These are :

- Submerged plateau (continental shelf)
- Coastal Plain I – Quaternary System over crystalline rocks

- Coastal Plain II – Quaternary System over Limestone
- Miocene Limestone Plateau
- Lowland Plain Wanni
- Lowland Plain Vijayan
- SW Lowlands
- Elahera Ridges
- Highlands, with subdivisions

Several prominent escarpments are found in the Highlands. This part of the country has over 50 waterfalls, which enhance the beauty of the Hill Country, and constitute some of the most treasured of the island's natural resources.

About one third of the land is under agriculture. Forests cover another third, and the rest has been transformed into human settlements and a variety of other anthropocentric uses.

CULTURAL HISTORY

Sri Lanka's location astride the sea routes between the east and the west has exposed her to wide cultural and political influences throughout her history. The island was well known to travellers of many nationalities from ancient times, and her reputation for precious stones, spices, elephants and scenic beauty is documented in the tales of Greeks, Romans, Arabs, Chinese and the Dutch. Historically, Sri Lanka's close proximity to the Indian sub-continent brought her under the cultural, religious, linguistic and political influence of India.

Sri Lanka plays a major role in the great Indian epic the 'Ramayana'. There are locations in the hill country and other parts of the island that are traditionally linked to certain locations mentioned in that epic. Hinduism is practised by most Tamil people. In various parts of the country there are a number of Hindu temples, some of which are very ancient. These include Mavittapuram Temple in Kankesanthurai, Valipuram Kovil in Point Pedro and the temple dedicated to God Skanda at Kataragama.

Buddhism was brought to Sri Lanka from India and Lord Buddha himself is said to have visited the island thrice. A Bo sapling brought by Sangamitta Theri to Sri Lanka was planted in Anuradhapura, then the capital city of the country. The Sri Mahabodi, as this Bo tree is known, is one of the oldest, historically documented trees in the world. The Dalada Maligawa in Kandy is the home of the Tooth relic of the Buddha, venerated by Buddhists, the world over.

While in India, Buddhism did not take permanent hold, in Sri Lanka it developed firm roots and has become the religion of the majority of the people of the country. The purest form of Theravada Buddhism is practised in Sri Lanka.

Buddhism was nurtured by the Sinhala kings who built 'Dagabas' and 'Viharas' in and around their cities, over many centuries. Most of these are concentrated in the northcentral region of the country around cities such as Anuradhapura and Polonnaruwa. The ruins of these structures lie scattered in those regions and are monuments to a great cultural heritage and highly advanced engineering skills, far in advance of the times to which they belong. These ruins enhance the quality of Sri Lanka as a tourist destination.

THE HYDRAULIC CIVILIZATION

From the middle of the first millennium BC to well after the first millennium AD Sri Lanka developed and sustained a hydraulic civilization. Basically, numerous large, medium and small sized reservoirs for the storage of water, commonly referred to as 'tanks', were built by the Sinhala kings. They lie scattered over much of the dry zone. They are masterpieces of engineering and represent a highly advanced technology aimed at storing water received during the rather short rainy season, for use in irrigated agriculture during the dry season. The tanks were supported by intricate systems of irrigation canals. Together they sustained an agricultural economy over many hundreds of years.

Conveyance of irrigation water over long distances needed efficient control over distribution and allocation of the water between the upper and lower ends of each system and efficient maintenance. Irrigation depending on micro-catchments required careful watershed management to reduce siltation. The land and water use system that developed over centuries to satisfy these requirements has been called a "cascade system" and is referred to in a later chapter of this book.

Organization of small tanks into a cascading sequence allowed greater efficiency in water use. Water from paddy fields in the upper parts of the cascade flowed into a downstream tank for reuse in paddy fields below. System management required community effort and coordination. Interdependency in a cascade required well co-ordinated management of land and water resources.

The land use patterns associated with tank cascades demonstrated a profound knowledge of resource management in a challenging environment, essentially transformed from natural ecosystems into agro-ecosystems (Abeywickrema, 1990). Integrated land and water resources management in ancient times is reflected in the zonation of land use within the micro-catchments. Tanks and paddy fields occupied the valleys, where Low Humic Gley soils with poor drainage had limited use, other than for paddy cultivation. Ridge summits, often strewn with rocky outcrops and 'inselbergs', were converted into works of art and places of worship and spiritual retreat. The influence of Buddhism led to the establishment of sanctuaries early in history and the enduring protection of wildlife, unusual in many parts of the world.

Outside of the village systems, the remainder of the population lived in the larger irrigated areas and in cities like Anuradhapura, in the dry zone, lowlands. The hill country and the wet zone on the other hand, attracted few settlements in ancient times.

The skills in irrigation technology possessed by the ancients were unique for a small country like Sri Lanka. As Needham (1971) noted "(a) already, in the first century AD they understood the principle of the oblique weir ; the height of dam spillways were adjusted by removable pillar sluices, the inside surfaces of reservoir abutments were faced with 'ripple bands' and acted as wave-breaking groynes. The most striking invention was the intake-tower or valve tower (*bisokotuwa*)." They developed the knowledge required to construct long canals with extremely low gradients, such as the Jaya Ganga, which carried water from Kalawewa to the city tanks of Anuradhapura, along a canal 87 km long. This *yoda ela*, which had a gradient of less than 10 cm/km within its first 27 km, continues to maintain itself as a natural stream to this day. Some of the major ancient tanks, such as Yoda Wewa in the Mannar District, were constructed to feed a large number of small tanks.

The establishment of forests and the construction of ponds, reservoirs and irrigation systems were considered great meritorious acts, in accordance with Buddhist principles. Sri Lanka's history is full of achievements of kings who contributed to the development of water resources. Since the first century AD, kings such as Vasabha (67-111 AD), Mahasena (276-303 AD), Dhatusena (455-473 AD), Agbo II (575-608 AD), and Parakramabahu I (1153-1186 AD) built numerous reservoirs and irrigation systems which fed vast expanses of paddy fields in the dry zone. Construction and upkeep of these irrigation systems became massive undertakings.

In the course of time the hydraulic systems went into decline and disuse. The capitals shifted from the dry zone to the wet zone and to the hill country, which eventually became the last bastion of Sinhala people against colonial forces. First Anuradhapura, the capital of Sri Lanka for over a millennium, yielded its status to Polonnaruwa. Then, after brief spells in Dambadeniya, Gampola, Kotte and Sitavaka, the capital was finally established in Kandy, until the British conquest.

In more recent times, with shifts of centres of population towards the maritime regions, the tank system went into neglect, disuse and disrepair. After independence, however, successive governments have undertaken programmes of rehabilitating the tank systems and restoring irrigated agriculture. In addition, a number of large multi-purpose reservoirs have been constructed.

In the history of our people, life was centered traditionally, in villages and revolved around the tank, the village and the temple. This was a tradition that enabled the population to live in harmony with nature. Modern civilized society has departed radically from that age-old tradition giving rise to the major environmental problems that we and other people of the world face today.

From the early years of the sixteenth century the island came under foreign domination, first under the Portuguese and then under the Dutch. Finally the British conquered the island and we remained under British rule, until Independence in 1948.

CLIMATE

Sri Lanka's tropical location and island status ensures uniform, year-round temperatures of around 27°C in the lowlands and lower temperatures at higher altitudes. Fluctuations in temperature are minimal over much of the island and do not determine seasons. Seasons are determined primarily by patterns of rainfall. Sri Lanka lies within the monsoonal system of the Indian ocean. There are two monsoons. The southwest monsoon is active during the period mid May to late August while the northeast monsoon is active during the period November to February. Southwest monsoon winds are strong and blow in across the southwest Indian ocean. The winds carry moisture- laden air which brings rain to the western and southwestern parts of the island. The southcentral mountain massif stands in the path of the southwest monsoon winds. Therefore, the rest of the island lies in a rain shadow and does not receive rain from the southwest monsoon. The northeast monsoon blows in across the northern part of the Bay of Bengal. The winds are weaker than those of the southwest monsoon and also carry less moisture. This monsoon brings rain to the north and east of the island and to the rest of the dry zone. The tanks of that region store the water received. Between the two monsoons two inter-monsoonals occur, the second, between the southwest and the northeast monsoon bringing almost as much rain as the southwest monsoon itself.

On the basis of this pattern of annual rainfall and its distribution, the country is demarcated into wet, dry and intermediate zones. Two arid zones are also recognized, one in the northwestern coastal fringe and the other in the southeastern coastal fringe. Agro-ecological zones have also been defined taking into account rainfall patterns, soil types and temperature. Details of these are provided in the appropriate chapters that follow. One major feature of interest is the natural underground reservoirs of water that underlie the Jaffna peninsula and the northwestern coastal belt. In this region the karstic limestone bed retains the rain water received during the northeast monsoon and has supported a thriving 'well' irrigated agricultural system from ancient times.

THE PEOPLE

At the last census taken in 1981, the population of Sri Lanka was estimated at 14.9 million. It is predicted that by year 2000 the figure will reach nearly 20 million and that it is likely to stabilize at between 23 - 25 million in the first half of the 21st century.

The population is multi-ethnic, multi-religious and multi-cultural. The majority of the population are Sinhala, about 75 per cent, most of whom are Buddhist. About 18 per cent of the population are Tamils, including Tamils of Indian origin. They are mostly Hindus. Muslims form about 7 per cent of the population. Most Muslims speak the Tamil language, a few speak Sinhala and all of them practise the religion of Islam. A few Sinhala and Tamil people are Christians, a larger proportion of these being Roman Catholics, the rest being Protestants. In addition, there is a small population of Malays and of Burghers, some of Portuguese descent and others of Dutch.

Population concentrates heavily in the southwest and central regions of the island and in the Jaffna Peninsula. The dry zone, in spite of state-aided settlement schemes, in recent decades, remains sparsely populated. Although the average density of population of the island is around 250 /km^2, it varies considerably from 50-3000 between areas of lowest density and areas of highest density.

Most Sri Lankans live in villages. While there is migration from rural to urban areas, the urban component of the population has remained virtually static at about 22 per cent during the past decade. These trends are expected to change with the ongoing process of industrialization and the decrease in extents of available rural, arable land.

Since independence, successive governments have adopted policies that have given a range of social benefits to the people of the country. Education was made free from Grade 1 through the school and university system in 1945. Health services are also available free of charge. With the introduction of free education, schools became accessible to all children of school-going age. In the long term, this has paid heavy dividends, especially in taking Sri Lanka to a literacy level of over 95 per cent, a figure that is well above literacy rates in other countries of the region. Free access to health services, combined with the near eradication of malaria in the mid-forties and improved levels of nutrition, led to a number of important demographic changes. Mortality rates declined, birth rates increased, while maternal and infant mortality rates declined. While in the early decades of the 20^{th} century, rates of population growth fluctuated between 1.0 per cent and 1.5 per cent, after 1946 there was an upsurge in population growth which peaked at 2.8 per cent by 1963. Another feature was the rapid rise in life expectancy. In the thirties the figure stood at around 38 years. Today, life expectancy at birth is around 79 for women and 77 for men. However, during the period of high growth rate between 1950 and 1980, the population of the island, doubled, rising from 7.7 million to 14.7 million.

Fortunately, the extension of education to all sections of the people had a major positive effect when it became necessary to exercise control over population growth. The use of contraceptives and the practice of family planning were readily accepted by the people. As a result, it was possible to achieve a reversal in the trend of population growth, rather rapidly. Today population growth rate stands at about 1.3 per cent. Even so, as a result of the period of rapid growth referred to above, we have a population approaching 19 million, at the present time.

Several major problems have emerged as a direct consequence of the size of our population. The land / man ratio is already below optimum level and is likely to become even lower. The quality of social services now available to the people has declined. The education system, which at one time was of high quality, has not kept pace with the needs of the nation and of changing circumstances and has gradually deteriorated. Realizing the prime importance of sound education as a key to economic development, the present government has launched a complete overhaul of the system. Similarly, health services though described as free, are not able to serve the real needs of the people. The transportation system, railways as well as road transport, are way below optimum level.

A major impact of population increase on the environment is evident in rapid deforestation, soil erosion, declining fertility of soils and lowered levels of productivity. More than half the population lives below the poverty line. A cause for great concern is that even among educated youth there is unemployment, both at the end of the secondary school stage and also after graduation.

The economy of the country is largely based on agriculture. Plantation agriculture, especially of tea, is the major foreign exchange earner. In earlier decades, rubber and coconut were important plantation crops, but rubber no longer holds a position of importance, while coconut plantations, in recent times, are being converted into residential properties, the latter commanding higher land values. Foreign employment, especially in West Asian countries, where women are employed as house maids, has become a major source of foreign exchange. The pace of industrialization has been rather slow and, at present, is based mainly on garment industries. These depend on imported raw materials and export markets are determined by quotas imposed by the importing counties. In recent years industrial zones have been created and the government follows an Open Economy Policy, which has encouraged the inflow of foreign capital and the diversification of our industrial base.

From about the mid-seventies the government of the day began to develop the tourist industry. Sri Lanka caught on as a tourist destination quite rapidly, until unsettled conditions in the country made it dangerous for free movement of tourists. However, the inflow of tourists is building up once more and prospects seem to be good for tourism becoming one of the leading foreign-exchange earners for the country, in the near future.

THE STATE

Sri Lanka is a unitary state under a Republican constitution promulgated in 1978. There is an Executive Presidency, a single House of Parliament, a Cabinet of Ministers, Provincial Councils with Governors, Chief Ministers and Provincial Ministers. Under the 13th Amendment to the Constitution, certain powers and responsibilities have been devolved to the Provinces. The sharing of responsibilities between the Centre and the Provinces has certain important implications for the management of natural resources and of the environment. These are enlarged upon in the relevant chapters that follow.

Unfortunately, from 1956 the country has been ravaged by recurring racial tensions which have on a number of occasions manifested themselves in the form of riots. Basically, these problems have arisen because the Tamil minority population has been agitating for a separate Tamil homeland in the north and east of the country. The unrest peaked in the riots of July 1983. One consequence has been the emigration of large numbers of the Tamil people to various countries of the world, often claiming refugee status. Because of these unsettled conditions, even some of the Sinhala people, have left the country. The other more recent and major development is the war situation that now prevails in the country and has taken a heavy toll on the lives of youth on both sides of the ethnic divide. Obviously, these conditions have impacted heavily on the economy, economic development, natural resources management and the environment.

Dissatisfaction among the youth has not been confined to outcomes of the ethnic problems. The country has seen organized uprisings in 1971 and again in 1989. These were based on anti-establishment premises and were predicated, also, upon lack of opportunity for employment and economic advancement. The war which is ongoing is a heavy drain on the economy and also is having major impacts on the environment. The latter can be assessed only after peace returns to the island. It is the fervent hope of all our people that, that day will not be long in coming.

NATURAL RESOURCES

This book is about the natural resources of Sri Lanka, how they have been used or misused in the past, their present status and future potential for sustainable use. Our resources include all major categories, living and non-living, renewable and non-renewable. Major resources include land, water and air, wetlands, forests, natural vegetation, varied natural ecosystems, man-made ecosystems, rich biodiversity, agricultural crops, domesticated animals, fish - both food fish and ornamental, and minerals, specially gemstones. Having made that listing, it must be emphasized that our most valuable resource is the human resource, especially the rising generation, that will take us into the 21st century. The island environment, as a whole, is itself a huge natural resource, because of its exceptional beauty, its rich biodiversity and its ancient cultural heritage. It has great potential to form the base for a booming, entirely sustainable tourist industry.

The following chapters of this book have been written, by invitation, by some of the foremost experts in the country on the various facets of our natural resource base. The book takes as its base the 1991 publication entitled 'Natural Resources of Sri Lanka, Conditions and Trends', published by the Natural Resources Energy and Science Authority (now the National Science Foundation). The intention of the National Science Foundation has been to revise and update the original publication, incorporating the most recent data available and any changes in policies and approaches that may have taken place since the time of the original publication. While, basically the original format has been retained, where appropriate the writers and editors have adopted different formats where they have judged that such changes are necessary. The book is published as a Year 2000 publication.

The original publication, the first one of its kind, has served a long-felt need as a resource book for policy makers, planners, researchers, students and the general public. However, certain sections of the book do not deal in sufficient depth with a number of important issues. It has to be noted that the original publication appeared before the major international deliberations of the early 90s on global concerns including, Climate Change, Loss of Biodiversity, Population Growth and Desertification.

This revised and updated edition follows upon the 1992 United Nations Conference on Environment and Development held in Rio de Janeiro (UNCED), the Rio Declaration, the Framework Convention on Climate Change and the Convention on Biodiversity. The main document that came out of UNCED is Agenda 21, an international blueprint for Sustainable Development. In this publication the unifying theme is Sustainable Development. The final chapter looks at Sri Lanka's Heritage of Natural Resources in terms of sustainable use for the benefit of our people, in the early decades of the 21st century and beyond.

REFERENCES

1. Abeywickrema B.A. (1990) Integrated conservation for human survival in Sri Lanka. In: *Ecology and Land Management in Sri Lanka*. Proceedings of the International Integrated Symposium, Colombo.
2. Needham J. (1971) Civil engineering and nautical science and civilization in China: Cambridge University Press.

Courtesy: The Island.

Crowd at a Bus Station

POPULATION PROFILE

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Summary

Sri Lanka's population growth rate between 1871 and 1946 was slow averaging 1.4 per cent, in spite of immigration. Growth rate rose to 2.8 per cent between 1946 and 1963 while death rates declined sharply during this period. Education, health and social welfare services contributed to this major change supporting the decline in mortality. Life expectancy, which stood at 44 years for males and 42 years for females in 1946 rose to 68.8 and 73.5 respectively, by 1988. Total fertility rate declined drastically from 5.0 during 1962 to 1964 to 2.3 during 1988 to 1993. Late marriage, contraceptive use, women's employment and education were contributory factors. The government's National Population and Reproductive Health Policy aims to maintain the declining fertility trends and stabilize the population at about 23 million towards the middle of the 21st century. The proportion of urban population to rural has increased very slowly. There has been considerable increase in the labour force and as the economy has not kept pace there has been an increase in unemployment in the 1960s and 1970s. Changes in age structure of the population are taking place. The population under 15 years is on the decline while there is a gradual increase in the proportion of the elderly.

POPULATION GROWTH

Changes in the population size and structure are influenced by three components namely, fertility, mortality and migration. The pace at which births, deaths and migration occur determines the rate of growth of a population. The population continuously increases by the birth of infants and the arrival of immigrants of different ages. On the other hand, population is being depleted, simultaneously by the death of persons and by emigrants of all ages. Thus the pace at which these events occur determines the growth and structure of the population. The difference between births and deaths is called "natural increase". The balance of immigration and emigration is termed "net migration". Thus in a given area, the size of population can change only in two ways – through natural increase and through net migration.

Changes in Population Size and Growth Rates

The first scientific census of population was taken in Sri Lanka in 1871, at which time the total population of the country was enumerated at 2.4 million. The total size of population has increased nearly eight fold and reached 19.2 million by the middle of year 2000. During the early period, after 1871, the population of the country grew at a slow pace mainly due to the fact that though birth rates were high, death rates including maternal mortality rates were high, as well. The average annual rate of growth of population during the period 1871 to 1946 was 1.4 per cent. The rate of growth of population during this period would have been even slower if not for immigration which contributed about 27 per cent to the total increase of population. The rate of growth of population accelerated during the period 1946 to 1963, the average annual growth rate almost doubling to 2.8 per cent. The rapid growth of population during this period was the result of a dramatic decline in mortality without a corresponding decline in fertility. Since 1963, the rate of growth of population has declined due to the gradual decline in fertility and immigration.

Table 1 : Growth of population, 1871-2000

Year	Population ('000)	Average Annual Growth Rate (%)	Total Increase of Population ('000)	Migration Increase ('000)	Migration Increase (%)
1871	2400	-	-	-	-
1946	6657	1.4	4257	1155	27.1
1963	10 582	2.8	3925	49	1.2
1981	14 847	1.9	4265	-831	-19.5
1991	17 247	1.5	2400	-378	-15.8
2000*	19 177	1.2	1930	-410	-21.1

Source: Reports of Census of Population; Population Division, Ministry of Health.
* Projected

Mortality Trends

The crude death rate in Sri Lanka remained high and fluctuated around 28 per thousand of the population until the beginning of the second decade of the 20th century. The death rate showed a definite declining trend between 1920 and 1945 due to the gradual expansion of primary health care facilities (Table 2). This decline was followed by a sharp decline during 1945 to 1950 as a result of the almost complete eradication of malaria and the expansion of health care services particularly in the dry zone districts of the country (ESCAP, 1976). The subsequent reductions in mortality were sustained through the growth and spread of the country's health care system including pre-and post-natal care, economic growth, food subsidies, improvements in sanitation and rising educational level of the population. As a result of these factors, the life expectancy at birth rose from 44 years for males and 42 years for females in 1946 to 68.8 and 73.5 years respectively in 1988 (Table 3). The higher

Table 2 : Crude death rate, infant mortality rate and maternal mortality ratio 1881-1995

Year	Crude Death Rate (per 1000 Population)	Infant Mortality Rate (per 1000 live births)	Maternal Mortality Ratio (per 100 000 live births)
1881	27.2	170	-
1920	29.6	182	-
1945	21.5	140	165
1950	12.6	82	56
1980	6.2	34	60
1995	5.8	17	24

Source: Registrar General's Department.

life expectancy for females since 1971, which is consistent with the pattern in developed countries, is due to the significant reduction in maternal mortality ratios.

Table 3 : Life expectancy at birth by sex 1946-1988

Life Expectancy						(years)
	1946	1953	1962	1971	1981	1988*
Total	42.2	58.2	61.7	65.5	69.9	71.2
Male	43.9	58.8	61.9	64.2	67.7	68.8
Female	41.6	57.5	61.4	66.7	72.1	73.5

Source: Department of Census and Statistics.
* Estimated

Fertility Trends

The fertility levels in Sri Lanka remained high until around the mid 1950s. The crude birth rate fluctuated around 38 per thousand of the population between 1896 to 1955 (Table 4). Since the early 1960s, as evident from Table 5, a clear downward trend in fertility was observed both in terms of age specific fertility rates and total fertility rates (ESCAP, 1986). The initial fertility decline has been attributed to the rise in age at marriage of females. Since the mid 1970s, the decline in fertility has been due increasingly to contraceptive use (Abeykoon, 1996). The contraceptive prevalence rate increased from 32 per cent in 1975 to 66 per cent in 1993. As a result, fertility decline among those aged 30 years and over has been rapid, particularly in the 1980s.

Among the socio-economic factors that have contributed to fertility decline is the rising educational levels of the population, particularly the education of females beyond the primary level. In recent years, the upward social mobility of females brought about by the wider availability of economic opportunities and their participation in the modern economic sectors have also contributed to higher contraceptive use and fertility decline (Abeykoon, 1998a).

Table 4 : Crude birth rate, 1896-1995

Period	Birth Rate (per 1000 population)	Period	Birth Rate (per 1000 population)
1896-1900	37.1	1961-1965	34.3
1926-1930	40.4	1971-1975	28.7
1941-1945	36.6	1981-1985	26.2
1951-1955	38.1	1991-1995	20.0

Source: Computed from data at the Registrar General's Department.

Table 5 : Age specific and total fertility rates 1962-1993

Age Group	Fertility Rates				
	1962-64	1970-72	1980-82	1982-87	1988-93
15-19	52.4	40.4	38.3	38	35
20-24	228.8	179.4	172.7	147	110
25-29	279.9	227.3	196.6	161	134
30-34	239.2	199.8	148.8	122	104
35-39	155.5	131.3	89.1	71	54
40-44	46.0	40.6	26.4	23	14
45-49	6.7	6.0	3.9	3	4
TFR	**5.0**	**4.1**	**3.4**	**2.8**	**2.3**

Source: ESCAP, *Level and Trends of Fertility in Sri Lanka, A District Level Analysis*; Demographic and Health Surveys, 1987 and 1993.

Migration and Urbanization Trends

International migration contributed positively to population growth until the early 1950s. Since 1951, migration has had a negative effect on the growth of population as shown in Table 6. The decline in immigration was mainly due to the gradual enforcement of the Immigration and Emigration Act of 1948 and the subsequent Citizenship Act of 1948 and Indian and Pakistan Residents Act of 1949 which restricted the movement of non-nationals into the country for permanent settlement. These pieces of legislation, along with the Sirima-Shasthri Pact of 1964, contributed to migration patterns that had negative effects on population growth. The acceleration of migration since 1971 to the Gulf States for contract employment reduced the population growth rate further.

Table 6 : Migration trends 1871-1995

Period	Migration*	Migration Rate %
1871-1950	138 427	26.8
1951-1970	-22 347	-2.2
1971-1990	-44 785	-3.0
1991-1995	-40 871	-2.3

Sources: Registrar General's Department.
* Average annual figure

The rate of urbanization in Sri Lanka has been rather slow. Between 1953 and 1981, the proportion of urban population to the total population increased from a low figure of 15.3 per cent to only 21.5 per cent (Table 7). During the intercensal period 1971 to 1981, the average annual rate of growth of urban population was lower than that of the total population. The slow pace of urbanization in Sri Lanka is the result of the weakening of "push" and "pull" factors. As a result of deliberate government policies industries have been located near areas where raw materials are available. The population has been redistributed from rural areas where the population is dense, to rural areas which are sparsely populated. In addition, development and expansion of the social infrastructure and the means of communication in rural areas narrowed the disparities between rural and urban living conditions. However, the urban population is expected to grow at a faster rate in the future. The proportion of urban population to the total population is expected to reach about 42 per cent by the year 2030 (United Nations, 1998).

Population redistribution was influenced also by indirect policies such as eradication of malaria in the dry zone. Malaria was an important factor in the de-population of the dry zone in the past. The successful eradication of malaria facilitated the movement of people from the densely populated wet zone to the sparsely populated dry zone.

Mortality decline in Sri Lanka also has been influenced by both direct and indirect policies. The development of health services and health education were the key factors in the decline of mortality. Socio-economic factors also, have, indirectly influenced the decline in mortality and morbidity levels.

The recognition of the work of the Family Planning Association of Sri Lanka, by the government, as far back as 1954, by providing a financial grant, was the beginning of government concern with regard to high fertility. Government provided a grant to the Family Planning Association of Sri Lanka as far back as 1954, recognizing the work done by the Association. The provision of the grant

Table 7: Growth of urban population, 1953-1995

Year	Urban Population ('000)	% Urban Areas	Total Urban Areas	Average annual Growth Rate (%)	
				Total Population	Urban Population
1953	1239	15.3	43	-	-
1963	2016	19.1	99	2.7	4.9
1971	2848	22.4	135	2.2	4.2
1981	3192	21.5	134	1.7	1.2
1995*	4538	25.0	-	1.4	2.5

Source: Census of Population.
* Estimated

Population Policies

The government's recognition of the importance of regulating the rate of growth of population dates back to the 1940s, at which time policies and programmes were initiated to redistribute population within the country and control immigration from other countries. These included, legislation introduced to control immigration and emigration, colonization policies and new settlement programmes.

was the beginning of government's concern with regard to the excessive child bearing particularly among the poorer segments of the population which resulted in higher infant maternal mortality. The Association was allowed to run Family Planning clinics in selected government hospitals until 1965, in which year Family Planning was accepted as a national policy. Another important step that was taken was the agreement signed between the governments of Sri Lanka and Sweden in 1958 to carry out a pilot study on the attitudes to and demand for family planning.

In 1968, the Family Health Bureau was established to implement the maternal, child health and family planning programmes of the government. In 1972 the government entered into an agreement with the United Nations Population Fund (UNFPA) to implement a series of projects including education, information, communication and service delivery in the field of family planning, both within and outside the Ministry of Health. In the latter half of 1970s great emphasis was placed on population activities in the country. In 1979, the government made a policy statement on population making commitments to enhance family planning services and financial incentives with a view to controlling population growth. In the same year, a Population Division was established in the Ministry of Plan Implementation to direct and coordinate the National Population Programme.

In 1991, recognizing the need to take measures to contain population size in line with the resources of the country, for the first time, the government set a target of achieving replacement level fertility, at least by the end of the decade. The objective was to reach a stable population size towards the middle of the 21st century.

In August 1998, the Cabinet of Ministers approved the National Population and Reproductive Health Policy for Sri Lanka which was formulated by an inter-sectoral Task Force appointed by the Minister of Health. The National Population and Reproductive Health Policy aims at achieving the following eight specific goals: Under each goal various strategies have also been identified: (1) Maintain current trends of decline in fertility so as to achieve a stable population size, at least, by the middle of the 21st century. (2) Ensure safe motherhood and reduce reproductive health system related morbidity and mortality. (3) Achieve gender equality. (4) Promote responsible adolescent and youth behaviour. (5) Provide adequate health care and welfare services for the elderly. (6) Promote the economic benefits of migration and urbanization while controlling their adverse social and health effects. (7) Increase public awareness of population and reproductive health issues. (8) Improve population planning and collection of quality statistics at the national and sub-national levels.

Population Projections

Given the current trends in fertility, mortality and migration, the population growth rate is expected to continue to decline in the coming decades leading to a zero growth rate in about four decades and a total stable population size of about 23 to 24 million. The total population is expected to increase from 19.2 million in the year 2000 to 22.9 million in 2030.

Table 8 : Population projections by age and sex 2000-2030

	Population ('000)							
Age Group	**2000**		**2010**		**2020**		**2030**	
	Male	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**
0-4	808	777	784	754	672	646	706	678
5-9	788	760	795	767	722	697	672	648
10-14	818	809	800	773	777	750	667	644
15-19	913	907	779	757	788	765	717	695
20-24	912	890	802	802	789	769	769	749
25-29	829	802	893	898	764	750	777	762
30-34	756	729	893	882	788	795	776	764
35-39	714	708	810	792	876	890	750	746
40-44	680	685	737	720	873	872	772	788
45-49	602	609	693	696	788	780	854	878
50-54	495	498	652	667	708	703	841	853
55-59	386	386	564	584	652	670	745	754
60-64	301	300	450	468	595	630	650	667
65-69	241	243	332	348	488	531	568	614
70-74	185	187	236	251	355	396	475	539
75-79	123	126	160	176	224	257	335	400
80+	102	108	146	169	195	241	291	380
Total	**9653**	**9524**	**10526**	**10502**	**11053**	**11142**	**11365**	**11559**

Source : A.T.P.L. Abeykoon (1998) *Demographic Projections for Sri Lanka.*

It is evident from Table 8 that the pre-school age population (0-4 years) will decline in absolute size from 1.58 million in 2000 to 1.38 million in 2030. The school age population which is generally regarded as those in the age category 5-14 years will decline in absolute number from 3.17 million in the year 2000 to 2.63 million in 2030. The youth population aged 15-24 years which constitutes nearly one fifth of the total population will decline from 3.62 million to 2.93 million during the same period. On the other hand, the working age population aged 15-59 years, which supplies labour for economic activity is projected to increase from 1.25 million in the year 2000 to 1.40 million in 2030. However, the proportionate share of those aged 15-59 years to the total population is expected to decline from 65.2 per cent to 61.0 per cent during the same period. The old age population aged 60 years and over, however, will increase in absolute and relative terms during the projection period. The population aged 60 years and over will increase from 1.92 million in the year 2000 to 4.92 million by the year 2030. The proportionate share of this

Table 9 : Distribution of population and land area by district 1871-1995

		Population (%)			
Province/ District	**Land/Area %**	**1871**	**1946**	**1981**	**1995**
Sri Lanka	100.0	100.0	100.0	100.0	100.0
Western Province	5.6	24.0	28.2	26.4	26.7
Colombo	1.1	17.9	21.3	11.5	11.6
Gampaha	2.1	-	-	9.4	9.8
Kalutara	2.4	6.1	6.9	5.6	5.4
Central Province	8.7	15.2	17.0	13.5	13.3
Kandy	3.0	9.7	10.7	7.1	7.0
Matale	3.0	3.1	2.3	2.4	2.4
Nuwara Eliya	2.7	2.4	4.0	4.1	3.9
Southern Province	8.5	16.6	14.4	12.7	12.8
Galle	2.5	8.1	6.9	5.5	5.4
Matara	2.0	6.0	5.3	4.3	4.3
Hambantota	4.0	2.5	2.2	2.9	3.0
Northern Province	13.5	11.7	7.2	7.5	7.2
Jaffna	3.5	10.3	6.4	5.6	5.3
Mannar	3.0	0.8	0.5	0.7	0.7
Vavuniya	3.0	0.6	0.3	0.6	0.6
Mullaitivu	4.0	-	-	0.5	0.5
Eastern Province	15.2	4.7	4.2	6.6	6.8
Batticaloa	4.3	3.9	3.1	2.2	2.3
Ampara	6.7	-	-	2.6	2.7
Trincomalee	4.2	0.8	1.1	1.7	1.7
Northwestern Province	12.0	11.5	10.0	11.5	11.4
Kurunegala	7.3	8.7	7.3	8.2	7.9
Puttalam	4.7	2.8	2.6	3.3	3.4
Northcentral Province	15.9	2.7	2.1	5.7	5.8
Anuradhapura	10.9	2.7	2.1	4.0	3.9
Polonnaruwa	5.0	-	-	1.8	1.8
Uva Province	13.0	5.4	5.6	6.2	6.4
Badulla	4.4	5.4	5.6	4.3	4.3
Moneragala	8.6	-	-	1.8	2.1
Sabaragamuwa Province	7.6	8.2	11.2	10.0	9.6
Ratnapura	5.0	3.8	5.2	5.4	5.3
Kegalle	2.6	4.4	6.0	4.6	4.4

segment will increase from 10.0 per cent to 21.5 per cent during the same period. Nevertheless, it is important to note that population aged 70 years and over will increase from 4.3 per cent to 10.6 per cent during the same period. In absolute terms the numbers involved of those over 70 years will be about 1.6 million compared to 3.0 million for those aged 60 years and over (Abeykoon, 1998b).

POPULATION DISTRIBUTION

The distribution of population is influenced by geographical factors such as climate, terrain, soils, natural resources etc. and a variety of social, cultural, demographic and economic factors. In Sri Lanka, over the years these factors have combined to determine the pattern of population distribution in the country.

Distribution by Administrative Divisions

The distribution of population by provinces and districts between 1871 and 1991 reveals interesting features. The Western Province, the smallest in land area with only 5.6 per cent has maintained a predominant position with nearly 27 per cent of the country's population. The second most populous province, the Central Province has about 13 per cent of the total population in 8.7 per cent of the total land area. The wet zone provinces, Western, Central and Southern together include only 23 per cent of the land area but have about 53 per cent of the total population. The North Central Province the largest in terms of land area has the smallest population size. There have been changes in the relative share of each of the nine provinces between 1871 and 1995 (Table 9). For instance, the share of the Western Province increased from 24.0 per cent in 1871 to 28.2 per cent in 1946 and thereafter declined to 26.7 per cent in 1995. Decline in the relative share of population between 1871 and 1995 are observed in the Central, Southern and Northern Provinces. On the other hand, increases in the relative share of population are noted in Eastern, Northcentral, Uva and Sabaragamuwa Provinces. In the Northwestern Province, however, the population proportions have remained more or less the same. Within provinces too, there is uneven distribution of population. For example, in 1995, in the Northern Province, the Jaffna district had a population which was more than six times that of the second largest district Mannar. In 1995, the most populous district in the country was Colombo with more than two million people. The other large districts, in order of population size, were Gampaha, Kurunegala and Kandy. The district with the smallest population was Mullaitivu with approximately 100 000 people.

Table 10 : Rural-urban distribution of the population by province, Sri Lanka, 1946 and 1981

Province	Population %			
	1946		1981	
	Urban	Rural	Urban	Rural
Sri Lanka	15.4	84.6	21.5	78.5
Western Province	33.5	66.5	46.7	53.3
Central Province	8.9	91.1	11.0	89.0
Southern Province	10.9	89.1	14.8	85.2
Northern Province	13.1	86.9	28.0	72.0
Eastern Province	16.3	83.7	22.1	77.9
Northwestern Province	4.9	95.1	6.2	93.8
Northcentral Province	8.8	91.2	7.3	92.7
Uva Province	4.4	95.6	6.3	93.7
Sabaragamuwa Province	2.6	97.4	7.6	92.4

Sources : Census of Population Reports 1946 and 1981, Dept of Census & Statistics.

Urban-Rural Distribution

As is evident from Table 7, the proportion of population living in urban areas has increased very slowly from about 15 per cent in 1953 to only 25 per cent in 1995. The urban population has been broadly defined to comprise all those living in areas designated as Municipal, Urban and Town Councils. The urban-rural distribution of population shows variations by province. Some provinces show a greater share of their population living in urban areas than others, as is evident from Table 10. The Western Province has the highest proportion of population living in urban areas with nearly 47 per cent. It is followed by Northern and Eastern Provinces with proportions of 28.0 per cent and 22.1 per cent respectively. It is noteworthy that in the Southern Province, the proportion of population living in urban areas has increased only by about four percentage points over a period of 35 years between 1946 and 1981, mainly due to the migration of the urban

Table 11 : Density of population /km² by province and district 1871-1998

Province/District	Land Area km²	Population Density			
		1871	1946	1981	1998
Sri Lanka	64 651.83	37	103	230	290
Western Province	3 651.84	157	513	1072	1372
Colombo	652.42	205	687	2605	3342
Gampaha	1 398.85	-	-	994	1303
Kalutara	1 606.57	91	286	516	628
Central Province	5 585.24	65	203	360	446
Kandy	1 890.76	99	304	486	696
Matale	1 988.59	32	68	180	229
Nuwara Eliya	1 705.85	48	221	354	423
Southern Province	5 513.83	72	174	341	435
Galle	1 673.91	116	275	487	615
Matara	1 246.56	116	286	516	653
Hambantota	2 593.36	23	58	164	215
Northern Province	8 685.53	32	55	128	155
Jaffna	2 072.25	96	166	401	479
Mannar	2 002.06	08	13	53	70
Vavuniya	2 645.16	04	06	36	45
Mullaitivu	1 966.06	-	-	39	50
Eastern Province	9 622.07	12	29	101	133
Batticaloa	2 464.63	13	25	134	179
Ampara	4 539.22	-	-	86	113
Trincomalee	2 618.22	07	28	98	126
Norhwestern Province	7 749.76	36	86	220	275
Kurunegala	4 772.83	44	103	254	310
Puttalam	2 976.93	23	18	165	218
Northcentral Province	10 532.97	06	13	81	103
Anuradhapura	7 129.21	06	13	82	102
Polonnaruwa	3 403.76	-	-	77	104
Uva Province	8 405.04	15	44	109	143
Badulla	2 818.17	15	44	227	287
Moneragala	5 586.87	-	-	49	70
Sabaragamuwa Province	4 901.55	40	152	302	368
Ratnapura	3 238.78	25	107	246	306
Kegalle	1 662.77	64	245	412	488

Source : Computed from census data and the estimated population.

Table 12 : Population km^2 / by sex and sex ratio 1871-2015

Census Year	Male	Female	Sex Ratio
1871	1 280 129	1 120 251	114.3
1881	1 469 533	1 290 185	113.9
1891	1 593 376	1 414 413	112.7
1901	1 896 212	1 669 742	113.6
1911	2 175 030	1 931 320	112.6
1921	2 381 812	2 116 793	112.5
1946	3 532 218	3 125 121	113.0
1953	4 268 730	3 829 165	111.5
1963	5 498 674	5 083 390	108.2
1971	6 531 361	6 158 536	106.1
1981	7 568 253	7 278 497	104.0
1991	8 739 000	8 523 000	102.5
2000	9 653 000	9 524 000	101.4
2015	10 837 000	10 869 000	99.7

Sources: Reports of Census Population; estimated and projected population.

Table 13 : Population composition by broad age groups, 1881-2030

	Population (%)		
Year	0-14 Years	15-64 Years	65 Years and Over
1881	43.6	54.2	2.2
1891	43.5	54.4	2.1
1901	42.2	56.4	1.4
1911	40.9	56.8	2.3
1921	39.4	58.2	2.4
1946	37.2	59.3	3.5
1953	39.7	56.8	3.5
1963	41.5	54.9	3.6
1971	39.0	56.8	4.2
1981	35.2	60.5	4.3
1991	31.2	63.4	5.4
1995	27.7	66.1	6.2
2000	24.8	68.3	6.9
2005	23.3	69.1	7.6
2010	22.2	69.2	8.6
2015	20.8	69.0	10.2
2020	19.2	68.7	12.1
2030	17.5	66.8	15.7

Sources: Data up to 1981 are from Census Reports, Department of Census and Statistics; Data from 1991 to 2030 are from *Population Statistics of Sri Lanka* (1996), Population Information Centre.

population to other provinces and in particular to the Western Province.

Population Density

Sri Lanka is one of the most densely populated countries in the world. The density of population which was 37 persons /km^2 in 1871 increased eight fold almost to 290 by 1998. Population density by districts shows that the districts in the Northern Province have relatively low densities while the districts in the Western Province are densely populated (Table 11). In 1998, the Vavuniya District had the lowest population density with 45 persons /km^2 while the density of Colombo District was about 74 times that of Vavuniya. In 1871, the districts of Colombo, Galle, Matara, Kandy and Jaffna had relatively high density. In 1998, Colombo, Matara and Kandy continued to remain as high density districts.

POPULATION COMPOSITION

In this section we will discuss the age-sex, ethnic, religious and the marital compositions of the population. These factors have a significant influence on fertility, mortality and migration and in turn on the rate of growth of population.

2015, the female population will outnumber the males due to the persistent higher life expectancy of females.

The changes in the age structure of the population is also evident from Table 13. The proportion of population under 15 years of age declined gradually to about 37 per cent by 1946

Table 14 : Distribution of population by ethnic groups for selected years 1911-1995

	Population %					
Ethnic Groups	**1911**	**1953**	**1963**	**1971**	**1981**	**1995***
Sinhala	66.1	69.4	71.0	72.0	74.0	74.9
Sri Lankan Tamils	12.9	10.9	11.0	11.2	12.7	11.9
Indian Tamils	12.9	12.0	10.6	9.3	5.5	4.9
Moors	6.5	6.3	6.5	6.7	7.0	7.6
Others	1.6	1.4	0.9	0.8	0.8	0.7
Total	100.0	100.0	100.0	100.0	100.0	100.0
Total Population ('000)	4106	8098	10 582	12 690	14 847	18 112

Source : Census Reports, Department of Census and Statistics.
* Estimated

Table 15 : Distribution of population by religious groups for selected years1911-1995

	Population %					
Religious Groups	**1911**	**1953**	**1963**	**1971**	**1981**	**1995***
Buddhist	60.2	64.3	66.3	67.3	69.3	70.2
Hindu	22.9	19.9	18.4	17.6	15.5	14.7
Christian	9.9	9.0	8.3	7.9	7.6	7.5
Muslim	6.9	6.7	6.9	7.1	7.5	7.5
Other	0.1	0.1	0.1	0.1	0.1	0.1
Total	100.0	100.0	100.0	100.0	100.0	100.0
Total Population ('000)	4106	8098	10 582	12 690	14 847	18112

Source: Census Reports, Department of Census and Statistics.
* Estimated

Age-Sex Composition

The sex structure of a given population is determined by the sex ratio at birth, the sex differences in mortality and sex selective migration. The age structure is influenced by the level of mortality, fertility and migration.

It can be seen from Table 12 that the sex ratio of the population has gradually declined from 114.3 males to 100.0 females in 1871 to 102.5 to 100 in 1991. The projected ratios show that by

and thereafter increased to 41.5 per cent by 1963 (Population Information Centre, 1996). The decline in the proportion of population under 15 years of age prior to 1946 can be attributed mainly to the increase of migrant population in the working ages. The increase in the proportion of young people between 1946 and 1963 is the result of the rapid increase of population due to the sharp decline in mortality levels. Since then the share of those under 15 years of age gradually declined to 31 per cent in 1991, due largely to the decline in fertility. This proportion is expected to decline further to 17.5 per cent by the year 2030, as a result of the expected continued decline in fertility.

Ethnic and Religious Composition

The percentage distribution of population in Sri Lanka by ethnic groups is presented in Table 14. It can be seen that between 1911 and 1995, the proportion of the Sinhalese population has increased from 66.1 per cent to 74.9 per cent while that of Sri Lankan Tamils and Moors have remained more or less the same. On the other hand, the proportion of Indian Tamils to the total population declined from 12.9 per cent to 4.9 per cent during the same period (Department of Census and Statistics, 1986). This is mainly due to the repatriation of stateless Indian Tamils to India under the Sirimavo-Shastri Pact and those who gained citizenship declaring themselves as Sri Lankan Tamils. The share of "Other" ethnic groups in which the Burghers comprise the majority also has declined gradually due to the emigration of Burghers to the more developed countries since the mid 1950s. The distribution of population by ethnic groups for 1995 is an estimate based on natural increase and international migration during 1981 and 1995.

The distribution of the major religious groups in Sri Lanka is shown in Table 15. It can be seen that Buddhists who are largely Sinhalese have increased their relative share in the population from 60.2 per cent in 1911 to 70.2 per cent in 1995. On the other hand, the Hindus who comprised 22.9 per cent in 1911 declined to 14.7 per cent in 1995 largely due to the fact that a significant number has migrated from the country. Christians also show a decline from 9.9 per cent to 7.5 per cent during the same period as Burghers

Table 16 :Population distribution by marital status, 1901-1981

Year	Population %				
	Unmarried	Married	Widowed	Divorced/ Separated	Total
1901	59.8	33.7	6.5	-	100.0
1911	59.9	33.6	6.5	-	100.0
1921	59.9	33.2	6.9	-	100.0
1946	56.8	37.5	5.5	0.2	100.0
1953	58.3	36.5	4.9	0.3	100.0
1963	61.2	34.7	3.9	0.2	100.0
1971	62.0	34.3	3.4	0.3	100.0
1981	59.5	37.0	3.2	0.3	100.0

Source : Computed from census data.

Table 17 : Singulate mean age at marriage by sex for selected years

(years)

Year	Age at Marriage	
	Male	Female
1901	24.6	18.3
1911	26.5	20.8
1921	27.0	21.4
1946	27.0	20.7
1953	27.2	20.9
1963	27.9	22.1
1971	28.0	23.5
1981	27.9	24.4
1987*	-	24.8
1993*	-	25.5

Sources: Census of Population, General Report, 1981; Demographic and Health Survey Reports, 1987 and 1993.
* Excludes the Northern and Eastern Districts.

who were Christians emigrated in large numbers since the latter part of 1950s. The proportion of the Muslims increased slightly while the other religious groups comprise a negligible proportion. The 1995 religious composition is based on the estimated ethnic composition and the 1981 ethno-religious composition of the population.

Marital Composition

The distribution of the total population by marital status shows that the proportion of unmarried persons has constituted around 60 per cent of the total population between 1901 and 1981 (Table 16). The proportion married has increased from 33.7 per cent in 1901 to 37.0 per cent in 1981. The proportion widowed which was 6.5 per cent has declined to 3.2 per cent during the same period due to the decline in mortality.

The singulate mean age at marriage shows that there has been an increase in the mean age at marriage between 1901 and 1993 (Table 17). In recent years the increase has been more marked in the case of females. The female age at marriage has increased from 18.3 years in 1901 to 25.5 years in 1993. In the case of males, it has increased from 24.6 to 27.9 years during the same period. A greater proportion of young people being retained in the educational system for a longer period, and a higher proportion of females seeking employment before marriage are some of the important factors contributing to the increase in the age at marriage in Sri Lanka.

FAMILIES, HOUSEHOLDS AND HOUSING NEEDS

The family is the basic unit of society. The size of families is determined by the demographic processes of fertility and mortality. The household as a unit derives its significance from the fact that it represents the smallest group of persons living together and making common provision for food and other essentials. Households and families live in housing units. Thus the demand for housing depends on the growth of families and households.

Families and households

Although the 1981 census of population did not provide any basic data on the total number of families and households, the housing censuses of 1953, 1963 and 1971 did provide information on these variables. It can be seen from Table 18, that

Table 18 : Growth of households and families 1953-1971

('000)

	Households and Families			Percentage increase	
Category	1953	1963	1971	1953-71	1963-71
Families	-	1995	2435	-	22.1
Households	1612	-	2446	51.7	-
Population	8098	10 582	12 690	30.8	19.9

Source: Census of Population and Housing.

Table 19 : Growth of housing, 1971-1981

('000)

Category	1971	1981	Percentage Increase 1971-81
Housing Units	2217	2814	26.9
Population	12 690	14 847	17.0
Occupancy Ratio	5.6	5.2	-7.1

Source: Census of Population and Housing.

Table 20 : Housing requirements by sector 1995-2005

('000)

Sector	1995	2000	2005	Increase	
				1995-2000	2000-2005
Total	3947	4270	4600	323	330
Urban	827	922	1021	95	90
Rural	2884	3092	3302	208	210
Estate	236	256	277	20	21

Source: A.T.P.L. Abeykoon (1998) *Population and Manpower Resources of Sri Lanka.*

between 1953 and 1971 the number of households increased by about 52 per cent, while the growth of the total population was much less with a percentage increase of 30.8 per cent. Similarly, during a much shorter period between 1963 to 1971, families have grown at a higher rate than the total population.

Housing conditions and needs

The changes in the housing stock in relation to population growth between 1971 and 1981 are shown in Table 19. It can be seen that the growth of housing units has been faster than that of the population. As a result, the occupancy ratio or the average number of occupants per housing unit fell from 5.6 in 1971 to 5.2 in 1981. The housing requirements for the period 1995 to 2005 has been estimated on the basis of the occupancy ratio and the projected population. It can be seen from Table 20 that the housing requirements during 2000 to 2005 would increase by about 330 000 out of which 90 000 would be in the urban sector.

LABOUR FORCE

The labour force or the economically active population is that part of the population which contributes to or is willing to contribute its labour to the production of economic goods and services. Thus the labour force comprises all those who are employed and unemployed. The employed category includes those who are under-employed as well.

Labour supply

Labour supply is determined by a variety of demographic, economic and social factors. The size and age-sex structure of the population and the age-sex participation rates in economic activity determine the size and structure of the labour force.

It can be seen from Table 21 that the total labour force has grown rapidly from 2.6 million in 1946 to nearly 7 million in 1990. The crude participation rate for females has increased from 18.2 per cent to 31 per cent during the same period.

The total labour force is expected to increase from 8.1 million in 1995 to 10.1 million in 2010 and to 11.1 million in 2030 (Table 22). Although the rate of growth of labour force will gradually decline from 1.95 per cent during 1995-2000 to 0.21 per cent during 2025-2030, the labour force will continue to grow at a faster rate than that of the population until the year 2020. Thus the task of employment creation to absorb the annual net addition to the labour force will continue for another two decades.

Table 21 : Growth of labour force 1946-1997

Title of Survey	Labour Force ('000)			Crude participation Rate (%)		
	Total	Male	Female	Total	Male	Female
Census of Population 1946	2611	2041	570	39.2	57.8	18.2
Census of Population 1953	2993	2268	724	37.0	53.1	18.9
Census of Population 1963	3464	2742	722	32.7	49.8	14.2
Socio-economic Survey 1969/70	4169	3124	1045	38.6	57.3	19.5
Census of Population 1971	4488	3312	1176	35.4	50.7	19.1
Survey of Labour Force Participation Rate 1973	4560	3267	1293	34.4	48.5	20.2
Consumer Finance & Socio Economic Survey 1978/79	5521	3712	1809	38.0	30.4	26.2
Census of Population 1981	5015	3767	1248	33.8	49.8	17.1
Labour Force & Socio Economic Survey 1985/86*	5961	4037	1924	38.5	52.5	24.7
Labour Force Survey 1990	6968	4374	2594	41.0	51.0	30.8
Labour Force Survey 1992*	5757	3880	1877	38.5	51.3	25.3
Labour Force Survey 1997*	6229	4176	2053	39.1	52.0	25.9

Sources: Respective Census and Survey Reports.

* Does not include the Northern and Eastern Districts.

Table 22 : Labour force projections, 1995-2030

Labour Force				Labour Force ('000)			
Year	Male	Female	Total	Year	Male	Female	Total
1995	5387	2695	8082	2013	6796	3529	10 325
1996	5483	2757	8240	2014	6845	3553	10 398
1997	5582	2821	8403	2015	6894	3578	10 472
1998	5682	2886	8568	2016	6925	3606	10 532
1999	5784	2952	8736	2017	6957	3635	10 592
2000	5888	3020	8908	2018	6988	3664	10 652
2001	5976	3063	9040	2019	7020	3693	10 713
2002	6066	3108	9174	2020	7052	3723	10 775
2003	6157	3152	9309	2021	7076	3736	10 812
2004	6249	3198	9447	2022	7100	3749	10 849
2005	6343	3244	9587	2023	7124	3763	10 887
2006	6404	3285	9689	2024	7148	3776	10 924
2007	6465	3327	9792	2025	7172	3790	10 962
2008	6526	3370	9896	2026	7178	3807	10 985
2009	6588	3413	10 001	2027	7184	3825	11 009
2010	6651	3457	10 108	2028	7190	3842	11 032
2011	6699	3481	10 179	2029	7195	3861	11 056
2012	6747	3505	10 252	2030	7201	3878	11 079

Source: A.T.P.L. Abeykoon (1998) *Demographic Projections for Sri Lanka.*

Table 23: Growth of employment by major industrial sectors, 1953-1997

Census/Survey	Employment ('000) Primary	Secondary	Tertiary	Total
Census 1953	1 597.9 (53.4)	349.2 (11.7)	1 046.2 (34.9)	2 993.3 (100.0)
Census 1963	1 691.3 (52.9)	385.2 (12.1)	1 118.6 (35.0)	3 195.1 (100.0)
Census 1971	1 842.0 (50.5)	452.6 (12.4)	1 354.3 (37.1)	3 648.9 (100.0)
Census 1981	1 902.4 (46.2)	556.8 (13.5)	1 660.1 (40.3)	4 119.3 (100.0)
Labour Force Survey 1985/86*	2 596.6 (50.6)	892.9 (17.4)	1 642.1 (32.0)	5 131.7 (100.0)
Labour Force Survey 1990	3 011.6 (50.5)	1 061.6 (17.8)	1 890.5 (31.7)	5 963.7 (100.0)
Labour Force Survey 1992*	2 156.8 (43.8)	915.9 (18.6)	1 851.5 (37.6)	4 924.2 (100.0)
Labour Force Survey 1997*	2 147.0 (38.5)	1 168.6 (21.0)	2 262.0 (40.5)	5 577.6 (100.0)

Sources: Computed from respective census and survey data. Figures within parentheses are percentages.
* Northern and Eastern Provinces not included.

Table 24 : Growth of employment by major occupational sectors, 1953-1997

('000)

Census/Survey	White Collar Workers	Blue Collar Workers	Agricultural Workers	Service Workers	Total
Census 1953	466.9 (15.6)	488.3 (16.3)	1 536.1 (51.3)	502.0 (16.8)	2 993.3 (100.0)
Census 1963	504.9 (15.8)	738.0 (23.1)	1 651.9 (51.7)	300.3 (9.4)	3 195.1 (100.0)
Census 1971	651.0 (17.8)	926.4 (25.4)	1 782.1 (48.8)	289.4 (8.0)	3 648.9 (100.0)
Labour Force Survey 1985/86*	1 021.8 (19.9)	1 420.9 (27.7)	2 438.3 (47.5)	250.7 (4.9)	5 131.7 (100.0)
Labour Force Survey 1992*	889.9 (18.1)	1 002.6 (20.4)	2 574.2 (52.3)	457.5 (9.2)	4 924.2 (100.0)
Labour Force Survey 1997*	892.5 (16.0)	1 175.2 (21.1)	2 849.4 (51.0)	663.0 (11.9)	5 580.1 (100.0)

Note: Computed from respective census and survey data. Figures within parentheses are percentages.
* Excludes the Northern and Eastern Districts.

Table 25 : Unemployment estimates, 1959/60-1997

Census/Survey	Estimated Unemployed Male	Female	Both Sexes	Unemployment Rate (%)
Survey of Employment, Unemployment, Under employment 1959/60	250 000	90 000	340 000	10.5
Census of Population 1963	199 450	63 480	264 970	7.7
Labour Force Survey 1968	312 000	152 200	464 200	13.4
Census of Population 1971	474 065	365 199	839 264	18.7
Adjusted 1971 Census	474 065	197 917	671 982	15.6
Determinants of Labour force Participation rates, Survey 1973	446 929	346 071	793 000	18.3
Land & Labour Utilization Survey 1975	499 500	484 800	984 300	19.7
Labour force & Socio-Economic Survey 1980/81	503 207	553 207	857 168	15.3
Census of Population 1981	487 740	409 509	897 249	17.9
Consumer Finance and Social Economic Survey 1981-82	297 729	321 337	609 266	11.7
Labour Force Socio-Economic Survey 1985/86*	394 781	391 395	786 170	13.2
Labour Force Survey 1990	398 100	607 000	1 005 100	14.1
Labour Force Survey 1992*	415 043	417 354	832 397	14.5
Labour Force Survey 1997*	319 383	325 487	644 870	10.4

Sources: Respective census and survey reports.
* Excludes the Northern and Eastern Districts.

Table 26 : Youth unemployment rates, 1992-1997

(%)

Age group	Unemployment 1992			Unemployment 1997		
	Male	Female	Total	Male	Female	Total
15-19	38.4	46.4	41.5	30.9	40.1	34.8
20-24	27.3	45.5	34.3	23.4	35.1	28.0
15-24	**30.7**	**45.8**	**36.4**	**25.9**	**36.9**	**30.3**

Sources : Labour Force Surveys, 1992 and 1997.
* Excludes the Northern and Eastern Districts.

Labour Demand

The demand for labour in Sri Lanka has been growing at a relatively slow pace despite the fact that growth in labour supply has been rapid since the mid 1960s, due to the rapid growth of population. The slow growth of employment has been due mainly, to the overall slow pace of economic transformation and structural change over the period of four decades as evident from Table 23. The proportion of those employed in the primary sector has declined only from 53.4 per cent in 1953 to 38.5 per cent in 1997. In the secondary sector (manufacturing and processing), employment has increased by only about 820 000 over a period of more than four decades. The tertiary or service sector has increased its share from 34.9 per cent in 1953 to 40.5 per cent in 1997. The employed population classified by major occupational sectors also points to the fact that there have been no significant structural changes in the economy which could bring about changes in the employment pattern in the country.

Unemployment

The problem of employment creation to absorb the rapidly growing labour force and the mismatch between employment opportunities and the expectations of educated youth has been the concern of policy makers and planners since the early 1960s. The initial shock of the demographic expansion was absorbed by the expanding educational system and subsequently resulted in the rapid growth of educated youth in the 1970s and 1980s. The expansion of the supply of labour and the relatively low demand for labour contributed to rising unemployment rates by early 1970s. The unemployment rate which was about 10 per cent of the labour force around 1960 increased rapidly to about 20 per cent by 1975. Since then, the unemployment rates have declined to about 10 percent in 1997. However, female youth unemployment rates have remained relatively high (Table 26).

Underemployment

The under utilization of labour is not only manifested in the form of unemployed but also as under-employed among the employed population. Underemployment measured by hours of work at the main job indicates that in 1992, 41.2 per cent worked less than 40 hours a week. By 1997 it had dropped to 36.1 per cent (Table 27).

Table 27 : Employed population by hours worked per week, 1992 and 1997 (hours worked at the main job, as a percentage)

Hours per week	1992	1997
Less than 40 hours	41.2	36.1
40 hours or more	58.8	63.9
Total	**100.0**	**100.0**

Sources: Labour Force Surveys, 1992 and 1997.
* Excludes the Northern and Eastern Districts.

POPULATION IMPLICATIONS OF SOCIAL WELFARE SERVICES

During the past five decades the pace of social development has been remarkable. The social welfare expenditures particularly in the field of education and health have produced manpower resources of relative high quality. However, the necessary transformation of the economy to sustain the social welfare measures did not take place at the same pace. This led to a situation where social welfare reform could no longer be sustained adequately, with the rising increases in population. In this section, therefore we will examine briefly, population implications of educational, health and food sectors of the economy.

Table 28 : Percentage distribution of population by educational attainment 1971,1981 and 1991

(%)

Educational Attainment	1971			1981			1990/91		
	Total	Male	Female	Total	Male	Female	Total	Male	Female
No Schooling	25.2	19.5	31.2	7.3	6.4	8.1	8.8	6.1	11.3
Primary	30.0	31.7	28.2	12.8	14.4	11.4	34.0	35.4	32.5
Secondary	43.6	47.4	39.7	79.0	78.0	79.8	56.6	57.8	55.7
Tertiary	1.2	1.4	0.9	0.9	1.2	0.7	0.6	0.7	0.5
Total	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**

Sources: Censuses of Population 1971 and 1981; Household Income and Expenditure Survey 1990/91.

* Excludes the Northern and Eastern Districts.

Table 29 : Projected pupil population by gender and school years 1995-2005

('000)

School Years	1995		2000		2005	
	Male	Female	Male	Female	Male	Female
Primary (Year 1-5)	759	704	728	660	741	673
Secondary (Year 6-11)	906	953	820	863	776	803
Collegiate (Year 12-13)	90	126	89	128	79	113
Total	**1755**	**1783**	**1637**	**1651**	**1596**	**1589**

Source: A.T.P.L. Abeykoon (1998) *Population and Manpower Resources of Sri Lanka.*

Educational services

The introduction of free education in 1945, the rapid growth of population and the development and expansion of educational services have contributed to the increase in school enrolments at primary and secondary levels from 867 309 in 1945 to 4.2 million in 1994. As a result, over the years the educational attainment of the population has improved. The proportion of population with no schooling has declined from 25.2 per cent in 1971 to 88 per cent by 1990/91. Consequently, the proportion with secondary and higher levels of educational attainment has increased (Table 28). As the participation rates of students at different levels of education are relatively high, the future growth of school going population will be largely determined by the growth of school age population. It can be seen from Table 29 that the school enrolments for both males and females will decline in absolute number at primary, secondary and collegiate levels in the future.

Health Services

The demographic and epidemiological transitions that have taken place in Sri Lanka over the past five decades have brought about new challenges for the health sector. The changing age structure of the population will have important implications for health care services in the future. With the expected continuing decline in fertility, the absolute number of births and the number of children under five years of age will decline while the number of women in the reproductive ages will continue to increase. This, on the one hand, will reduce pressure on maternal and child health services while on the other, the increase in the sexually active population would create an increasing demand for family planning and reproductive health services. Numbers in the age category 15-49 years will increase in the future and will comprise both the youth and the most productive segment of the labour force. Emotional and behavioral problems of youth need to be addressed as well as, occupational diseases and safety measures at work places. The increase in the population of those aged 45 to 59 years is significant, as it is in this age group that most of the degenerative diseases begin to surface. It must be emphasized that meeting the demands of health care of this segment of the population is important as it comprises the most experienced and skilled segment of the work force.

Also, with the expected increase in the proportion of population living in urban areas in the future, increased environmental pollution, and population density can be expected as well as shifts in occupation patterns, consumption and lifestyles. All these changes will have significant health implications.

Table 30 : Projected per capita supplies and total requirements of specified food items 1995-2005

(kg)

Commodity	Per capita Supplies				1995 ('000)		2000 ('000)		2005 ('000)	
	1992	1995	2000	2005	A	B	A	B	A	B
Cereals	132.0	138.6	145.5	152.8	2393	2512	2531	2790	2660	3079
Sugar	24.5	25.7	26.3	27.6	444	466	470	504	494	556
Pulses and Nuts	5.4	5.7	6.0	6.3	98	103	104	115	109	127
Vegetables	37.3	39.2	41.2	43.3	676	711	715	790	752	873
Meat	2.8	2.9	3.0	3.2	51	53	54	58	56	64
Eggs	2.6	2.7	2.8	2.9	47	49	50	54	52	58
Fresh Fish	7.0	7.4	7.8	8.2	127	134	134	150	141	165
Fresh Milk	12.6	13.2	13.9	14.6	228	239	242	267	254	294
Fruits	2.9	3.0	3.2	3.4	53	54	56	61	58	69
Oil and Fats (Including Coconut)	33.7	35.4	37.2	39.1	611	642	646	713	679	788

Source: A.T.P.L. Abeykoon (1998) *Population and Manpower Resources of Sri Lanka.*

Note : Per capita supplies for 1992 are from the Food Balance Sheets of the Department of the Census and Statistics.

A: Assumes the 1992 per capita supply levels to remain constant.

B: Assumes the 1992 per capita supply levels to increase by 5 per cent between 1992-1995, 1995-2000 and 2000-2005.

Age structure will become weighted towards the older segments of the population and thus population ageing will assume increasing importance in the coming decades. As evident from Table 30, the proportion of population aged 65 years and over has increased from 2.2 per cent in 1881 to 6.2 per cent in 1995. This proportion is expected to increase at a faster pace in the future reaching 15.7 per cent in the year 2030.

Therefore, appropriate action will have to be taken to plan and develop adequate health care services to meet the increasing needs of elderly population. This would require higher allocations of financial resources for health care. In addition, population ageing would create a demand for trained personnel to cope with the increase in the numbers of elderly patients who will need personal attention. The cadre of Family Health Workers will have to be re-trained and oriented towards the care of the elderly.

Food Requirements

Given the level of technology and land area for cultivation, excessive growth of population can have a serious impact on the domestic food situation. During the past five decades food production has been increased by expanding the area under cultivation and increasing the average yields per unit of land. However, the country has not yet reached self sufficiency in rice despite the fact that paddy production has increased by about nine fold over the past five decades.

With continued increase in population over the next decade and the likely increase in per capita consumption, a significant increase in both food production and the nutritional value of food would be necessary to avoid a deterioration in food and nutritional intake. It can be seen from Table 30 that food requirements of specified basic food items will increase during 1995 to 2005 even if per capita food supply levels remain constant, as at 1992.

REFERENCES

1. Abeykoon A.T.P.L. (1996) *Population Trends in Sri Lanka: The Post War Experience.* Working Paper No.10. Centre for Women's Research (CENWOR), Colombo, Sri Lanka.

2. Abeykoon A.T.P.L. (1998a) *Population and Manpower Resources of Sri Lanka.* Natural Resources Series No.3, Natural Resources, Energy and Science Authority of Sri Lanka, Colombo, Sri Lanka.

3. Abeykoon A.T.P.L. (1998b) *Demographic Projections for Sri Lanka.* Research Paper Series No. 9, Population Information Centre, Colombo, Sri Lanka.

4. Department of Census and Statistics (1986) *Census of Population and Housing 1981-General Report.* Ministry of Plan Implementation Colombo, Sri Lanka.

5. ESCAP (1976) *Population of Sri Lanka,* Country Monograph Series No.4. United Nations, Bangkok, Thailand.

6. ESCAP (1986) *Levels and Trends of Fertility in Sri Lanka: A District Level Analysis.* Asian Population Studies Series No. 62F, United Nations, New York.

7. Population Information Centre (1996) *Population Statistics of Sri Lanka.* Population Division, Ministry of Health, Highways and Social Services. Colombo, Sri Lanka.

8. United Nations (1998) *World Urbanization Prospects; The 1996 Revision.* Department of Economic and Social Affairs. Population Division,NewYork.

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Women at Work

ECONOMIC CONDITIONS AND TRENDS

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Summary

In the fifty years since independence Sri Lanka's economy grew at an average of 4.2 per cent per year. During the 1990-1998 period its growth was 5.3 per cent per year. Agriculture which was the main source of national income in the 1950s, accounted for only 21 per cent of GDP in 1998 while manufacturing contributed 16.5 per cent and services 53 per cent of GDP. Sri Lanka's per capita income of Rs. 54 035 or US$ 837 in 1998, though higher than those of other South Asian Countries, is much lower than those of some Southeast Asian and East Asian countries. Social Development Indicators are however much better than for most countries of the same levels of per capita income with the country registering 0.71 on the UNDP Human Development Index. Economic policies alternated between market-oriented and socialist policies till 1977. Since then successive governments have accepted a private enterprise led growth strategy, privatized state owned enterprises and have liberalized trade and exchange controls. Free health, free education and welfare programmes for poor are being continued. Low per capita incomes, a high proportion of households below the poverty line and a high rate of unemployment, especially among the educated, are the main economic problems. An economic growth of around seven per cent sustained over a period of about a decade is needed to solve these problems. This requires an increase in investment from the current level of about 25 per cent of GDP to around 35 per cent of GDP. Pre-conditions for enhanced investment and rapid economic growth include better security conditions and improvement in social and economic infrastructure and skills.

INTRODUCTION

In 1998 Sri Lanka had a population of 18.8 million. Her per capita income was Rs. 54 035 or US$ 837. The per capita income in terms of the Purchasing Power Parity (PPP) was estimated at US$ 3250 in 1995. In 1998, agriculture, forestry and fishing contributed 21 per cent of GDP, manufacturing industry 16.5 per cent and services 53 per cent. Mining and quarrying was responsible for 1.8 per cent of GDP, while construction contributed 7.1 per cent of GDP. In 1997 the GDP grew at 6.4 per cent and GNP at 6.9 per cent. In 1998 GDP growth was 4.7 per cent, while GNP growth was 4.6 per cent.

Sri Lanka's per capita income of US$ 837 was significantly higher than those of her neighbours in the sub-continent: India's being about US$ 400, Pakistan's US$ 500 and Bangladesh's US$ 300. However Sri Lanka's per capita income is significantly lower than those of Southeast Asian and East Asian countries. Sri Lanka still ranks as one of the poorer countries in the world and is now classified as a 'lower middle income' country by the World Bank. China, Indonesia, the Philippines and Thailand are in this category.

However, Sri Lanka's social indicators are much better than those of countries at similar levels of per capita income. The UNDP Human Development Index for Sri Lanka is 0.711. The life expectancy at birth is 72 years with a male life expectancy of 69.5 years and a female life expectancy of 74.2 years. Adult literacy is estimated to be above 90 per cent with female literacy at 86 per cent. Some of the most important Socio-Economic indicators are given in Table 1, while Table 2 gives a comparison of Sri Lanka's Socio-Economic indicators with several other countries.

At the time of independence in 1948, Sri Lanka's per capita income was considerably higher than those of her South Asian neighbours and most other Asian countries. In 1950, Sri Lanka's per capita income was over twice that of India, higher than that of Korea and Taiwan and over half that of Japan and Malaysia. The economy was predominantly agricultural, and highly export-import dependent. Foreign exchange reserves were strong. Economic policies were fairly liberal. She also had reasonably good social indicators for a poor country, with an adult literacy rate of 58 per cent and a life expectancy of 55 years, just prior to independence.

Table 1 : Socio-Economic indicators, Sri Lanka

	Year	
Population (Millions)	1998	18.8
Population Density (persons per square mile)	1998	299
Population Growth Rate (per cent)	1998	1.2
Labour Force (Millions)	1998	6.7
Labour Force Participation Rate (per cent)	1998	51.9
Unemployment Rate (per cent)	1998	9.1
GDP per capita at Market Prices (Rs)	1998	54 035
GDP per capita at Market Prices (US$)	1998	837
GDP per capita (Purchasing Power Parity US$)	1995	3250
GDP Growth Rate (per cent)	1998	4.7
GNP Growth Rate (per cent)	1998	4.6
Adult Literacy Rate (per cent)	1991	88.6
Male Literacy (per cent)	1991	92.2
Female Literacy (per cent)	1991	86.2
Life Expectancy at Birth (years)	1991	72
Male		69.5
Female		74.2
Infant Mortality Rate (IMR) per 1 000	1995	17
Maternal Mortality Rate per 100 000	1995	140
School Enrolment (5-19 years) per cent	1991	73.4
Human Development Index (max 1.0)	1995	0.711
External Assets US$ million	1998	2907
External Assets as number of months imports	1998	5.9
External Debt (US$ million)	1998	8753
External Debt as per cent of GDP	1998	55.6
Fiscal Deficit as per cent of GDP	1997	4.5
(after grants)	1998	8.1

Sources: Central Bank of Sri Lanka, Department of Census and Statistics.

Table 2: Socio-Economic indicators: Sri Lanka and selected countries 1996

Indicator	Sri Lanka	India	Paki-stan	Bang-ladesh	Singa-pore	Rep.of Korea	Mal-aysia	Thai-land	Philip-pines	Indo-nesia	Japan	USA	UK
GDP per capita (US$)	760	370	449	262	31 354	10 373	4 628	3 068	1 162	1 138	36 575	28 646	19 884
GDP per capita PPP (US$)	3 415	1 500	2 340	1 450	24 610	12 390	9 835	8 165	3 020	4 140	23 440	28 646	20 170
Growth of Real GDP (per cent)	3.8	7.1	6.1	5.4	7.0	7.1	8.2	6.7	5.5	7.8	3.6	2.8	2.3
Investment (per cent of GDP)	24.2	26.2	19.6	17.0	35.1	38.2	43.0	42.8	24.9	32.7	29.8	17.2	15.8
National Savings (per cent of GDP)	19.2	23.9	12.5	12.0	50.1	34.3	37.0	33.6	19.8	29.8	30.4	16.0	16.5
Inflation (per cent) (change of CPI)	15.9	9.0	10.4	2.7	1.4	4.9	3.5	5.8	8.4	8.0	0.1	2.9	2.4
Exports per cent of GDP	29.5	9.1	15.4	10.6	133.0	26.8	79.8	30.2	24.4	22.1	8.9	8.2	22.6
Imports & of GDP	38.9	10.2	20.1	21.3	139.6	31.0	79.9	39.2	41.3	19.0	7.6	10.8	24.8
Trade Balance & of GDP	-9.4	-1.1	-4.7	-10.7	-6.7	-4.3	-0.2	-9.0	-16.9	3.1	1.3	-2.6	-2.2
BOP Current A/c per cent of GDP	-3.9	-1.6	-5.7	-2.8	15.2	-.4.8	-8.4	-.8.0	-.27	-.3.5	1.4	-1.9	-
International Reserves Minus Gold: In Months of Imports	5.2	6.8	2.0	4.7	7.2	3.2	4.0	6.4	2.9	4.4	7.1	1.3	2.1
Debt Service (per cent of exports)	7.0	28.2	26.9	13.3	0.5	4.9	7.8	10.2	16.4	30.9	n.a.	n.a.	n.a
Budget Surplus/Defi-sit (-) (per cent of GDP)	-8.9	-1.3	-5.0	-2.6	-1.9	-0.9	-0.7	-0.9	0.3	0.8	n.a	-.1.5	-5.4
Govt Debt per cent of GDP Domestic Foreign	92.2 45.4 46.8	52.1 47.1 5.0	78.9 45.7 33.2	n.a n.a n.a	74.8 74.8	6.9 5.4 1.5	41.8 35.7 6.1	4.7 1.8 2.9	56.4 37.7 18.7	24.1 - 24.1	44.7 44.7 -	50.1 35.3 14.8	34.0 28.2 5.8
Human Development Index (HDI) (1994) Rank on HDI (of 175 countries)	0.711 91	0.446 138	0.445 139	0.368 144	0.900 26	0.890 2	0.832 60	0.833 59	0.672 98	0.668 99	0.940 7	0.942 4	0.931 15
Life Expectancy (Years)	72	62	60	58	76	72	71	69	66	64	80	77	77
Literacy Rate (per cent)	89	51	37	37	91	98	83	93	94	83	99	99	99
Infant Mortality (per 1000 Live Births)	17	77	78	75	4	10	11	36	40	55	4	8	6
Telephones (per 1000 persons)	18	13	16	2	478	415	166	59	21	17	487	627	502

Source: Central Bank of Sri Lanka.

In 1950, the economy was highly dependent on agriculture, which accounted for about 40 per cent of GDP. Services accounted for 50 per cent of GDP, owing to the importance of trade, finance and other services devoted to agricultural production and exports. Manufacturing, (mainly the processing of tea, rubber and coconut) contributed 10 per cent of GDP.

A notable feature of the economy was a dualistic agriculture. It consisted of small holdings, cultivating rice, other food crops and some cash crops, and plantation agriculture devoted mainly to tea and rubber and to a lesser extent to coconut. The higher productivity of the plantations and good prices for tea and rubber in particular, enabled the country to enjoy a relatively high per capita income, as well as to provide a source of taxation, to finance the country's extensive welfare programmes, consisting of, free health, free education and subsidized food.

Economic growth over the five decades since independence is generally considered to be inadequate. However, the average economic growth of 4.2 per cent over the last 50 years is not a mean achievement. This growth is considered inadequate owing to the relatively good initial economic conditions of the country and also in comparison to the high growth rates of East Asian and Southeast Asian countries, since the 1970s. Further, the country's economic growth has not been adequate to raise per capita income to the level of a medium income country or to provide adequate employment opportunities, reduce poverty and improve income distribution patterns. A much higher rate of economic growth of about eight per cent, sustained over a decade or more, is considered essential to achieve the country's economic and social goals.

The next section of this chapter summarizes the changes in economic policies since the country gained independence in 1948, with a special emphasis on the changes in economic policies since 1977. This section concludes with a brief description of current economic policies. The third section discusses the economic performance of the country since independence, by sub-periods. The fourth section discusses the structural changes within the economy. The fifth section discusses the economic prospects in the next decade and the constraints to higher economic growth. The final section sets out some concluding observations on the economy.

ECONOMIC POLICIES SINCE INDEPENDENCE

A significant feature of the first three decades of Sri Lanka's post independence period is that economic policies alternated between regimes which were market oriented and ones which relied on state intervention, state ownership and state control of the commanding heights of the economy. Since 1977, successive governments have accepted private enterprise led, market oriented economic policies.

From independence till 1956 the government pursued policies with a minimum of state intervention. The government placed considerable emphasis on land settlement and agricultural development, set up a few state industries, and pursued a welfare package consisting of free health, free education, subsidized food and social service payments. Liberal import policies were pursued as the country had accumulated foreign exchange reserves equivalent of about nine months of imports.

The change of government in 1956 led to drastic changes in economic policies. From 1956 to 1965, the government pursued socialist policies with greater state ownership and control of the economy. It nationalized, bus transport, the handling of port cargo and insurance. The largest commercial bank, the Bank of Ceylon, was nationalized and another state bank, the People's Bank was established. Government discouraged private foreign investment and obtained very little foreign aid. The international prices for the country's main exports tea and rubber fell sharply and foreign exchange reserves declined to crisis proportions in the 1960s. With foreign exchange reserves at a very low level and the balance of payments adverse, the government pursued a policy of import substitution. High tariffs protected local industry. The import of a number of commodities, including some agricultural imports, was banned. These policies failed to stimulate any significant industrial growth but succeeded in increasing agricultural production, particularly of subsidiary food crops, poultry and eggs. This period witnessed a comprehensive agricultural strategy for food crop agriculture. The government introduced an agricultural credit scheme, minimum guaranteed prices, government purchases of paddy and other food crops, a limited crop insurance scheme, subsidized fertilizer and an improved extension programme. The Paddy Lands Act of 1958 controlled share rentals and established cultivation committees.

The government which took office in 1965, attempted to return to a free market economy. It encouraged foreign investment and assured investors that their investments would not be nationalized, and if nationalized, that full compensation would be paid. A dual exchange rate was introduced in 1966. Non essential items were imported at a higher rate of exchange and non traditional exports earned rupees at a higher exchange rate. Although there was a limited liberalization in trade, the import substitution policies continued. A new impetus was given to food crop agriculture with a "Food Production Drive". This resulted in an impressive growth in output and yields of food crops.

The election of the coalition government of 1970 resulted in a return to dirigiste policies. There were further take overs of private businesses. A Business Acquisition Act was enacted and private enterprises faced continuous threats of take over hanging over their heads. A land reform programme nationalized the large tea, rubber and coconut estates. The deteriorating foreign exchange situation resulted in further tightening of exchange and import controls.

The 1970-77 period was one in which the economy faced a number of external and internal shocks. In 1971, one year after assuming power, a serious youth insurrection threatened to overthrow the government. Petrol price hikes, escalating prices of essential food imports (wheat, rice and sugar), and increased prices of fertilizer, came at a period of drought and bad weather. Scarcities of essential foods and basic commodities characterized these years.

Economic Reforms of 1977

The government which came into power in 1977 reversed the economic policies pursued by the previous government. The economic reforms introduced in November 1977 included the liberalization of trade and exchange controls and an economic strategy dependent on private investment and market forces. Foreign investment was encouraged and a greater reliance was placed on exports. To support these policies, the government adopted a unified exchange rate, devalued the Sri Lankan Rupee and adopted a floating exchange rate. These policy reforms relied on large scale support from international agencies, notably the IMF and World Bank and donor countries.

The reforms of 1977 were a sharp break from past economic regimes. The political courage to undertake these bold reforms was derived from the failure of the 1970-77 policies to generate economic growth and employment opportunities. The new policies transformed a closed, tightly controlled inward looking economy into a market-oriented, outward looking one. It was the beginning of a process which laid greater emphasis on private enterprise and lesser reliance on state owned and controlled economic enterprises. It sought private foreign investment, aggressively, under the auspices of the IMF and World Bank and obtained considerable amounts of foreign aid and assistance for investment. Another important element of the economic policies was a shift away from administered prices and subsidies to market prices. The reduction of subsidies was part of a movement towards the removal of subsidies and a reduced welfare programme, in which universal subsidies were to be replaced by more targeted subsidies.

More specifically the economic liberalization programme consisted of the following:

1. Quotas were replaced by tariffs. With the exception of controls on less than 200 items, such as motor cars, guns, ammunition, aircraft etc., no restrictions applied to the import of other commodities. Tariff rates were reduced on most commodities.

2. The dual rate of exchange for the Rupee was abolished. The new exchange rate devalued the Rupee substantially from about Rs.9 for a US dollar to Rs. 16; and the country adopted a floating flexible exchange rate system. Foreign exchange restrictions were drastically modified and the foreign exchange regime liberalized.

3. Most price controls were removed and barriers to internal trade were abolished.

4. The fiscal policy orientation changed drastically. Fiscal policies were used to support the market orientation and private sector emphasis on economic growth and to create a climate conducive to private investment and private economic enterprise. The reduction in taxes and the use of a wide range of tax incentives encouraged investment. Direct taxation became an instrument for resource allocation rather than to mobilize resources for public investment or for income distribution. The emphasis in government expenditure shifted to investment, particularly in infrastructure and large scale projects like the Accelerated Mahaweli Scheme, rather than on consumption, welfare and social development expenditures. (Jayasundera, 1986).

5. Foreign assistance was sought, aggressively, and successfully obtained. The multi-lateral agencies supported the liberalized measures. The IMF provided balance of payments support, while the World Bank gave term credit for development programmes and arranged donor assistance through the annual Aid Club meetings.

6. Foreign investment was sought by giving investment guarantees and tax concessions. The safety of foreign investment was guaranteed in the new constitution adopted in 1978. The opening of the Free Trade Zone under the Greater Colombo Economic Commission (GCEC) was to encourage foreign direct investment for export industries.

7. An export-led economic strategy was the cornerstone of the new policies. It was recognized that high rates of economic growth could be achieved only by increasing new industrial exports. There was an attempt to emulate the NIC's, Singapore in particular. Export industries obtained favourable terms and concessions and an export based policy stance was developed.

The economic policies pursued included an urban renewal programme, the development of economic infrastructure, the establishment of a Free Trade Zone and the implementation of an Accelerated Mahaweli Development Programme, which was to increase agricultural production and enhance energy supply by the generation of hydro electricity. The extensive food subsidies programme was curtailed by targeting food subsidies to a smaller section of the population through a programme of food stamps.

The economic reforms and enhanced foreign funds led to a high rate of economic growth till 1983, when ethnic disturbances resulted in a set back. The subsequent terrorist demand for a separate state in the north and east and terrorist attacks undermined business confidence, foreign investment and tourism, besides dislocating agriculture, fisheries and a few industries in the north. Consequent to the arrival of an Indian Peace Keeping Force in the country, an insurgency developed in the south. From 1987 to 1989, this insurgency dislocated work and seriously impaired economic activity. The economic growth rate fell from 4.3 per cent in 1986 to 1.5 per cent in 1987. In 1988-89 growth averaged only 2.5 per cent.

The weak economic performance in the late 1980s led the government to adopt further structural reforms. The reforms aimed at strengthening budgetary management, reducing inflation, improving the balance of payments and external reserve position which had weakened considerably. The economy was liberalized further after 1989. The tariff structure was simplified and import duties reduced, foreign exchange restrictions on current account transactions were removed and the country accepted IMF's Article VIII obligations, from March 15, 1994.

In the latter half of 1989, the government depreciated the Rupee by about 17 per cent and cut budgetary expenditures by 20 per cent. Central

Bank holdings of Treasury Bills (TB) were reduced by allowing market interest rates to prevail in the TB market, thereby encouraging TBs to be absorbed by the private sector.

Other reforms in the 1989-93 period included the restructuring of the tax system to eliminate distortions and reduce tax on savings. A reduction in the maximum rate of corporate tax to 35 per cent and personal taxation to 40 per cent was also effected. A four band customs tariff on imports with a maximum 50 per cent tariff was introduced and export duties on tea, rubber and coconut were progressively reduced and ultimately eliminated.

The process of privatization gained momentum and by the end of 1993, 42 state enterprises had been privatized. Further, most of the state owned plantations were handed over to 22 companies for management. The two state banks were restructured to meet the capital adequacy requirements by the infusion of Rs.24 billion and restrictions on foreign investment in the Colombo Stock Market were removed.

Economic Policies since 1994

The change of government in 1994 was very significant. For the first time since independence, despite a change of government, continuity of economic policies was assured. The government announced its commitment to continue market friendly open economic policies. Also it gave private enterprise, the lead role in economic activity and pledged to support private enterprises. It characterized its strategy as "Open Economic Policies with a Human Face".

The first Economic Policy Statement of the government stated that :

> The government stands committed to building a strong national economy within a market framework. The principal engine of growth is expected to be the private sector, both domestic and foreign. The role of the state is to provide an institutional framework that is wholly supportive of rapid private sector development. In order to do this effectively, the government will pursue "market-friendly" policies which support rather than supplant markets. Accordingly, government intervention will be limited to areas where markets fail to function effectively and therefore need to be strengthened or supplemented in order that they serve the welfare of the people, better.

The government placed emphasis on fiscal discipline and reduction of the budget deficit, in order to reduce inflationary pressure. The reduction of inflation was considered a pre-requisite for growth and a cornerstone of fiscal and monetary policy.

The Economic Policy Statement made this clear when it said:

> The eventual goal of policy would be to continue to reduce the overall fiscal deficit from a level of eight per cent of GDP in 1993 to a level of three to four per cent of GDP well before the year 2000, which would both be consistent with a significant reduction in inflation and be sufficient to absorb a reasonable amount of concessional aid. In order to accomplish this goal, budgetary revenue will be buoyed up by rapid economic growth and tax reform. A substantial current account surplus will be generated both by the significant reduction of military expenditure and by curtailing unnecessary and wasteful current expenditures, both through the improved targeting of welfare programmes and reducing the role of the public sector in the economy. The long run objective would be to run an overall surplus in the budget so as to enable the retirement of the high stock of outstanding public debt.

The government liberalized trade further by decreasing tariffs and reducing corporate and personal taxation to a maximum of 30 per cent. The corporate tax rate was reduced to 15 per cent for enterprises in agriculture, fisheries, livestock and tourism. It gave further incentives for foreign investment and embarked on a far reaching programme of privatization. The government privatized, *inter alia*, the plantations, telecommunications, the National Development Bank and Air Lanka. It introduced a new safety net for the poor, **Samurdhi**, which was similar to the earlier **Janasaviya** programme. The government also gave incentives for garment industries to be established in the regions and introduced a number of measures to assist agriculture.

The high interest rate regime which prevailed for many years was reversed in 1997. The Central Bank reduced the statutory reserve requirement of commercial banks several times. In August 1999 the Central Bank's statutory reserve requirement was reduced to 11 per cent. This increased commercial bank liquidity and reduced their cost of funds. Since 1977, Treasury bill rates declined and commercial bank lending rates decreased owing to the actions of the Central Bank.

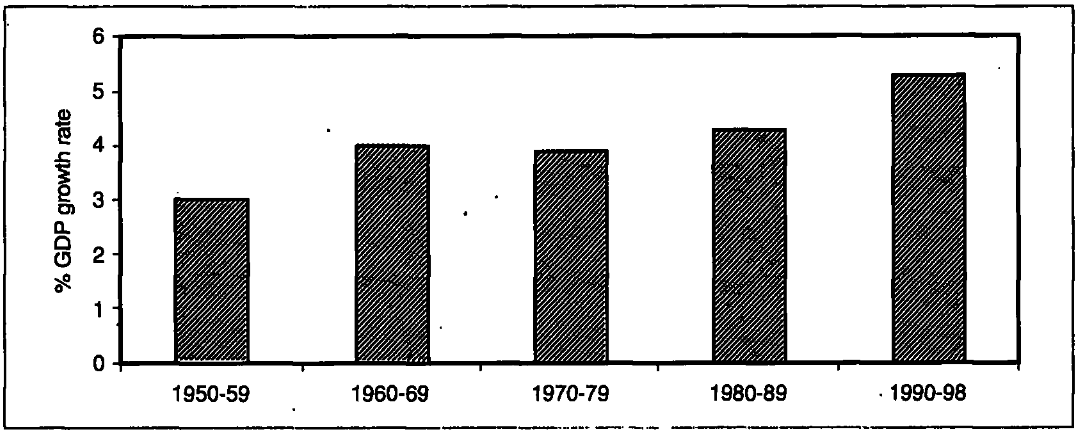
ECONOMIC PERFORMANCE

Overview

During the entire 50 year period since independence, the Sri Lankan economy grew by an average of 4.2 per cent per year. Economic growth was however, uneven during the five decades. In the 1950s, the economy grew by about 3 per cent per year; in the 1960s, about 4.7 per cent per year; in the 1970s, 3.9 per cent per year; in the 1980s 4.3 per cent and by 5.2 per cent per year in the 1990s. During the period 1990-1998, the growth rate ranged from 3.8 per cent to 6.9 per cent.

Within these decades there were significant differences in economic growth rates. In the first half of the 1970s, the economy grew at 2.9 per cent per year, while during the second half, under more liberal policies, a higher growth of 4.9 per cent was achieved. The lowest rates of growth were during 1970-77 and 1987-89 when the average annual rates of growth were only 2.8 and 2.2 per cent, respectively. The low rates of growth in the 1970 to 77 period were due to droughts, an insurrection in 1971, inefficient state control of the economy, discouragement of private enterprises, unfavourable international factors such as food grain shortages, an oil price hike, and unfavourable terms of trade. The adverse security situation was mainly responsible for the low growth in the period 1987 to 1989.

In 1978, consequent to the policy reforms introduced in 1977, the economy attained a growth rate of 8.2 per cent. Between 1978 and 1984, the economy grew at an average rate of 5.9 per cent per annum. The rate of growth declined from 5 per cent in 1985 to 2.2 per cent in 1987-89, mainly due to internal security conditions. With the restoration of law and order, GDP growth reached 6.2 per cent in 1990. Economic growth reached 5.5 per cent for the 1990-93 period and 5.3 per cent in the most recent period 1994-98.



Source : Central Bank of Sri Lanka.

Figure 1 : Economic performance by decades

Having given an overview, the economic performance of the entire post 1977 period is reviewed first. It is then analyzed in terms of four sub-periods: 1978-82; 1983-89; 1990-93 and 1994-98. This periodization is based on both economic factors and socio-political developments in the country. The 1978-82 period was the first five year period after the Structural Adjustment Programme and prior to the ethnic disturbances of 1983, which caused a serious set-back to the economy. The 1983-89 period was marked by considerable social tensions and ethnic disturbances, terrorist attacks and an insurgency in the south. These disrupted economic activity and created a period of grave insecurity (1987-89). The 1990-93 period was one of re-emergence into fairly stable security conditions and further economic reform. Though the civil war continued in the north and east of the country, . its direct impact on the economic activities of the country was modest. It had an indirect impact through the war expenditures, refugee maintenance costs, loss of investor confidence and reduced tourism. In 1989, the country adopted the second Structural Adjustment Programme and ushered in a second phase of fiscal reform and liberalization of the economy. Privatization gained in momentum. This third period was one of economic recovery and high growth. The fourth period 1994-1998 was under a new government which continued market friendly policies, privatized key industries, attempted fiscal discipline and liberalized the economy further.

Post 1977 Economic Performance

The country's performance in terms of the main economic indicators during the 1970-77 period and the 1978-98 period by sub periods is given in Table 3. During the 1978-93 period as a whole, the economy grew at 4.9 per cent per annum, compared to 2.9 per cent in the 1970-77 period. The higher rates of growth were achieved by a considerably higher rate of investment, 25.6 per cent, compared to only 14.4 per cent during 1970-77. The higher rate of investment was due to a significant increase in foreign funding. In 1993, investment was 24 per cent of GDP.

Table 3: Main economic indicators

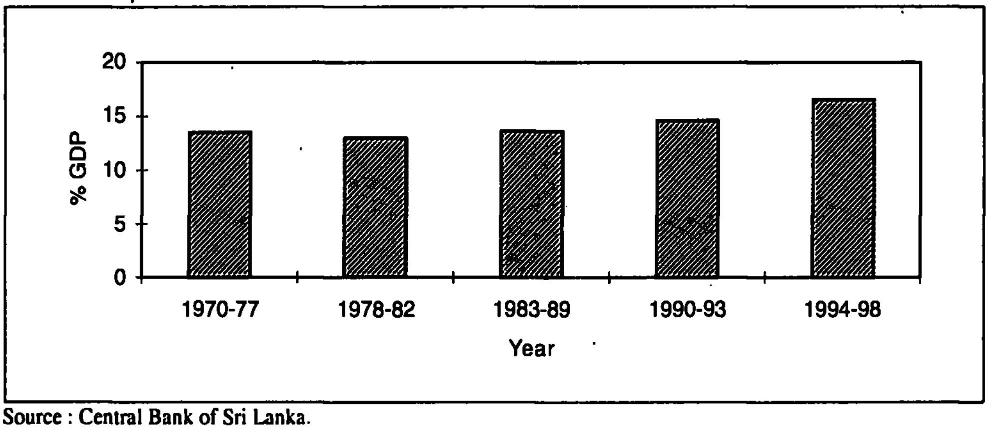
Indicator	1970-77	1978-82	1983-89	1990-93	1994-98
GDP Growth Average per annum	2.9	6.2	3.7	5.3	5.2
Investment as per cent of GDP	14.4	27.9	25.5	23.0	25.3
Domestic Savings as per cent of GDP	13.4	12.8	13.5	14.5	16.4
Budget Deficit as per cent of GDP	-9.3	-16.7	-12.0	-9.3	-9.4
Inflation CCPI per cent Increase	5.8	15.6	14.7	14.0	10.2

Source : Central Bank of Sri Lanka Annual Reports, Institute of Policy Studies Data Base.

The domestic savings ratio fluctuated and averaged 13.5 per cent of GDP, but national savings rose owing to remittances from Sri Lankans living abroad. Domestic savings reached nearly 16 per cent in 1993 compared to 13 per cent in 1970-77. Foreign investment, savings of nationals abroad and foreign aid, which contributed about one per cent of GDP in the earlier period, had by 1993 reached eight per cent of GDP.

The post 1977 period was characterized by a high rate of inflation. The annual average rate of inflation was 15.6 per cent between 1978-82 and 14.7 per cent per annum between 1983-89. The removal of price controls and administered pricing, continuous depreciation of the currency, large budget deficits and increased defence expenditure, were among the reasons for the high inflationary trend. Inflation has been reduced in the post 1994 years.

Unemployment declined but still remained high. Unemployment which had reached 24 per cent of the labour force by 1973, was halved to 11.7 in 1978, but rose again to 15.5 per cent in 1986/87. (Central Bank - Consumer Finances and Socio-Economic Surveys). Unemployment abated to around 11-12 per cent by 1993 from an earlier estimate of 18 per cent for 1989. Unemployment was 9.1 per cent in 1998. By mid 1999 unemployment had declined to less than 9 per cent. (Department of Census and Statistics Unemployment Surveys).



Source : Central Bank of Sri Lanka.

Figure 2 : Domestic savings ratio

1978 - 1982: Initial growth thrust

This period was characterized by high growth, a massive increase in investment, large volume of foreign aid and very high rates of inflation. The high rates of investment and the liberalization of trade had a visible impact on the tempo and pace of economic activity. The availability of goods, particularly consumer goods was a notable feature of this period. The period also witnessed the second oil price hike and a significant deterioration in the terms of trade. The balance of trade was unfavourable owing to both a deterioration in the terms of trade and an increased volume of imports.

The economic performance during this period reflects both direct and indirect impacts of the economic policy reforms. The rate of growth of GDP doubled in real terms, averaging 6.2 per cent per year during 1978-82, as against an annual average of 2.9 per cent in 1970-77. Per capita GDP registered an annual average growth rate of 4.3 per cent per year.

A substantial increase in investment was mainly responsible for the high rate of growth. This increase was mainly in public investment supported by large inflows of foreign aid and concessionary credit. Investment, which stagnated at an annual average of 14.4 per cent of GDP prior to 1978, reached a peak of 34 per cent in 1980 and averaged 27.8 per cent during 1978-82.

The domestic savings ratio, however, was below 13 per cent during 1978-82. The large gap between investment and domestic savings was met by the mobilization of foreign resources on concessional terms at low interest rates with long periods for repayment. National savings increased owing to a considerable inflow of foreign exchange remittances from Sri Lankan workers in the Middle East. This, together with the foreign funds, enabled the overall investment ratio to rise to 31.2 per cent in 1982. The relatively poor performance of savings during this period was due to low per capita incomes, unfavourable terms of trade, higher personal consumption induced by the availability of imported commodities to meet a pent up demand and the inelastic government revenue base. The low level of savings coupled with the massive public investment programme entailed both budgetary and balance of payments deficits, which in turn, contributed to inflationary pressures in the economy.

The budget deficit, which was around 18 per cent in 1978 and 1979 rose to a peak 26 per cent of GDP in 1980, declined to 19 per cent in 1981 and rose again to 21 per cent in 1982. Inspite of foreign funding and use of captive sources like the Employees Provident Fund and National Savings Bank, the large budget deficit (an average 20 per cent of GDP in 1978-82) was the fundamental and underlying factor for the very high rates of inflation. Inflation during this period averaged 16 per cent per year. From 12 per cent in 1978 it peaked to 26 per cent in 1980 and abated to 18 per cent and 11 per cent in the subsequent two years, 1981 and 1982.

The rate of unemployment fell during this period. According to the Consumer Finance Survey of the Central Bank, unemployment which reached 24 per cent in 1973, dropped to 14.7 per cent by 1978/79 and to 11.7 per cent in 1981/82. According to the Socio-Economic Surveys of the Department of Census and Statistics, unemployment dropped to 13.6 per cent in 1980/81 compared to 19.8 per cent estimated in the Central Bank Land and Labour Utilization Survey of 1975. Employment creation was mainly through the Public Investment Programme and the newly established industries in the Free Trade Zone. The out-migration of about 150 000 persons for employment in the Middle East also helped reduce the extent of unemployment.

Domestic agriculture, construction, trade and transport contributed to the rapid growth of the economy during this period. Domestic agriculture grew at about five per cent. The growth in paddy production, owing to both an increased extent under cultivation and increased yields, enabled the country to come close to self-sufficiency in rice. In contrast, the plantation crops stagnated and dragged down the overall growth of the agricultural sector, with a negative growth of four per cent. The construction sector witnessed an unprecedented average growth of about eight per cent per year. The import and exchange liberalization fuelled trade and transport activities in particular. The services sector as a whole registered a growth rate of 7.4 per cent. Tourism gained in momentum and nearly 400 000 persons visited the country in 1982.

Inspite of the higher rates of economic growth and lower unemployment, this period was one of increasing disparities in income and a drop in real wages of institutional workers (Sanderatne, 1985).

1983 - 1989: Economy under political and social stress

The 1983-89 period witnessed one of the most serious internal shocks to the economy. The ethnic disturbances of July 1983, not only disrupted economic activity, damaged industries and dislocated services, but also resulted in a substantial jump in defence related expenditure. Repeated terrorist attacks had an adverse impact on foreign investment and tourism, as well.

By 1987, the security situation in the north and east of the country deteriorated to such an extent that India intervened by sending a peace keeping force. As a response to this, an insurgency developed in the south and the security situation deteriorated throughout the country. Economic activity was seriously impeded: industries, banking, trade, plantation agriculture, tourism and construction were all adversely affected. The drop in GDP growth to 1.5 per cent in 1987 and an average 2.2 per cent growth in 1987-89 reflects these developments.

The GDP growth fell to 3.7 per cent during 1983-89, compared to 6.2 per cent in 1978-82. Investment declined somewhat to 25.5 per cent of GDP, but domestic savings increased slightly to 13.5 per cent of GDP. The budget deficit, though still high, was brought down to 12 per cent of GDP.

In the face of these adverse developments, private industries displayed an astonishing resilience. While public sector industrial production declined by 22 per cent, overall, industry grew by 57 per cent during 1983-89. Growth in private industry was the silver lining in the economy.

In 1983 and 1984, the terms of trade improved significantly by around 22 per cent each year. Yet the country was not able to capitalize on the improved prices of tea and rubber due to a reduction in output. In 1985-86 tea prices plunged to create enormous stress on the plantation economy, as the cost of production was higher than the estate level prices. Tea production picked up after 1983 and reached a peak 227 million kg in 1988, but declined to 207 million kg in 1989. Paddy production reached a peak of 2 661 000 tonnes in 1985 but declined thereafter. This period was generally a crisis period for agriculture.

The lower economic performance was not entirely due to security conditions. The growing public debt and its servicing costs, the high rates of inflation and the macro-economic imbalances generated in the earlier period constrained economic growth. The growth momentum could not be sustained at the earlier levels owing to these macro-economic conditions. The large public investment programme could not be continued and employment creation fell. Unemployment rose to 15.5 per cent in 1985/86 compared to 11.7 per cent in 1981/82 according to the Central Bank Surveys. The Labour Force and Socio-Economic Survey of the Department of Census and Statistics, estimated unemployment of 14.1 per cent in 1985/1986.

Inflation alone showed some abatement, particularly in the 1985-87 sub period, when it averaged less than 6 per cent with a low 1.5 per cent in 1985. But other developments reached crisis proportions by 1989. The continuing deficit in the current account of the balance of payments eroded the country's foreign exchange reserves to reach just three months of imports by the end of 1989.

In this crisis situation the government adopted the second Structural Adjustment Programme in 1989. At the end of 1989, the insurgency which threatened the very fundamental base of the economy was quelled and peace returned to the south, though the war in the north and east continued. The darkest days for the economy, it appeared, had ended.

1990-1993: Revival of the economy

The 1990-93 period witnessed a recovery and growth of the economy due to the return of peaceful conditions in the south, as well as the implementation of the stabilization measures, the further liberalization of the economy and other policy measures discussed earlier.

In 1990, the economy grew at 6.2 per cent, largely due to resuscitation of economic activity and the low rates of growth in the previous three years. The growth declined somewhat in 1991 and 1992, when it was 4.6 and 4.3 per cent, respectively. In 1993, the economy grew by 6.9 per cent due to increased production in plantation agriculture and higher industrial growth.

Like in the previous period, industrial growth continued and industrial exports showed a remarkable expansion. The garment industry, which accounts for about two thirds of manufacturing output, witnessed further growth over this period. There were also signs of growth in new industrial areas, particularly rubber based goods, leather products, food processing and ceramics. The privatization of a number of state ventures also resulted in increase in industrial output. Plantation agriculture, which had witnessed considerable difficulties under state management, entered a new era of privatized management of the estates in July 1992. Better management of the estates and good weather resulted in tea production rising in 1993.

Tourism bounced back and by the end of 1993 tourist arrivals reached the levels attained prior to its disruption in 1983. The financial sector expanded rapidly. There was also a deepening and widening of financial institutions.

There were signs that unemployment was abating, with unemployment levels falling from about 18 per cent in 1987 to around 11 per cent in 1993. Inflation reached a high 21.5 per cent in 1990, but abated in the subsequent three years to 12.2 per cent in 1991 and a little over 11 per cent in 1992 and 1993. However, double digit inflation continued to be a cause for anxiety.

The pursuance of market oriented funding of Treasury Bills resulted in a rise in interest rates during most of this period. The yield on three month Treasury Bills peaked to 20.82 per cent, per annum, by September 1992. Consequently market interest rates rose to around 25-26 per cent. Industrialists were particularly perturbed and complained about the high interest rates. There was little that could be done to bring down interest rates owing to the government's heavy dependence on borrowings to finance its deficit. However, in late 1993, the lobbying to bring down high interest rates resulted in a change of policy. Once again the government turned to more captive sources of financing Treasury Bills and brought down its borrowing rates.

The pruning of the budget deficit was one of the main measures of the stabilization programme. The government did succeed to an extent in bringing down the budget deficit from 9.9 per cent in 1990 to around 8 per cent in 1993. However, this was achieved with long term costs to the economy, as it was mainly capital expenditures which were pruned down, rather than current expenditure. The debt burden, which had initially been created owing to the large public investment programme, increased progressively owing to its cumulative effect, the high interest rates and increased expenditure on defence. By 1993, as much as 29 per cent of government revenue was used for servicing the debt. This together with defence expenditure and expenditure on salaries and wages resulted in 70 per cent of revenue being used for these directly unproductive items.

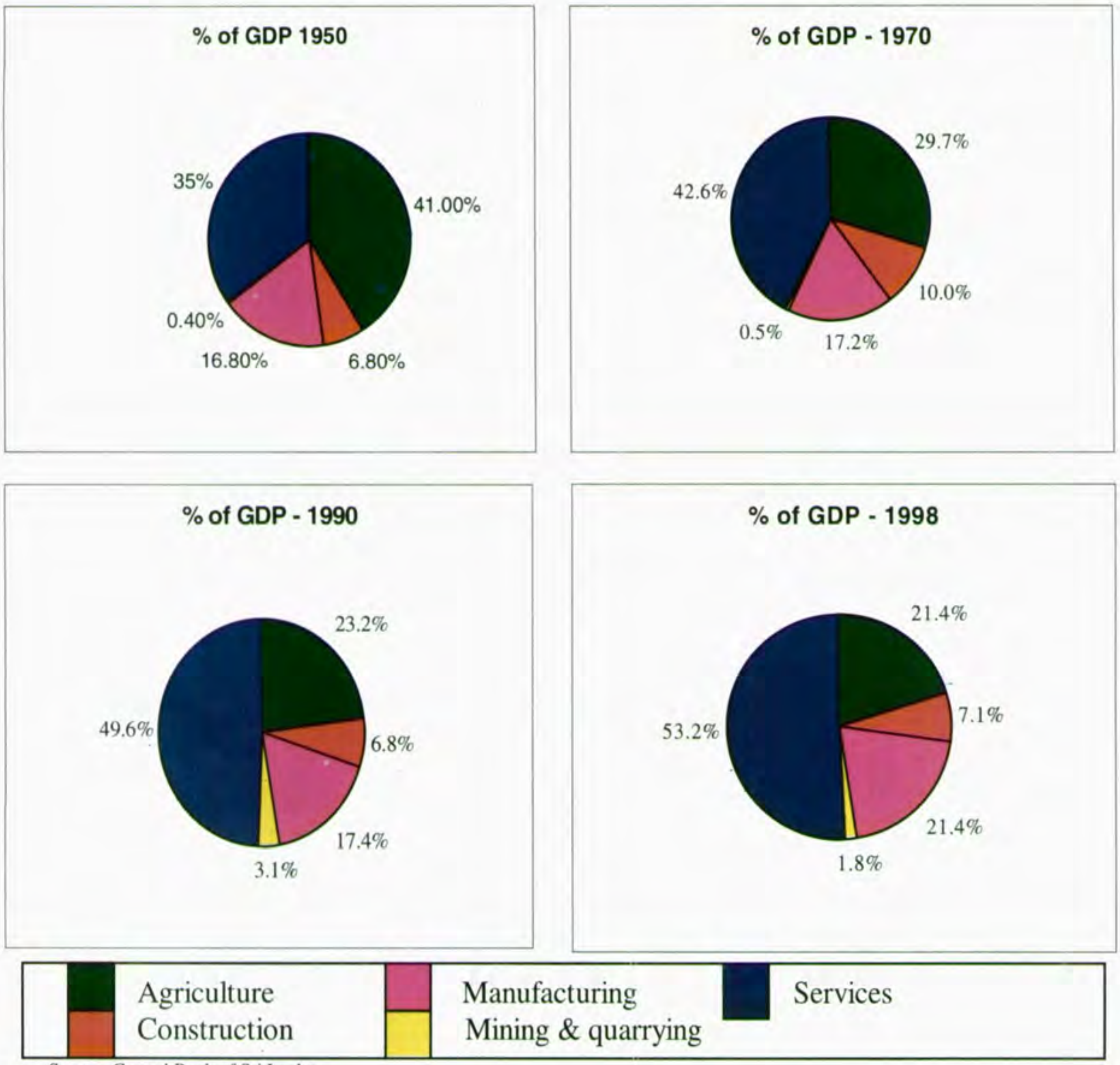
A further blow to stabilization came from increased expenditure on welfare. Welfare expenditure, which had been curtailed to about five per cent of GDP, rose owing to the government's ambitious poverty alleviation programme (Janasaviya), the reintroduction of a mid-day meal and free uniforms for school children. These welfare measures alone absorbed about 4.5 per cent of GDP (Sanderatne, 1997).

During this period there was a significant increase in the inflow of private foreign capital. In 1993 foreign capital inflows amounted to US$ 170 million. However, most of this inflow was for portfolio investment rather than direct investment. Nevertheless the increased foreign capital inflow indicated greater confidence in the economy. Several consequences flowed from the increased capital flows. The large inflow of foreign funds made monetary management more difficult and a new cause of inflationary pressure emerged. The country's foreign exchange reserves soared to about US$ two billion by 1994, adequate to cover over eight months of imports. The inflow of foreign funds into the Colombo Stock Exchange resulted in a booming stock market in 1993.

Table 4 : Key economic indicators 1993-98

Indicator	1993	1994	1995	1996	1997	1998
Per Capita Income (US$)	588	656	719	759	814	837
GNP Growth Rate (per cent)	7.7	5.3	6.0	3.2	6.9	4.6
GDP Growth Rate (per cent)	6.9	5.6	5.5	3.8	6.4	4.7
Sectoral Growth						
Agriculture Forestry & Fisheries	4.9	3.3	3.3	-4.6	3.1	2.5
Mining & Quarrying	11.9	6.0	3.4	8.9	3.4	-5.4
Manufacturing	10.5	9.1	9.2	6.5	9.3	6.3
Construction	6.5	6.0	4.9	3.4	5.4	7.1
Services	6.3	5.2	5.1	5.8	6.8	5.2
Domestic Savings (per cent of GDP)	16.0	15.2	15.3	15.3	17.3	18.9
Rate of Inflation (per cent)	11.7	8.4	7.7	15.9	9.6	6.9
Rate of Unemployment	13.8	12.1	12.0	11.1	10.3	9.1

Source: Central Bank of Sri Lanka Annual Reports.



Source: Central Bank of Sri Lanka

Figure 3: Structural changes in economy 1950 - 1998

1994-1998

During the 1994-98 period the economy grew by an annual average of 5.2 per cent. In 1996 the economic growth rate declined to 3.8 per cent from around 5.5 per cent in the two previous years. A deterioration in the security situation combined with drought conditions, reduced paddy and food crop production. It also caused power cuts which in turn disrupted industrial production. These factors depressed the economic growth. Tourism too suffered a set-back and business confidence weakened. In 1997, the economy bounced back to record a GDP growth of 6.3 per cent. In 1999,adverse global conditions affected the economy and resulted in economic growth declining to 4.7 per cent. The economy achieved a growth of this level, despite the Asian economic crisis, due to a continued growth in the garment industry, rise in tea exports and increased paddy production.

This period witnessed a resurgence of tea production, which increased by 21 per cent. Garment exports too, increased significantly to contribute to an average industrial growth of about eight per cent per year. In fact, manufacturing grew by over nine per cent in each of the years except in 1996. The rate of inflation abated to a single digit except in 1996 when it was 15.9 per cent. The rate of inflation was 9.4 per cent in 1998. The rate of unemployment is also estimated to have declined from 13.8 per cent in 1993 to 9.1 per cent in 1998 and dipped below 9 per cent by mid 1999.

Key indicators of economic performance for 1993-98 are given in Table 4.

Structural changes in the Economy

During the last five decades, the economy has undergone significant structural changes. Agriculture, fishing and forestry which contributed about 40 per cent of the GDP in the 1950s declined to about 30 per cent in 1960, 26 per cent in 1970, 25 per cent in 1990 and 21 per cent in 1998.

A significant development in the economy has been the increased share of manufacturing, especially since 1978. The share of manufacturing output increased from about nine per cent of GDP in 1950 to about 11 per cent in the 1970s and rose to 19.4 per cent in 1997. Manufacturing output increased by an average of five per cent during the period 1978-85, by over six per cent in 1986-89, by over nine per cent in 1990-93 by eight per cent in 1994 - 98.

21 per cent during this period. A relatively stagnant agriculture after 1985, and an increase in industrial production contributed to this transformation. The growth in the output of tea from 1994 resulted in agriculture maintaining its share. By 1998, industrial output had increased but manufacturing accounted for only 16.5 per cent of GDP while agriculture's contribution remained at 21 per cent.

The share of the services sector increased modestly to 53 per cent of GDP by 1998 but its character has changed significantly. Financial services, tourism, trade and private transport contribute a large proportion to the services sector compared to the pre 1977 dominance of services related to agricultural exports. The structural transformation since 1977 is captured in Table 5.

PROBLEMS AND ISSUES

Despite the economic growth attained since independence, the country is still at a low level of per capita income, a high proportion of the country's population is below the poverty line, income distribution is uneven and the rate of unemployment high. The need to increase per capita income, reduce poverty and increase employment opportunities are the main challenges facing the economy.

Table 5 : Structure of Sri Lankan economy

	Per cent of Gross Domestic Product			
	1977	1984	1993	1998
Agriculture	28.3	23.2	21.2	21.3
Mining and Quarrying	0.7	3.3	2.5	1.8
Manufacture	16.6	13.7	19.4	16.5
Construction	5.6	4.2	7.0	7.1
Services	48.7	55.7	49.9	53.0
GDP	100	100	100	100

Source : Central Bank of Sri Lanka.

The most significant structural changes in the economy occurred since 1978. Manufacturing, which contributed 16.6 per cent of GDP in 1970-77 contributed 19.4 per cent in 1993, while agriculture's contribution fell from 28 per cent to

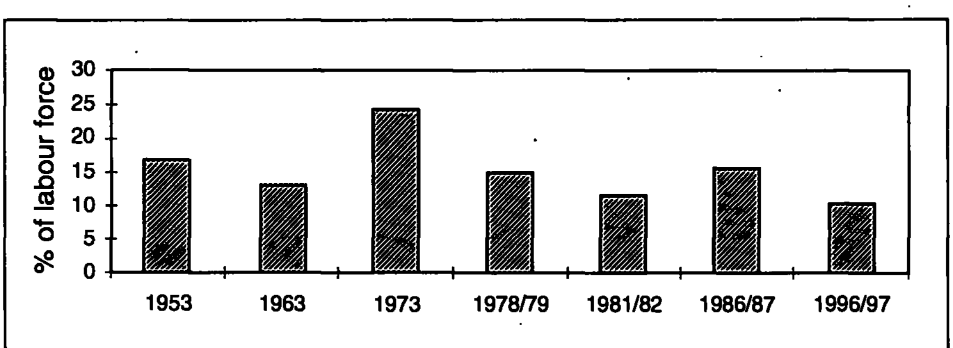
Although Sri Lanka's per capita income has risen to US$ 837 and is higher than those of her neighbours, many of the Southeast Asian and East Asian countries have much higher incomes. The current level of per capita income is also below the aspirations of the population. Therefore the objective of economic policy has been to double per capita income within a decade.

Two related issues are the skewed distribution of income and the high proportion of the population deemed to be below the poverty line. The Consumer Finance Survey of the Central Bank discloses an improvement in income distribution between 1953 to 1973 and a deterioration since then. The 1986/87 Consumer Finance and Socio Economic Survey disclosed that the top decile (10 per cent) of income receivers received 41 per cent of income, while the lowest 40 per cent obtained only 11 per cent of income. The deterioration of income distribution during a period of higher economic growth reflects the nature of economic policies since 1977. However, the latest estimates indicate an improvement in income distribution. The share of income of the poorest 40 per cent has increased from 11.4 to 12.9 per cent and the share of the top decile of income receivers has fallen to 37.3 per cent. The Gini coefficient of income distribution has also improved to 0.47 in 1996/97, compared to 0.52 in 1986/87. While rural and estate income distribution has improved, urban inequality has increased. (Central Bank Consumer Finance and Socio Economic Survey, 1996/97).

The country has also had a high proportion of the population below the poverty line. Estimates of the poor vary considerably. Those receiving food stamps and hence deemed to be poor make up as much as 40 per cent of the population. This estimate, as an estimate of the level of poverty, is flawed because of the tendency to declare low incomes, in order to derive the benefits of the food stamps and other welfare benefits. In 1987, it was estimated that around 28 per cent of the population was below the poverty line. This estimate defined the poverty line as consisting of households which had not been receiving an adequate nutritional level of food intake and spent 80 per cent of their income on food. In 1991, the World Bank estimated that about 21 per cent of the population was poor. It is now generally accepted that about one fourth of the population receive incomes inadequate to meet their basic needs.

The country has grappled with the problem of unemployment since the 1960s. The Census of Population conducted in 1946, disclosed a negligible level of unemployment. Unemployment emerged as a problem during the latter part of the 1950s when it was estimated to be 16.6 per cent. The Consumer Finance Survey of 1973 disclosed that the unemployment rate had risen to 24 per cent. This is the highest level of unemployment estimated for the country. Unemployment declined in 1978/79 to 14.8 per cent and has shown a declining trend in the 1990s. The Consumer Finance and Socio Economic Survey of 1996/97 estimated unemployment to be 10.4 per cent of the labour force, compared to 15.4 per cent in 1986/87. In 1998, unemployment was estimated at around 10 per cent of the labour force.

Despite the declining rate of unemployment, the nature of the unemployment creates considerable problems. Consequent to the social development polices pursued by successive governments and the high rate of school enrolment, the rate of unemployment among the educated remains high. Nearly half (48.3 per cent) of the



Source : Central Bank of Sri Lanka.

Figure 4 : Unemployment

unemployed had the GCE (O/L) or higher qualifications and 9.3 per cent of the unemployed were graduates. There is also a higher rate of unemployment among females. Unemployment among the educated has been an underlying factor in the emergence of unrest and social tensions. The insurgency of 1971, in particular, is attributed to the high level of unemployment among educated youth.

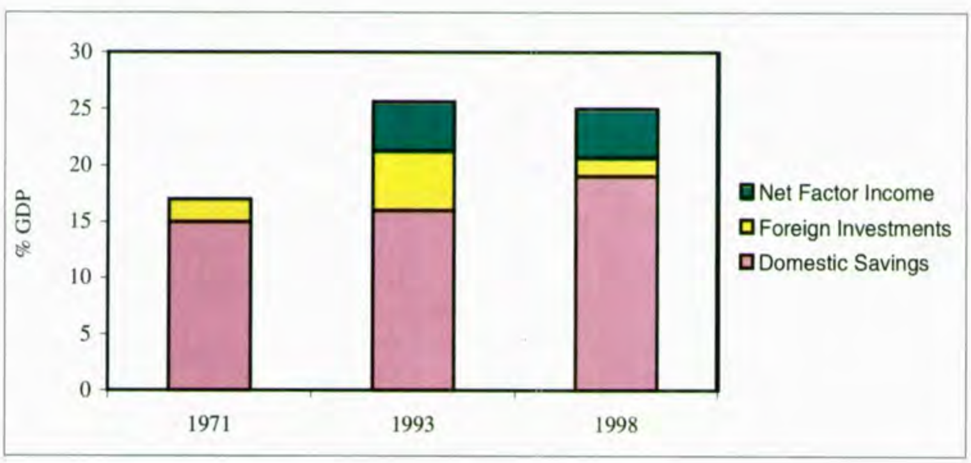
Governments since the 1970s have placed a high priority in providing employment, but the rate of economic growth has been inadequate to absorb the large numbers entering the labour force. Currently around 100 000 persons enter the labour force annually and the absorption of such numbers in employment continues to pose a problem. The accumulated unemployed is estimated to be around 900 000 persons. The resolution of the problem of unemployment requires a high rate of economic growth, providing employment opportunities in agriculture, industry and services. Educational reforms, especially the structure of university education, would have to ensure larger output of technically qualified youth rather than of mediocre liberal arts graduates.

One of the fundamental problems facing the economy is the weaknesses in the public finances of the country. The high debt-servicing cost, large expenditures on defence, and the costs of public administration and pensions absorb a very high proportion of government expenditure. Current expenditure on social services, education, health and welfare absorb a further one third of current expenditure. Consequently the government has no

Table 6: Savings and investments 1993/1998 (% GDP)

		1993	1994	1995	1996	1997	1998
1	Domestic Savings	16.0	15.2	15.3	15.3	17.3	19.1
2	Remittances & Net Factor Income	4.3	3.9	4.2	3.7	4.1	4.3
3	National Savings (1+2)	20.2	19.1	19.5	19.0	21.4	23.4
4	Foreign Savings / Investment	5.3	7.9	6.2	5.0	3.0	1.7
5	Total Savings / Investment	25.6	27.0	25.7	24.2	24.4	25.1

Source : Central Bank of Sri Lanka.



Source : Central Bank of Sri Lanka.

Figure 5: Components of investment

resources from current revenue for capital expenditure and runs a current account deficit. This means that capital expenditure has to be financed from other sources and is inadequate to support much needed infrastructure development. The budget deficits and their financing have also been the underlying causes for inflation, high interest rates and inadequate resources for private investment.

ECONOMIC PROSPECTS

There is a consensus that an annual economic growth rate of over seven per cent, sustained throughout a decade or more, would be needed to double per capita income, provide adequate employment opportunities, reduce poverty and propel the economy into a path of self-sustained high growth. Such a level of growth requires a much higher level of investment and a number of other non-economic pre-requisites to be in place.

Currently the country achieves an economic growth of around five per cent with an investment of around 25 per cent of GDP. This implies that an economic growth of seven per cent would require around 35 per cent of GDP to be invested. The substantial increase in investment of about 10 per cent of GDP would have to be contributed partly through higher domestic savings, but mainly through foreign investment.

The current investment of around 25 per cent of GDP consists of 19 per cent of GDP from domestic savings, about 4 per cent from foreign remittances of nationals living abroad and about 2 per cent of foreign investments, grants and aid. Precise data on savings and investment in recent years are given in Table 6.

Although domestic savings have increased in recent years and reached a high 19.1 per cent of GDP in 1998, it is unlikely that domestic savings could be increased much beyond 20 per cent of GDP in the foreseeable future. Therefore foreign investment would require to be increased to over 10 per cent of GDP. If the efficiency of capital could be improved, the investment required could be reduced.

The attraction of this level of foreign investment requires certain pre-conditions to be met. Foremost among these is peace and security. If a settlement to the war in the North and East is achieved, there would be a growth thrust in three ways. Certain expenditures on the war could be saved and directed towards investment; the investment climate would improve and foreign investments, in particular, could be expected to increase; several sectors of the economy, which are performing at lower than potential capacity, would increase production.

The other set of pre-conditions for economic growth would be the development of the country's infrastructure, which is inadequate to support a higher level of industrial production. Roads, rail transport, port development, augmentation of energy and increase of water supply are among such requirements. In addition to this, there is a vital need to improve the quality of general education, develop scientific and technical skills, enhance scientific research capability and improve management skills. The competitive capacity of the Sri Lankan economy would depend very much on an improvement in skills and scientific and technical education.

Another important pre-requisite is the improvement of the administrative capacity of government. Although the private sector plays the lead role in economic production, the regulatory authorities and policy makers would continue to play an important role in decision making. Quick decision making and understanding of modern business issues by the bureaucracy are vital for rapid economic growth.

There is an urgent need to have a society where the rule of law is firmly established and the law enforcement agencies could be expected to act without fear or favour. A paramount requirement is the speedy settlement of legal issues and the development of a body of modern commercial law. At present there are considerable delays in the settlement of property and commercial disputes.

In summary, the economic prospects for the country depend very much on enhancing the level of investment, improving the country's economic, social, legal and administrative infrastructure and the attainment of peace. The economic factors which contribute to economic growth are very much dependent on cultural factors which are conducive to the formulation and implementation of economic development policies.

CONCLUDING OBSERVATIONS

Although the economy has grown by over four per cent per year in the last half century and at a slightly higher five per cent in more recent decades, this rate of growth has been inadequate to solve the country's problems of unemployment and poverty. There is consensus that a higher rate of economic growth would be necessary to raise per capita income, increase employment opportunities adequately and reduce poverty. The factors which constrain the country's economic growth are not only economic. The war in the north and east not only absorbs considerable funds and is a burden on the public finance, but also creates an inhospitable climate for investment, tourism and the establishment of hi-tech industry. The return to peaceful conditions would contribute considerably towards a much higher rate of economic growth and the utilization of the country's resources more economically.

The constraints to economic growth are not confined to the burdens of war alone. There is a need to fulfill a number of economic and non-economic conditions to support a more rapid thrust in economic growth. Physical infrastructure is a significant constraint to more rapid industrialization. The road network requires to be improved and expanded. Public transport is quite inadequate and is the underlying reason for traffic congestion. While considerable progress has been made in modernizing the country's main port, there is a need to further expand the facilities and enhance its efficiency. Flights to and from the country are also inadequate. The power crisis in 1996 was a dramatic warning of the need to enhance power generation. The country requires to enhance power capacity by installing non-hydro electric power plants to cope with the increasing demand for power for both industrial and domestic users.

While the country can boast of a high level of literacy and school enrollment, the quality of education requires to be improved with science based education and technological education being expanded considerably. There is also a need to develop technical schools and restructure the curriculum of universities to meet the practical needs of a modern industrial state.

Recent years have witnessed also a deterioration in the law and order situation. Law and order are pre-requisites for rapid economic growth. Considerable delays in obtaining justice through the courts, a weakened bureaucracy and an erosion of property rights require to be remedied in order to support economic growth. In addition, there is a need to improve the work ethic and minimize politicization at all levels. The country's capacity to implement accepted policy must also be strengthened. There is a need to improve institutions to enable the development of multi faceted capacities required for economic development.

The road to higher rates of economic growth is therefore not a simple issue of increasing investment. It is one of providing the overall milieu which could attract such investment. The development of such a milieu would indeed require a significant thrust in reforming the country's education, developing a system of values conducive to economic growth and making all branches of government activity far more efficient than at present. Therefore, the country's prospects for higher rates of economic growth rest largely on a multitude of non-economic factors as well.

REFERENCES

1. Central Bank of Sri Lanka, Annual Reports.

2. Central Bank of Sri Lanka, Consumer Finance Surveys 1953, 1963 ; 1996/97 & Consumer Finance and Socio Economic Surveys1978/79, 1981/82, 1986/87 and 1996/97, Colombo.

3. Central Bank of Sri Lanka (1998) Economic progress of independent Sri Lanka, Colombo.

4. Dept. of Census and Statistics, Unemployment Surveys, Colombo.

5. Government of Sri Lanka (1994) The Economic policy statement, Colombo.

6. Jayasundera P. B. (1986) Fiscal Policy In Sri Lanka. In: *Facets of Development in Sri Lanka.* pp. 43-82. Ministry of Finance and Planning, Colombo.

7. Sanderatne N. (1985) The Effects of Policies on Real Income and Employment. In: *The Social impact of economic policies in the last decade.* pp. 11-24. UNICEF, Colombo.

8. Sanderatne N. (1997) Social development expenditure 1950 - 1995. *Upanathi, Journal of the Sri Lankan Association of Economists.* Vol.9.

Courtesy: The Island.

Harvesting Paddy

LAND RESOURCES: CONDITIONS AND TRENDS

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Summary

Sri Lanka with a land area of 65 525 km² and a population of 19 million people represents one of the most densely populated countries in the world. The majority of the people earn their living from activities based on land. A land balance sheet shows that about 40 per cent of the total land area is presently used while sparsely used land such as chena and patana accounts for a little over 10 per cent. Of the balance, the area under forest covers another 30 per cent and only about 20 per cent remains for all other conservation purposes, such as stream and reservoir reservations.

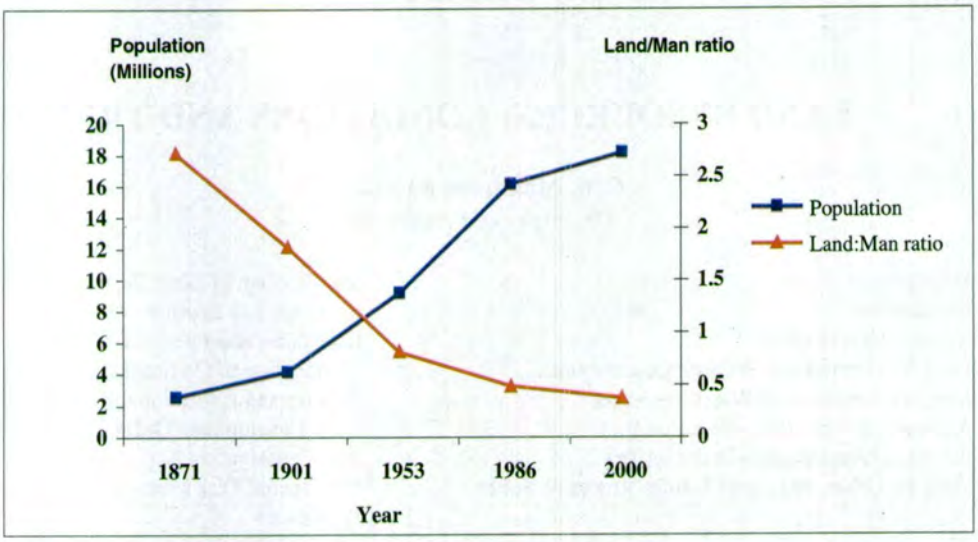
With increasing pressure on land due to increasing population and the slow growth of the economy, the problem of land degradation has assumed serious proportions in recent years, resulting in high rates of soil erosion and problems of land slides. The coastline of the Island too has come under heavy population pressure due to internal migration and coast-based development activities including tourism. This has resulted in high rates of coastal erosion and increasing investments for coast conservation. Despite the multitude of legal and institutional provisions available, a high rate of encroachment on state land continues to take place. This has compelled successive governments to transfer a large amount of state land to the landless people. Nevertheless, nearly 80 per cent of the total land area of the country is still held under the ultimate ownership of the state.

INTRODUCTION

Sri Lanka has a land area of 65 525 km². Among the nations of the world, Sri Lanka ranks 118th in area, 47th in population size, and 19th in population density. The coastline of the island is 1920 km long, including the coastline of the off-shore islands of the northwest (Madduma Bandara, 1989a).

The total land area is 6 552 500 ha of which about 130 300 ha is covered by irrigation and hydro-power reservoirs. There are some 160 large reservoirs and around 25 000 village tanks. Thus the exposed land surface area is around 6 422 200 ha (Somasekeram, 1996). Sri Lanka's land resources are not determined by surface area alone. The nature of the resource is affected by climate, topography, soils, hydrology, biota and human activity.

An indication of pressures and demands on land resources is given by the major changes in land/man ratios. In 1871 when the population of Sri Lanka was around 2.4 million, the ratio was 2.7 ha. Today, with about 19 million people, the ratio has decreased to about 0.35 ha (Fig.1). The gross ratio is misleading. It makes no allowance for the fact that much of the land is not directly available for human use. There are areas of land that are topographically unsuitable for use (such as steep slopes). Other areas cannot be used because of factors such as water shortage, salinization and water logging. Further, land has to be set apart for conservation purposes. If the share of presently used land excluding *chena*, pasture and *patana* is considered, per capita land use stands at 0.15 ha indicative of heavy pressures, particularly on agricultural lands.



Source : Erdlen (1993).

Figure 1: population & Land/man ratio in Sri Lanka

A LAND BALANCE SHEET

Approximately, a little over one third of the total land area of Sri Lanka is under agricultural uses. Another third is under forest or set apart for wildlife conservation. The balance provides for all other uses such as urban areas and infrastructure development. Also included in this category are barren lands and *chena*, pasture and *patana*. A land balance sheet is given in Table 1.

Table 1 : Land balance sheet

	ha
Reserved Land (Reservoirs, streams, roads etc.)	585 300
Forests and Catchment Areas	2000 000
Steep Lands	380 000
Lands above 1500 m (5000 ft) Contour	76 400
Barren Lands	77 000
Marshes and Mangroves	70 000
Presently Used Land	2 635 000
Sparsely Used Land (Chena, Patana etc.)	728 800
Total Land Area	6 552 500

Source : Somasekeram (1996).

LAND FOR FORESTRY AND WILDLIFE CONSERVATION

Every country needs a reasonable extent of land for conservation purposes depending on its stage of development and the intrinsic value of certain land related natural resources. Sri Lanka had a tradition of conserving natural resources from pre-historic times, which had evolved through a combination of indigenous wisdom, religio-cultural norms and values, and the political will of the rulers. These rulers carried the honorific titles of *bhupathi* and *patavipathi* indicating their primary function of being lords over the land.

Before the island came under colonial rule, over 80 per cent of the land was under forest cover. In particular, land in the hill country where the sources of major river systems are located remained under a natural montane forest cover.

However, during the British period large extents of sloping land in the hill country were converted to plantation agriculture (Land Commission, 1990) and the long term effects on the quality of land has been disastrous. It must be mentioned, in this connection, that finally in 1873, the Colonial Secretary of Great Britain ordered that no land above 5000 ft (1500 m) should be alienated.

Even after the advent of plantation agriculture in the middle of the last century, a considerable extent of land in the island remained under forest cover. It has been estimated that nearly 50 per cent of the total land area of the island was under forest at the time we gained Independence in 1948. Since then under our own stewardship this has been reduced to less than 25 per cent over a period of 50 years (Fig 2). Encroachment, increased *chena* cultivation, illicit felling of timber and conversion to agricultural and other uses necessitated by increasing population have been responsible for this decline.

The world average of forested lands is around 30 per cent and in Asia it is estimated to be around 20 per cent which is slightly lower than that of Sri Lanka. In contrast, Japan - an industrialized country-still retains nearly 70 per cent of its land area under forest cover. This is partly due to the fact that much of the land in Japan is topographically unsuitable for agriculture and not arable. Also, Japan's forest policy promotes scientific forestry and encourages the importation of a large share of the national timber requirement. In Sri Lanka serious ecological considerations demand that, as a matter of Land Policy, land now under natural forest must be maintained as such. However, in areas of forests with fertile soils, demographic and political pressures seeking to convert these to agricultural use are bound to increase in the future. Under these circumstances the only realistic policy option would be to create forest areas that can replace, over a period of time, the forests cleared due to socioeconomic considerations.

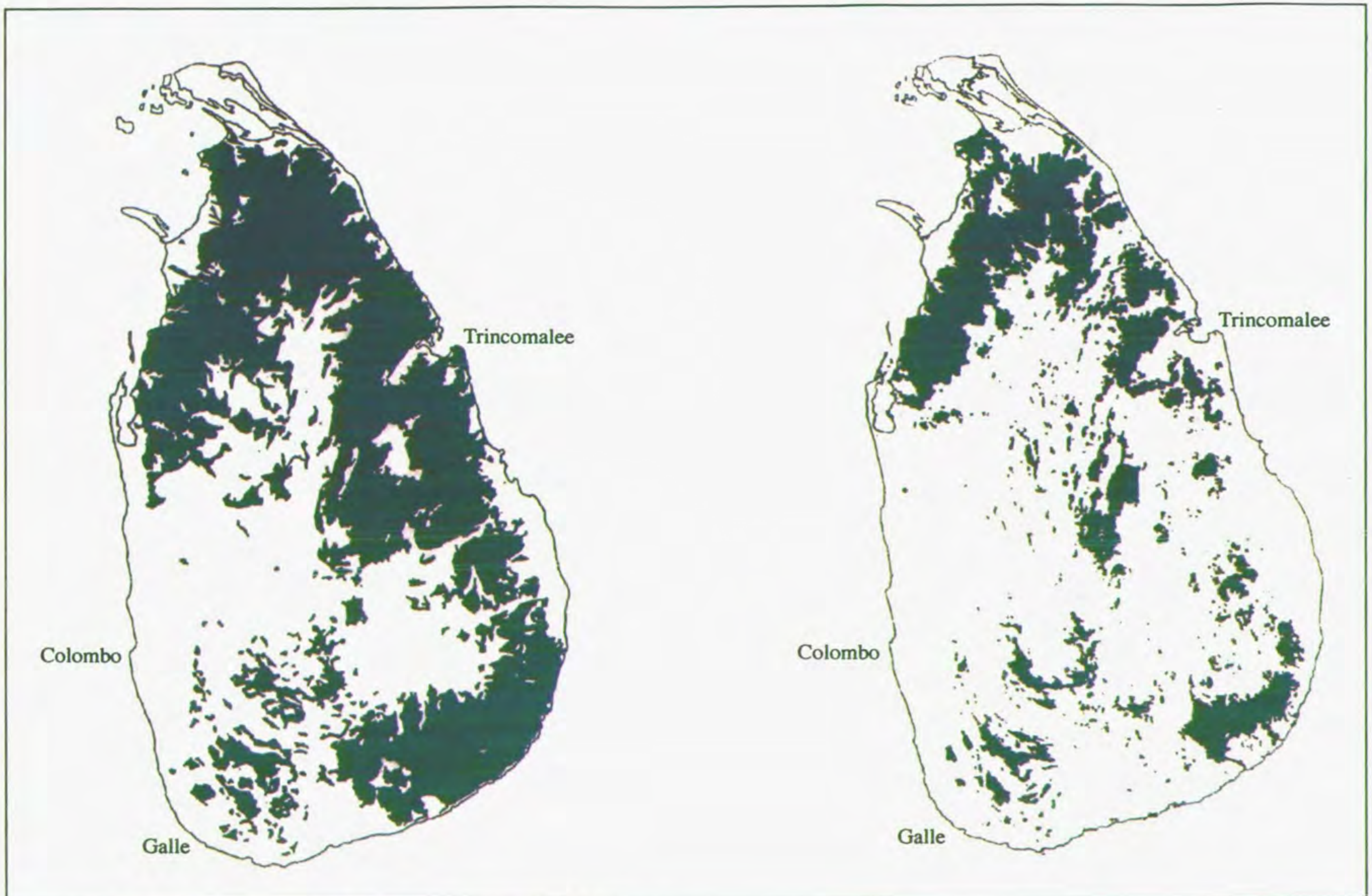
Similar pressures could be expected regarding land presently under wildlife conservation. This accounts for nearly 13 per cent of the total land area. Sri Lanka is fortunate to have such an extent of land under wildlife conservation. This figure is one of the highest in Asia and Sri Lanka ranks only next to Bhutan (where much of the land is not arable) in this regard. As in the case of forested lands a realistic policy would be to adopt a well planned programme of converting land to other uses while retaining the present total extent.

LAND FOR PROTECTION OF WATER RESOURCES

Apart from forest areas to serve the conservation needs of forests and wildlife, there is an urgent need to set apart land for the protection of streams and reservoirs. A radial network of 103 distinct stream basins provides the vital requirements of water for irrigation, hydropower generation and domestic, urban and industrial water supplies in Sri Lanka. It is of interest to note that, in the traditional systems of measurement, land was estimated in terms of sown area or the irrigable area as denoted by traditional measures such as *pela* and *amuna.* Measurement of land by surface area was introduced during the colonial rule when acreage as a measure was adopted as in the case of *sinnakkara* (freehold) and *baduakkara* (leasehold) lands.

The importance of conserving land at elevations above 5000 ft (1500 m) above sea level, where the sources of most river systems lie and the need to protect stream banks was recognized increasingly during the latter part of the colonial period. This was partly initiated as remedial action for the adverse ecological impacts of opening montane forests for plantation agriculture. The enactment of the now infamous Crown Lands Encroachment Ordinance of 1840 which converted over 85 per cent land area of the Island into Crown ownership, was associated with this need for remedial action.

The Crown Lands Ordinance (1947) provided for protection of ecologically sensitive areas such as stream banks and coastal lands. The regulations under the Crown Lands Ordinance provide for the protection of stream reservations of varying widths of riparian lands depending on the size of the streams. Similarly, belts of land on reservoir margins were set apart as reservoir reservations. Therefore, in Sri Lanka, it is unlawful to alienate, encroach upon or occupy stream or reservoir reservations. It has been estimated that under the provisions of the Crown Lands Ordinance, approximately 290 000 ha of land should be under streams and their reservations (Somasekeram, 1996).



Adapted from Biological Conservation in Sri Lanka (Revised Version ,1993), IUCN.

Figure 2 : Sri Lanka's forest cover in 1965 (left) and 1992

However, due to the weak enforcement of these legal requirements, most of the stream reservations particularly in the hill country areas are occupied unlawfully and used for agricultural and other purposes. For example, some surveys conducted by the Water Resources Board in 1969 in the Badulla District revealed that more than 80 per cent of the reservations are occupied by encroachers. Similarly in the area around Nuwara Eliya virtually all stream reservations are utilized for market gardening. Any attempt to clear the reservations would be resisted strongly.

A similar situation prevails with regard to reservoir reservations particularly in the dry zone. With increasing demand for agricultural lands and a need of access to a water source, the practice of *tavalu* (cultivation of the upper tank-bed) spread rapidly into the tank reservation areas. Although the traditional form of *tavalu* cultivation had been less harmful, in recent times, *tavalu* lands were gradually converted to permanent cultivation, sometimes with lease-hold status under the Land Development Ordinance. This has resulted in increased siltation of reservoirs along with increased clearance of forested areas in the tank catchments.

AGRICULTURAL LAND USE – FOCUS ON RICE

Agriculture continues to remain a dominant sector of the economy despite recent changes in earnings from manufactured goods and migrant labour. The share of agriculture in the GDP in 1988 was 22.8 per cent and the economically active population in this sector in 1985 was 52.55 per cent according to Central Bank reports. However, the situation has changed in recent years and by 1995 the share in the GDP dropped to around 20 per cent and the employment in agriculture dropped to 36.8 per cent. Rice being the staple diet of Sri Lanka accounts for about 37 per cent of per capita calories and 30 per cent of the per capita protein in the average Sri Lankan diet.

Some trends in land use under major agricultural crops since Independence are indicated in Table 2.

It is evident from Table 2 that, all major crops except paddy suffered a significant decrease in the area cultivated. The increase in the extent of paddy

Table 2: Changes in land use under major crops ('000 ha)

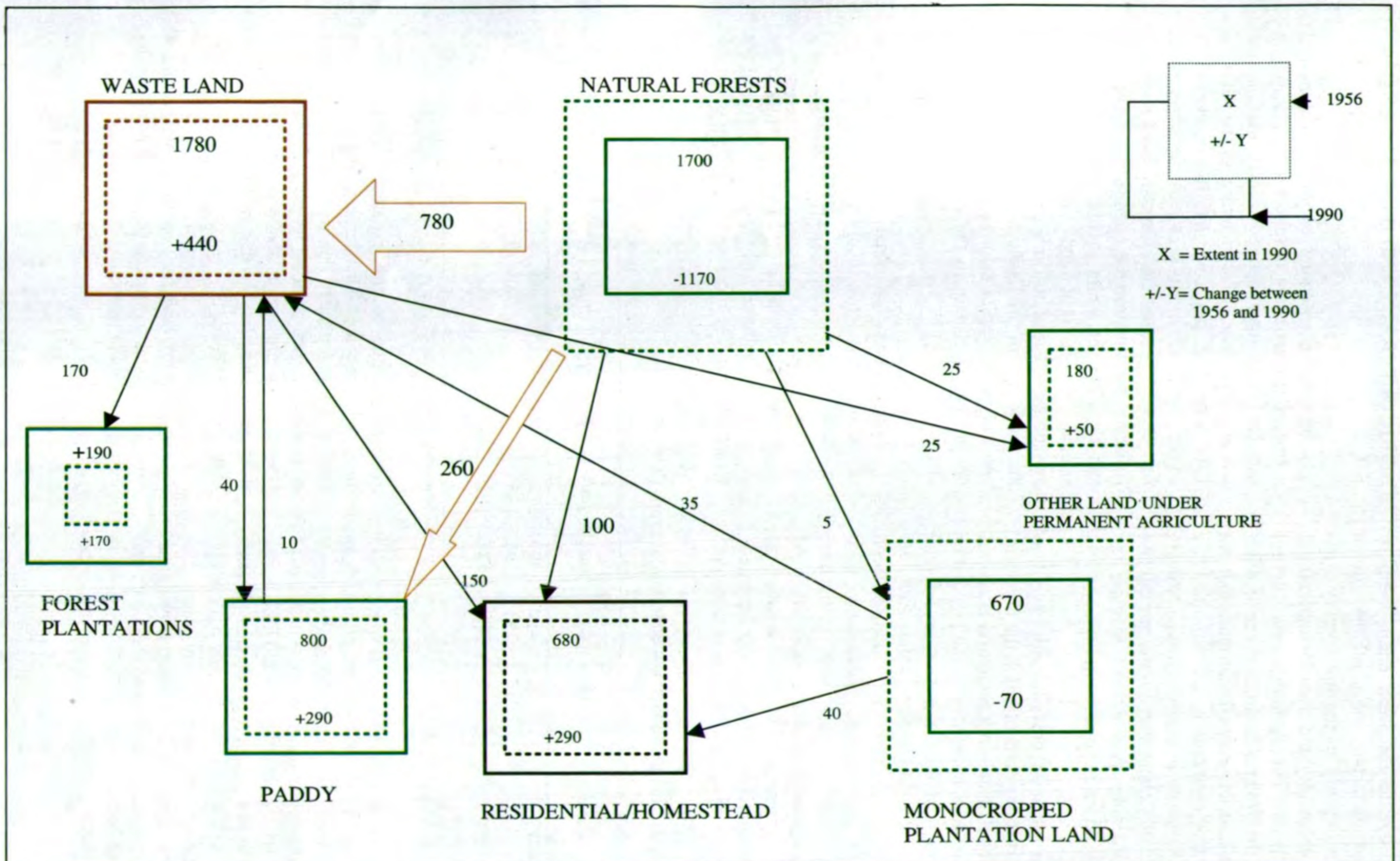
Crop	1946	1962	1982	1995	% Change (1962-1982)	% Change (1982-1995)
Paddy	370	460	499	890	+08.48	+78.36
Tea	215	231	207	188	-10.39	- 09.18
Rubber	232	229	171	162	-25.33	- 05.26
Coconut	433	466	416	-	- 10.72	-

Source : Census of Agriculture, 1946, 1962 and 1982 and Central Bank reports.

In accordance with the provisions of the Coast Conservation Act, a belt of 300 m landwards from the high water mark is considered as the coastal zone. If this is applied to the entire coast line of Sri Lanka with a length of 1920 km, some 57 600 ha should be set apart for the coastal zone. However this belt too is utilized for agriculture, human settlements and tourism and cannot be exclusively set apart as a conservation zone. Nevertheless, it is essential to make residents and other users of these areas aware of its fragile nature and of their responsibility to conserve the areas they occupy.

was largely due to the expansion under major irrigation schemes. The largest losses were in rubber lands, primarily due to conversion of land to other uses such as housing. Similar changes are occurring at present in the area under coconut cultivation also, largely due to the same reasons (Fig. 3).

In terms of land use, paddy is the dominant crop with a total sown area of some 0.6 million ha during the *maha* season.



Notes: a) The data matrix does not include land covered by inland water bodies and salterns.

b) "Waste Lands" category includes scrublands, grasslands, chena, abandoned agricultural land, certain types of 'wet lands' and other unused land.

All extents are given in '000 ha and are approximations based on several sources.

Source: Peiris, 1996.

Figure 3: Main land use changes in Sri Lanka between 1956 and 1990

Its drop to about half during the *yala* season, is primarily due to constraints of water policy and import of rice and wheat flour, in order to keep the price of rice low for consumer benefit. In fact, the import of wheat flour reached an all time high in 1995, with a reduction of bread prices. Such trends affect the farming community adversely, leading to agrarian poverty and a shift of labour away from agriculture.

In Sri Lanka, paddy is cultivated under major irrigation, minor irrigation or rainfed conditions. The share of land under major irrigation witnessed a rapid increase during the last decade mainly due to the expansion of irrigable areas under major projects like the Mahaweli , while the areas under minor irrigation remained static or showed only a slight increase in some districts. The cropping intensity also remained low in minor irrigation areas partly due to water scarcity but also due to tenurial constraints such as fragmentation and multiple ownership according to a survey carried out by the Water Resources Board in 1968. Meanwhile the productivity of paddy lands under major irrigation such as those in system 'C' of Mahaweli seem to have declined gradually. With regard to actual paddy yields in irrigated areas, non-climatic factors such as transplanting, choice of variety, fertilizer and irrigation have important determining impacts. However, impacts of climate variability have been always the most adverse under rainfed cultivation.

In minor irrigation systems, there has been unplanned expansion of *asweddumized* areas under village tanks. Also there is increasing siltation of tank beds. Together, these factors seriously affect the storage capacity of the tanks and contribute to water scarcities. This has led to a situation where paddy cultivation is practised over a wider area, the limited quantity of available water being distributed thinly over the expanded extent. Thus, it has been found that the greatest amount of damage due to drought is experienced in minor irrigation areas (Madduma Bandara, 1982). It can be argued, therefore, that misuse of land rather than the scarcity of water is a major factor that limits agricultural productivity in the dry and intermediate zones.

A significant development during the last decade is the rapid growth of agrowells in the dry zone. There are over 10 000 agrowells in the Anuradhapura District alone, today. In some areas such as Galgamuwa it has been reported that signs of over exploitation of ground water are already beginning to appear and therefore some remedial measures have become necessary to avoid adverse ecological consequences similar to those witnessed in South India.

In the wet zone, paddy cultivation is often affected by tenurial complexities, low yields and competition from other uses. Water logging, salinity and iron toxicity also affect the yields in many areas. The competition from other uses particularly for housing and urban development has resulted in haphazard filling of low lying lands creating several ecological disturbances such as the blocking of natural water ways and drainage channels. The demand for land in the wet zone, as reflected in the rising land values aggravated by the property development agencies have made many paddy lands commercially non-viable. Apart from the high cost of production and low returns under current market prices of rice, the opportunity costs of maintaining paddy fields remain high. In the future, it may be necessary to concentrate on paddy production in the dry zone leaving the bulk of wet zone paddy lands for other uses, as a matter of national land use policy.

PLANTATION AGRICULTURE – FOCUS ON TEA

Among the major plantation crops of tea, rubber and coconut, tea is the leading crop in terms of employment and export earnings. In terms of environmental sensitivity too, the area under tea requires consideration. Although the composition of export earnings from different sectors has changed significantly in recent years, tea continues to remain the highest net foreign exchange earner. Within the tea sector, the contribution of small holders has increased significantly and at present around 60 per cent of the total production comes from the small holdings and particularly from the low country. At the same time, the cost of production rose rapidly, largely due to high taxation and to rapidly increasing wages negotiated by strong trade unions. It had also been shown that, the ex-estate cost of production is closely associated with yield variations. The yield per hectare in turn is sensitive to adverse weather conditions, the level of use of high technologies and poor management practices. Whatever the reasons, the cost of production of a kilogram of made tea in Sri Lanka is much higher than that of other major producers such as India and Kenya, making competition in international markets difficult.

The trends in the yield of tea indicate that the yields fell during the 1970s and recovered in the 1990s while the area cultivated gradually declined (Table 3).

Table 3: Yield and extent of tea lands

Year	Yield (kg/ha)	Area ('000 ha)
1960	869	227
1970	952	227
1981	836	229
1990	1045	222
1995	1309	188

Source: Annual Reports, Central Bank.

It is also evident from Table 3 that the yield per hectare has increased significantly since 1990 while the area cultivated has declined. Despite this decrease in the area, the volume of production increased by about 16 per cent compared with 1970 level. This, in a way, is a healthy trend where marginal and uneconomical land in the ecologically fragile areas is being used for more sustainable uses.

The decrease in the area under tea was most marked in the mid-country districts of Kandy, Matale and Kegalle. It is in these areas that land degradation has been most severe and large extents of land have been abandoned, particularly after the Land Reforms of the 1970s. In these areas, a significant extent of tea land had been converted to human settlements, home gardens and cash crops. Some of the tea estates have reverted to *patana* grasslands. It was reported that in the upper Mahaweli basin above Peradeniya some 22 per cent of tea lands have been converted to other uses or abandoned during the period from 1956 to 1986, while the land devoted to settlements and cash crops grew rapidly (Madduma Bandara & Kuruppuarachchi, 1988 &1994). These changes are reflected in the river regimes and in soil erosion and siltation. It has been shown that hydrologically a well maintained tea cover acts almost like a natural forest in reducing the direct impact of raindrops on the soil thus, reducing soil erosion.

At present even in better managed plantations, which were earlier under the State Plantations Corporation or the Janatha Estate Development Board, some 10-15 per cent of the planted land do not contribute to production (Peiris, 1996). After the transfer of management of plantations to the private sector attempts have been made to utilize some of these lands. However, 'uneconomical' or 'marginal' lands continue to comprise sizeable extents in most plantations. Some of the remaining forest patches within the plantations were also exploited by the new management companies while there has been much less interest in developing planted forests. The net effect of these trends will be continuing ecological disturbance as manifested by, soil erosion, siltation and modification of river regimes. The need for heavy inputs of fertilizer and agrochemicals to maintain production levels may have other environmental implications.

LAND FOR URBAN, INDUSTRIAL AND INFRA-STRUCTURAL NEEDS

Despite the slow growth of the urban population in Sri Lanka, compared to many other developing countries of the Asian region, the need for land for urban expansion has been significant. The land area falling within a few major urban centres indicate some significant patterns (Table 4).

It is evident that, definition and demarcation of 'urban' areas in Sri Lanka has also resulted in bringing rural land within urban areas. Thus many paddy and rubber lands that came within urban areas are being converted increasingly to urban uses. Conversion of agricultural land to residential, commercial and industrial uses takes place at the urban fringe, as well as, within the city limits. In many cities much of the land is state owned, as in the

the case of Colombo, where state land is around 45 per cent. With changing life styles and demand

Table 4: Area of urban centres

Urban Centre	Area (km^2)
Anuradhapura	41.0
Colombo	37.3
Kandy	25.6
Puttalam	25.6
Ampara	24.7
Seeduwa-Katunayake	21.8
Vavuniya	21.5
Dehiwala-Mt. Lavinia	21.0
Jaffna	20.2
Ratnapura	20.2

Source: Dept. of Census & Statistics.

for urban uses there has been an unprecedented rise in urban property values. The natural expansion of the urban sprawl is also accelerated by business interests, that acquire agricultural land from the urban periphery for property development. In recent years the largest losses of agricultural land for such purposes appear to have occurred in coconut lands not only from the urban fringe but also from lands bordering main roads. The activities of the Greater Colombo Economic Commission and, more recently, the Board of Investment, Sri Lanka also have resulted in the conversion of agricultural land for urban and industrial uses.

Land is required for the development of infrastructure facilities such as roads, railways, power and telecom lines, coastal protection works, harbour and airport development and tourism. It has been estimated that, Sri Lanka has a total length of about 94 651 km of roads, including all classes. With recent additions, it is likely that this figure has risen to, at least 100 000 km. At an average reservation width of 10 m this would work out to at least 100 000 ha of roadways. The railways with a total length of around 1400 km, with requirements for buildings, sidings, etc., take up around 10 000 ha. The land needed for other infrastructure facilities is estimated to be around 55 000 ha (Somasekeram, 1996). A total of around 165 000 ha of land is needed as reservations for existing infrastructure facilities. With the progress of economic development programmes, the land area needed for such facilities will increase further. Since much of the road and railway reservations have been already encroached upon, they may require multiple use management strategy while making allowance for future expansion.

THE PROBLEM OF LAND DEGRADATION

Land degradation includes all natural or anthropogenic processes that diminish or impair productivity of land. Natural processes include climatic and oceanographic changes over long periods of time. Among the anthropogenic factors are, over exploitation of land and water, deforestation, excessive use of agrochemicals and careless disposal of wastes. In Sri Lanka, man induced land degradation is more significant than that by natural forces. This is evident in high rates of soil erosion and siltation, landslides, floods, salinization, coastal erosion and the decline in productivity of agricultural lands.

Problems of land degradation in Sri Lanka have been evident through several periods of our history. *Chena* cultivation practised from prehistoric times, undoubtedly contributed to deforestation but the effects were local and temporary due to the small scale of operation. The collapse of the *Rajarata* civilization, may have been caused, at least in part, by the loss of soil fertility or the development of salinity in the rice fields due to centuries of continuous use.

An early example of land degradation during the colonial period is found in the impact of the construction of the Dutch canal across swampy areas, paddy fields and fresh water bodies along the western coast. It has been claimed that, Muthurajawela, a flourishing paddy field during the time of Sinhala kings, turned into a marshy land as a result of that coastal development. However, land degradation at an unprecedented scale was witnessed only after the advent of the commercial plantation agriculture in the hill country. Through the enforcement of the Crown Lands Encroachment Ordinance of 1840 and the Waste Lands Ordinance of 1897, the colonial government sold around 728 450 ha of state land to the private sector at give away prices, during the period 1833-1906 (de Silva, 1981). Apart from the adverse social and economic consequences, particularly to the Kandyan peasantry, this led to the denudation of the hill country resulting in high levels of soil erosion, landslides and siltation of stream beds and drying up of springs.

FOCUS ON SOIL EROSION

Soil productivity remains a basic factor in determining good land condition and appropriate land use. Sri Lanka's soils are vulnerable to severe erosion due to a combination of high intensity rainfall, sloping nature of land, and the high intensity of land use in some parts of the country. Soil is a renewable resource but not in terms of generations. It has been shown that the natural process of soil formation from consolidated metamorphic rocks may take around 1000 years to develop a soil layer of 46 mm. In Sri Lanka soil erosion can remove up to 5-10 mm in one year and it cannot be replaced within one human lifetime.

Serious concerns about soil erosion in Sri Lanka have been expressed since 1873, when J.D. Hooker stressed the dangers of indiscriminate clearing for plantation agriculture, in the hill country. A major result was the imposition of restrictions regarding the alienation of land above 5000 ft (1500 m) by the Colonial Secretary of Britain of that time. In 1931 the Committee on Soil Erosion was "appalled by the wastage of soil which it observed during field inspections" and held that "estate agriculture was responsible for a very large part of the erosion in progress" (Sessional Paper III of 1931). Even so, it took almost 20 years for the enactment of the Soil Conservation Act, following devastating earth slips in the hill country and particularly in the Kotmale Valley. It took another 10 years to gazette the regulations declaring erodible areas. As Stocking (1986) observed "the reality of soil conservation in Sri Lanka today, is one of much rhetoric, little action: the concern of some, the disdain of others". Thus the draft of a new Land Use and Soil Conservation Act, which was to supersede the 1951 Act, prepared by the Ministry of Agriculture several years ago has received Parliamentary approval only recently.

One indicative measure of soil erosion and its impacts is the sedimentation of streams and reservoirs. Some studies have indicated that an average of around 15 million tonnes of sediment passed through Peradeniya gauging station on the main Mahaweli Ganga. The Polgolla barrage located down stream trapped about 70 per cent of this load and it has been reported that, some 44 per cent of the capacity of the Polgolla reservoir was found silted within a period of 12 years after its commissioning. Other estimates of soil erosion indicate excessively high rates of soil erosion from cultivated lands. Thus Stocking (1986) reported that some of the highest field estimates of erosion (70 – 200 t/ha/year) were from the mid-country *chena* lands on high slopes cultivated with tobacco. It was also observed to be exceptionally high (40-60 t/ha/year) in bare, clean weeded land under clonal tea and those under old seedling tea with little conservation. In the low-country dry zone excessively high soil erosion rates (20-25 t/ha/year) were reported from land under sorghum and cotton without mulch. The impact of soil erosion in the dry zone is reflected in the siltation of village tanks where in some cases nearly 60 per cent of the capacity has been lost (Dharmasena, 1991).

Studies on soil erosion in general, reveal two major facts:- The rates of soil loss are highest in the mid-country (300-1000 m in elevation) where the slopes are steep, rainfall intensities high and the soils are more erodible. The other is that the use of the ground cover is the crucial factor in the conservation of soil. The use of mulch can bring down the rate of soil loss, from over 50 t/ha/year to less than 5 t/ha/year. Apart from soil loss due to agricultural land use, construction of roads and buildings without protective measures can cause high levels of erosion. The recent experience of building road access to a hotel site on the Ambuluwagala Range near Gampola provides an interesting example.

LANDSLIDES AND RELATED PHENOMENA

In Sri Lanka, landslides present another significant result of land degradation. High rates of soil erosion often occur in the same areas, but landslides cause sudden and often disastrous consequences. Landslides commonly occur following heavy rainfall events, particularly on highly sloping lands of the hill country. Available evidence suggests that the frequency and magnitude of landslides have increased in recent years.

Although records of past landslides maintained by the Social Services Department are neither systematic nor comprehensive, they indicate the magnitude and geographical distribution of most major landslides that received the attention of the Department. An examination of these records indicate that about one third of the landslides were reported from Kegalle District while another third was reported from Ratnapura and Nuwara Eliya Districts. It is clear that Sabaragamuwa Province deserves priority attention in any plans for mitigation of landslides. With its rugged topography, high rainfall, intensity of land use and dense human settlements it is not surprising that the damage caused by landslides in Sabaragamuwa is much higher than in other areas. Nevertheless, certain areas of the Nuwara Eliya, Kandy and Matale Districts too deserve special attention as already considered by the NBRO in its landslides mapping exercise (NBRO, 1994).

In 1986 – a year of high landslide damage, around 1500 families were displaced in the Maturata area alone. It has been estimated that altogether over 25 000 persons were made homeless in that year while there were serious disruptions in the transport system in the affected areas. The affected families became "environmental refugees" who had to be accommodated in special camps and later to be relocated at great expense to the State. In early June 1988, ironically on the World Environment Day, Sri Lanka experienced one of its worst landslide disasters causing over 300 deaths. In the AGA Division of Galigamuwa alone 167 people were buried alive by a landslide. Another very damaging landslide took place more recently (3rd June 1992) at Watawala, the location at which the highest rainfall in the island is usually recorded. This led to the disruption of the main railway line to the hill country for several months, while rehabilitation was undertaken at great cost (NBRO, 1994).

In the public and academic debates that ensued after devastating landslides of recent years, their increasing frequency was attributed to several causes. These included the cultivation of tobacco on steep slopes, impacts of the accelerated Mahaweli Project, high intensity rainstorms, geological instabilities, blocking of drainage ways and the impact of colonial land policy and land clearing in the hills (Madduma Bandara, 1989 b, 1993). Conditions that favour landslides fall generally under two broad categories. First are the natural reasons such as geological, structural, topographic and climatic factors of an area over which man has little control. Second are human impacts on the land through the clearing of forests of watershed, obstruction of natural waterways and drainage lines, and construction of buildings and roads in vulnerable locations.

What triggers most landslides is the saturation of the unstable sub-soil layers and a build up of water pressures along critical zones. Saturation of the soil mass results from the intense and continuous rainfall so common in the hill country and the wet zone. Landslides appear when such rainstorms exceed a certain threshold level. While some hold that a threshold figure of 350-400 mm rainfall during two consecutive days is critical, others found a direct correlation between antecedent precipitation and landslide occurrence.

Increasing damage to life and property from landslides is also related to the spread of human settlements into unstable areas. Some effort has been made in the recent past by the UNDP/NBRO Landslide Mapping Project to identify and map out such areas. However, the relevant authorities have not used the information gathered in preventing landslide disasters.

The measures normally adopted for soil conservation may not prove effective in managing landslides. Some features like contour ditches may even facilitate landslides by allowing greater infiltration of water to the sub-soil and providing lubrication of unstable soil masses that lie above. Therefore, preventive action aimed at minimizing landslide damage and any necessary remedial measures as well, should be rooted in scientific knowledge.

DEGRADATION OF COASTAL LANDS - FOCUS ON COASTAL EROSION

Sri Lanka being a tropical island is endowed with a wide variety of coastal environments and resources that extend along a coastline of 1920 km, including that of her off-shore islands. Five out of the nine provinces of the island share the coastline while the other four are land-locked without access to the sea.

The coastal areas of Sri Lanka, are of great social and economic significance. Over one third of the population and two thirds of the urban areas are located in the coastal region. Coastal areas also account for nearly 80 per cent of the tourism related infra-structure and for two thirds of the country's industrial production (Fig. 4). As the economy grows, with greater emphasis on tourism and industrial development and the migration of people to urban and industrial areas, the coastal belt will assume increasing importance in the future.

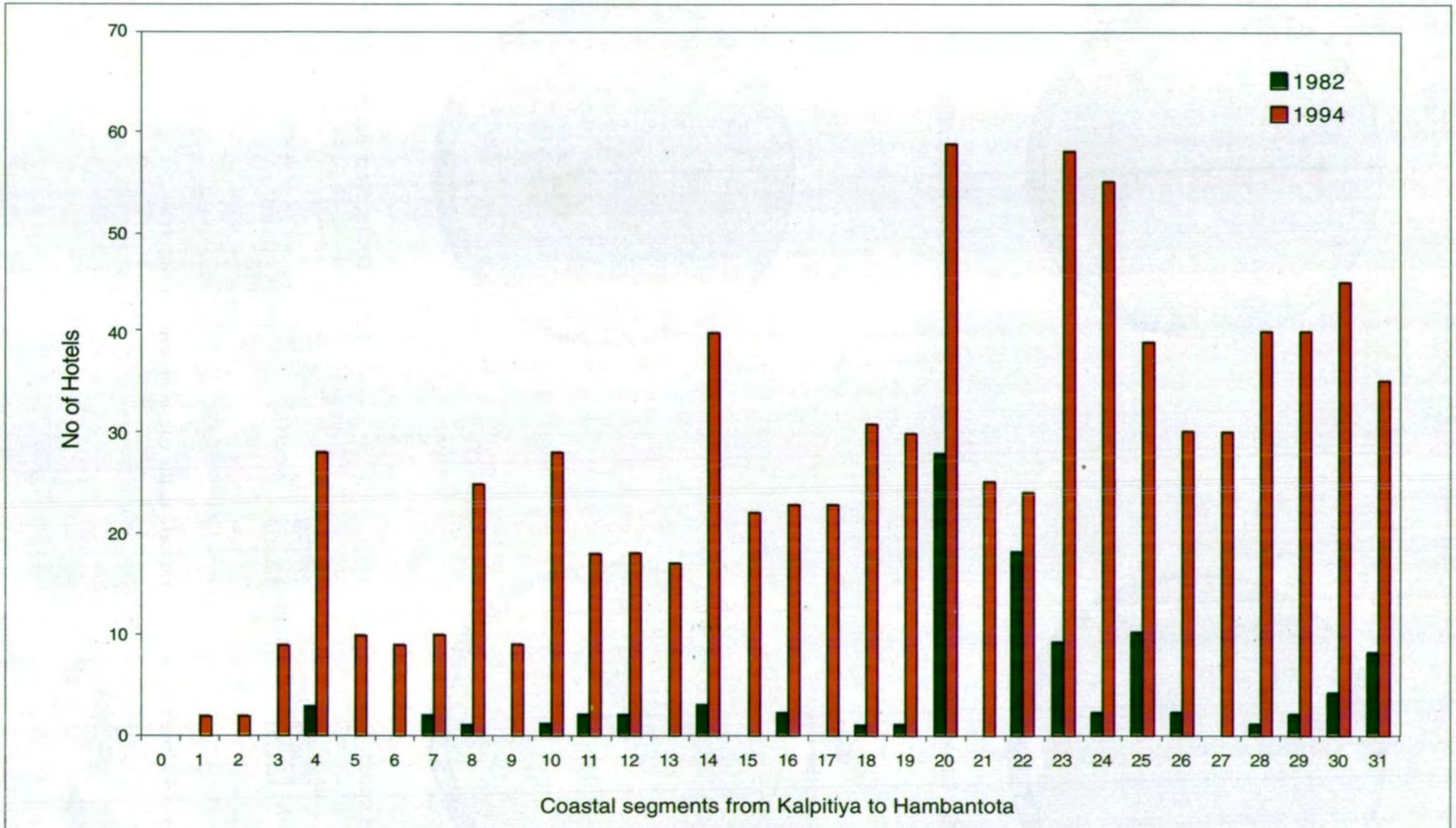
The recession and development of shorelines is observable in many locations around the island. Although some of them are of a seasonal nature, others indicate long term trends. On the basis of available information which is more qualitative than quantitative, it was estimated that the average annual recession of the shoreline of Sri Lanka is in the order of 1.1 m while the rate of coastal development was reckoned at around 0.51 m (Madduma Bandara, 1989 c, 1991).

Coastal erosion is caused by an imbalance in the sediment budget of the beach. The long term coastal stability depends on the overall sediment supply from the rivers and sand transport from long shore currents. The nature of the coastline depends on the sediment sources and sinks as well as the forces that move the sediments. These forces are waves, currents and winds. Waves and currents move sediments along the shore and offshore. Winds move sediments across the beach to form dunes. In addition to natural causes, human activities such as mining beach and river sands aggravate problems of erosion.

Coastal erosion in Sri Lanka is not unusual in comparison with world trends as indicated by Figure 5. Coastal erosion shows both temporal and spatial variability. It is greatest when monsoons are onshore. The southwest monsoon expends much of its energy on the southwest coast, where the density of population and of coastal structures are high. Around Ambalangoda and Hikkaduwa long shore drift moves both northwards and southwards, creating a region of maximum potential erosion. In this area the historical evidence suggests that much land has been lost to the sea as seen around Seenigama *devale* which formed part of the mainland 50-60 years ago but is now located on an islet several hundred metres off-shore. The main highway to the south is also under constant threat from high waves and long time residents report that two Galle roads have been lost to the sea in the past, along with many coconut lands. Along the coastal segment extending 685 km from Kalpitiya to Kirinda, some 175 000 – 285 000 m^2 of coastal lands are lost annually through erosion. Of this nearly half is lost from the area from Kelani Ganga outfall to Talawila in the Kalpitiya Peninsula. The historical changes that have taken place in the Crow islands area (Fig 6) at the mouth of Kelani Ganga have been documented (Madduma Bandara, 1989c).

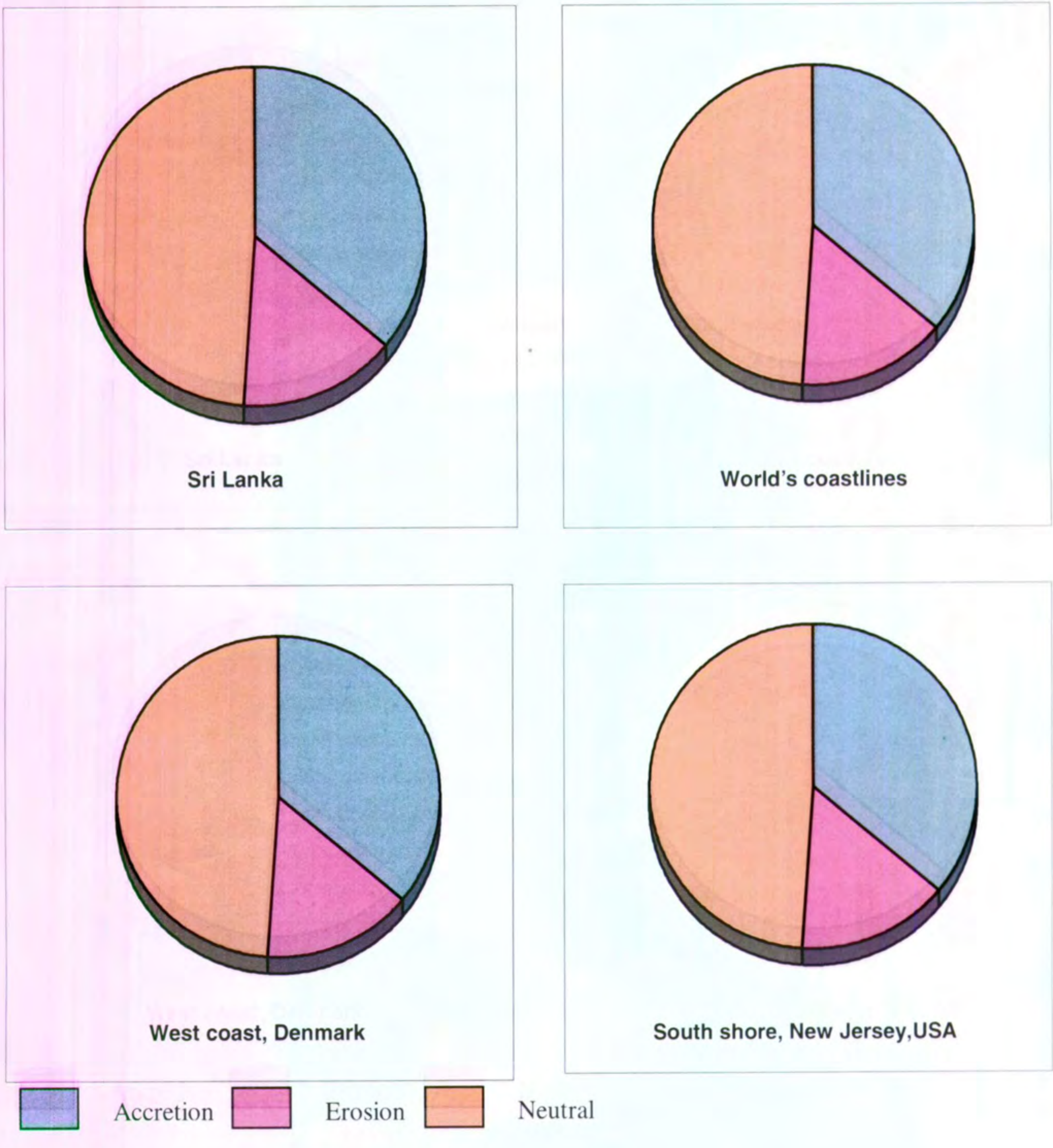
The construction of coastal protection structures such as groynes, revetments, stone walls, and off-shore break waters have been undertaken during the last few decades. However, these 'hard solutions' have proved inadequate and have even produced negative results in some places. Therefore, 'soft solutions' including legal and administrative measures aimed at the protection of barrier reefs, restrictions on building construction on the beach-front, coral extraction and sand mining need to be adopted. Some biological approaches such as the establishment of beach forests, were also tried out to improve beach stability, as for example at Weligama. Some new approaches, such as 'beach nourishment' under which sand has been replenished from off-shore sources, have also been tried out as for example in the case of beaches to the north of Negambo. Another school of thought advises that the coastal zone should remain a conservation zone, in which heavy investments should be discouraged, in the future.

While there has been much interest in the problems of coastal erosion, comparatively little attention has been focussed on adverse issues relating to coastal accretion. These include



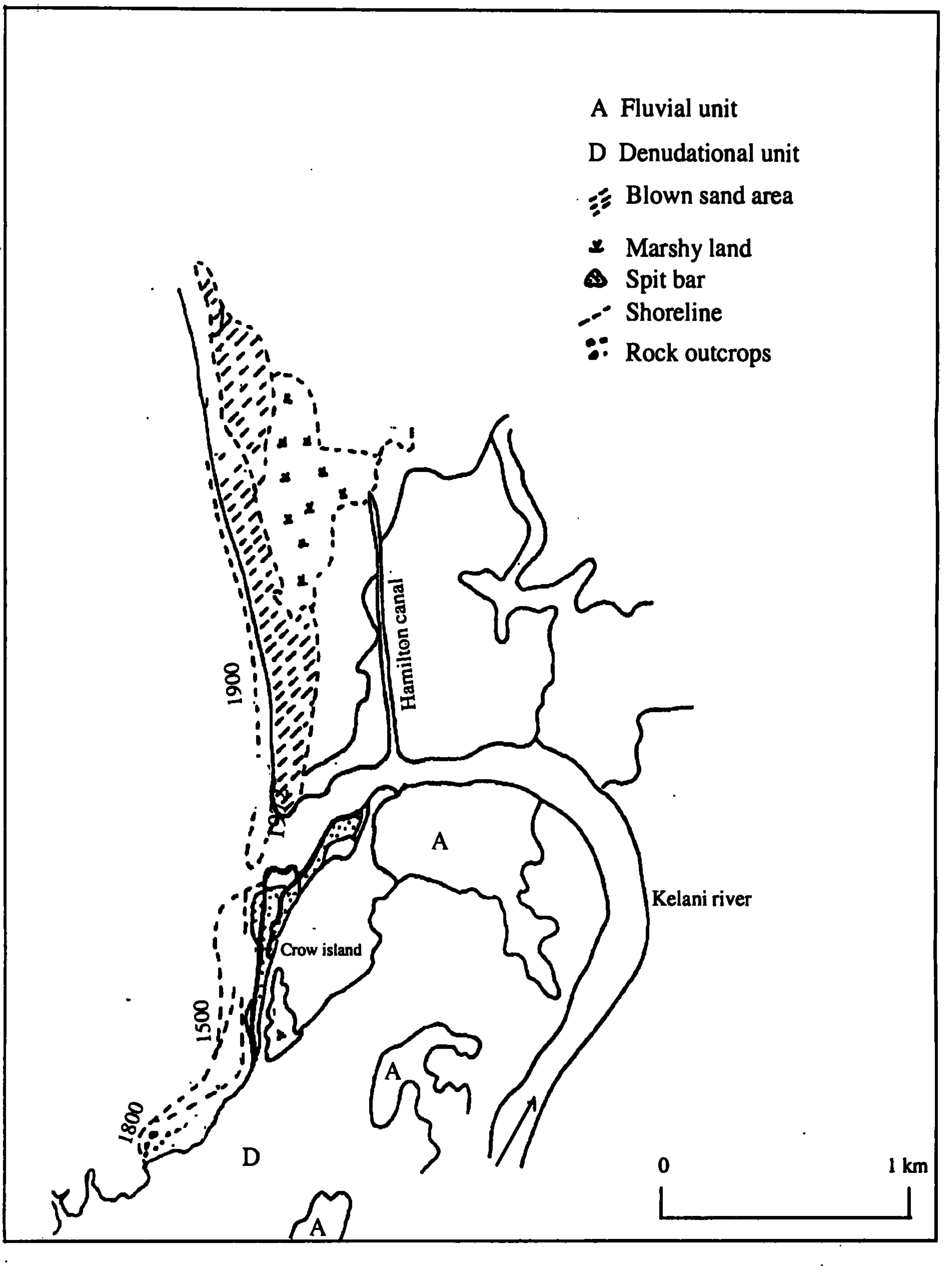
Source: **Madduma Bandara and Wickramagamage (1996).**

Figure 4: Tourist hotels on the west coast of Sri Lanka



Source : Sri Lanka Master Plan for Coast Erosion Management (1986).

Figure 5 : Erosion and accretion along the coasts of selected countries



Source: Madduma Bandara (1985).

Figure 6 : Shoreline changes at Crow Island reconstructed from historical maps and aerial photographs

siltation of harbours (Colombo as well as several fishery harbours such as Kirinda), the obstruction of river mouths affecting the outflow of flood waters (Kalu Ganga and Maha Oya), siltation of lagoons (Negombo and Chilaw) and obstruction to navigation along coastal canals. Many poorly planned efforts to open the accretional sand bars to release flood water have resulted in accelerated erosion at Kalutara north, or in problems of salinization as witnessed at Tangalu *wel yaya* fed by Kirama Oya in the south. Similarly, it had been claimed that ecological disturbances that followed the construction of Hamilton Canal for navigation between Colombo and Negombo led to the abandonment of Muthurajawela, a flourishing rice field of the past due to increased salinity.

POLICIES AND INSTITUTIONAL RESPONSES

Underlying Sri Lanka's current land use and management practices are a multitude of policies and laws evolved historically, particularly since the colonial period. The Crown Lands Encroachment Ordinance of 1840, which brought over 85 per cent of the total land area of the country under the state, is a critical land mark in the evolution of land policy. Since then legislative enactments such as the Waste Lands Ordinance of 1897, Land Development Ordinance of 1935, Crown Lands Ordinance of 1947, Paddy Lands Act of 1957, the Land Reform Laws of the 1970s, and the establishment of the Provincial Councils in the 1980s, affected the tenure, administration and management of land in Sri Lanka in significant ways.

The tenure of privately owned lands, though limited in area compared with state lands but carrying higher land values, is governed by at least four types of customary and other laws. These are the traditional Kandyan law affecting the Sinhalese in the up country areas, the *tesawalamai* affecting the Tamils of the Jaffna Peninsula, the Muslim Koranic Law and the Roman Dutch Law which was introduced during the colonial period. Thus despite its small size, the ethnic diversity of the population has led to the development of a complexity of tenurial practices in the island.

State ownership has remained at around 80 per cent of the total land area – significantly higher than in most European and other Asian countries. Yet nearly 1.5 million hectares have come under near private ownership under the provisions of the Land Development Ordinance of 1935 and its subsequent amendments. Today, nearly one third of all Sri Lankans live on land alienated by the state. With the completion of the Mahaweli project and the land alienation programme under the Presidential Task Force, this has increased further. On the other hand, through the land reform laws of the 1970s, the state acquired ownership of more lands largely in the plantations but also in other sectors, due to the imposition of ceilings on private land ownership.

Land policy in the country has been examined periodically by Land Commissions since 1927, the year in which the first Land Commission was established. The Second Land Commission came in 1955 and the third was established in 1985. The third Land Commission listed some 39 pieces of legislation operational at the time of its establishment in 1985 (Table 5).

In addition to the above operational laws, there are many other legislative enactments which have either a direct or an indirect bearing on the management of both private and state lands. Since 1985 several new pieces of legislation have been introduced, while almost all the laws listed in Table 5 continued to be in operation. In view of the multiplicity and the complexity of land laws referred to above, attention is focussed here on a few major enactments which have enduring impacts on society.

LAND DEVELOPMENT ORDINANCE

The Land Development Ordinance (LDO) introduced in 1935 on the recommendations of the first Land Commission was described as the *magna carta* of the peasantry (Brohier, 1956). It has been stated that, during the period of the State Council, LDO contributed more to the progress of Sri Lanka than any other single law, with the exception of the Free Education Ordinance of 1944. Over one million hectares of state land have been passed on to the peasantry under this Ordinance since its enactment in 1931. The

Ordinance constituted a reversal of the early colonial land policy (Farmer, 1957).

now, this has not been fully realized despite attempts made through *'swarnabhoomi'* and *'jayabhoomi'* programmes which have made the title closer to a freehold status. It has been contended that the continued restrictions on the tenure of lands can have a negative effect on land development, since the land cannot be used as a collateral security in raising loans. It also depresses the value of the land in the market compared with lands with full freehold tenure. On the other hand restrictions were considered necessary to

Table 5: Operational land laws (1985)

1	Encroachments Upon Crown Lands Ordinance (1840)
2	Definition of Boundaries Ordinance (1844)
3	Service 'Praveni' Lands Ordinance (1852)
4	Registration of Temple Lands Ordinance (1856)
5	Land Surveys Ordinance (1866)
6	Service Tenures Ordinance (1870)
7	Prescriptions Ordinance (1871)
8	Land Resumption Ordinance (1887)
9	Forest Ordinance (1907)
10	Plant Protection Ordinance (1924)
11	Flood Protection Ordinance (1924)
12	Tea Research Ordinance (1925)
13	Coconut Research Ordinance (1925)
14	Rubber Research Ordinance (1930)
15	Crown Land Marks Ordinance (1930)
16	Crown Lands (Claims) Ordinance (1931)
17	Land Settlement Ordinance (1931)
18	Land Development Ordinance (1935)
19	Fauna and Flora Protection Ordinance (1937)
20	Temple Land (Compensation) Ordinance (1944)
21	Irrigation Ordinance (1946)
22	Crown Lands Ordinance (1947)
23	Tea Control Act (1949)
24	Land Acquisition Act (1950)
25	Requisitioning of Lands Act (1950)
26	Soil Conservation Act (1951)
27	Rubber Replanting (Subsidy) Act (1953)
28	Wood Protection (Estates) Act (1954)
29	Rubber Control Act (1956)
30	Tea and Rubber Lands Fragmentation Act (1958)
31	Colombo District (Low Lying Areas) Reclamation and Development Board Act (1968)
32	Land Reform Law No.1 (1972)
33	Urban Development Authority Act (1978)
34	State Lands (Recover of Possession) Act (1979)
35	Land Grants (Special Provision) Act (1979)
36	Agrarian Services Act (1979)
37	National Housing Development Authority Act (1979)
38	Mahaweli Authority Act (1979)
39	Coast Conservation Act (1981)

Source : Land Commission, 1985.

The LDO was not only meant for alienation of state lands but also for their development to full capacity to increase national wealth. This was anticipated through the 'mapping out' procedure as provided for in the Ordinance and by continuous monitoring through land administration. The original intention of the architects of the Ordinance was to pass the full ownership of the allotment to the farmer, once the land is fully developed. Up to discourage improvident alienation and excessive fragmentation.

Coast Conservation Act

Development activities in the coastal areas of Sri Lanka have lacked proper planning and management for many decades. As the intensity of activities in the coastal zone increased, a variety of environmental and social problems have emerged. The usual response was a curative and fire-brigade kind of approach, where solutions were sought only when a problem emerged. It was also largely a technical and engineering approach where 'hard solutions' were applied without a comprehensive understanding of all factors involved.

The government having recognized the need for a comprehensive and integrated form of coastal zone management responded by enacting the Coast Conservation Act of 1981. The key elements of the Act included the requirement for the Coast Conservation Department to develop a Coastal Zone Management Plan to regulate and control development activities of the coastal zone and to design and implement coast conservation projects. For purposes of the Act, the 'Coastal Zone' was defined as covering the belt of land extending 300 m from the high water mark (landwards), 2 km landwards along water ways opening into the sea and 2 km seawards from the low water mark. The need for modification of this definition was felt after several years of experience in coastal zone management.

The Coastal Zone Management Plan as approved in 1990, recognized the need for decentralizing management responsibilities to the local authorities. This was followed in 1992 by the publication of *Coastal 2000: Recommendations for a Resource Management Strategy for Sri Lanka's Coastal Region* which advocated a policy of achieving 'effective and participatory resource management by governmental and non-governmental agencies'. A revised *Coastal Zone Management Plan* was introduced in 1996 endorsing the Special Area Management approach as a means to increase community participation in management.

Soil Conservation Act

The Soil Conservation Act which was introduced in 1951, *inter alia* provided for : (a) the declaration of erodible areas by the minister; (b) surveys in relation to erosion problems and conservation needs; (c) framing of land use and soil conservation regulations; (d) acquisition of lands and imposition of penalties.

The implementation of the Soil Conservation Act was entrusted to the Soil Conservation Division of the Department of Agriculture. However, it took over 10 years to gazette the necessary regulations. The Land Commission in 1986 traced the 'rise and fall' of that Soil Conservation Division. In the early 1970s, it was decided by the relevant ministry that, soil conservation work should be handled by the extension staff in the districts, in addition to their usual functions. In pursuance of this decision, the trained staff of the Soil Conservation Division were transferred out, with no replacements. Proposals made to strengthen this division never materialized eventually. The division ceased to exist as a separate unit. In the meantime problems of soil erosion grew and accumulated and assumed serious proportions. Recently, there was an effort made by the Department of Agriculture and concerned agencies to introduce new soil conservation legislation covering soil and water, as well as land use. After many years now, the draft legislation has gone through the parliamentary process. Subsequently, in 1996 certain amendments to the Soil Conservation Act were effected. The amendments provided for the establishment of a Soil Conservation Board and a Soil Conservation Fund while covering several aspects of land degradation including soil erosion, damage by floods, stream bank erosion, salinity, alkalinity and water logging. Now the soil Conservation Board is in the process of formulating regulations under the amended Act.

Table 6 : Land alienation programme 1989 - 1994

Province	Identified ha	%	Agriculture ha	%	Housing ha	%	Alienated ha	%
Northcentral	115 518	40	32 570	32	10 208	52	42 778	35
Uva	45 140	16	11 262	11	827	04	12 089	10
Northwestern	34 911	12	27 857	27	1 232	06	29 089	24
Southern	28 520	10	10 365	10	1 809	09	12 174	10
Eastern	26 476	09	3 559	03	771	04	4 330	04
Sabaragamuwa	13 101	05	6 730	07	1 626	08	8 356	07
Central	12 704	04	6 213	06	303	02	6 516	05
Northern	8 524	03	2 459	02	1 091	06	3 550	03
Western	2 762	01	531	01	1 582	08	2 113	02
Sri Lanka	287 656	100	101 546	100	19 449	100	120 995	100

Source : Report of the Presidential Task Force on Land Alienation.

One of the major shortcomings in soil conservation legislation has been the lack of provisions to integrate the implementation of soil conservation measures on a watershed basis. Implementation of conservation measures on isolated farming units is ineffective. Recognizing this need, the Land Commission (1986) recommended the establishment of a 'Watershed Management Authority'. Yet, after nearly fifteen years nothing significant appears to have happened in this direction. Further, even the recent amendments to the Soil Conservation Act too have failed to provide for the drainage basin perspective in soil conservation.

The institutional set-up introduced by the recent amendments appear highly bureaucratic, requiring many high level officials such as ministry secretaries to sit on the Soil Conservation Board. These busy officials, based in Colombo cannot really devote sufficient time and energy to largely rural problems such as soil erosion. Further there is hardly any provision to involve the private sector, particularly the plantation management sector which needs to play a critical role in soil conservation. The membership of the Secretary, Plantation Industries on the Board does not satisfy this need. In its present form, the Soil Conservation Board may eventually become another forum of bureaucrats which cannot address, seriously, the highly technical problems of soil degradation.

PRESIDENTIAL TASK FORCE ON LAND ALIENATION

In view of the findings of the Land Commission (1987) that a large extent of developable land is lying idle, and in the light of the many problems of landlessness that surfaced at a Presidential Mobile Service held at Matara, a Presidential Task Force was set up in 1989, to alienate available state land on a scale never attempted before. Under this programme a large extent of available state land had been identified in all provinces, with the assistance of the divisional secretaries and the Survey Department. Some data on identification, classification and alienation of these lands is given in Table 6.

As could be seen in Table 6 the largest extent of available land was in the dry zone areas. More than half of the identified land was in the northcentral and uva provinces. A large proportion of the land alienated, was degraded either due to *chena* cultivation or due to encroachments. Most of them were also of a marginal nature, lacking in easy access to water or located on poor soils and eroded slopes. This was despite the fact that, certain environmental guidelines, such as the avoidance of steep slopes, and stream and reservoir reservations were adopted in the identification of available lands. The allottees of these lands were poor and landless families, who had little resources to develop the land given to them. Therefore, much of the programme turned out to be a mere exercise in encroachment regularization and giving over poor lands to poor people. The task of increasing the productivity of these lands proved to be a difficult one for the agricultural authorities and little has been achieved. The only significant achievement of this programme was the alienation of a large extent of land within a short period of time. Here too, it was confined largely to the lands in the dry and intermediate zones where land hunger is less acute, while having little effect in the hill country where it is a major problem.

REFERENCES

1. Annual Reports, Various Issues, Central Bank of Sri Lanka, Colombo.

2. Brohier R.L. (1956) D.S. Senanayake as Minister of Agriculture and Lands. *Ceylon Historical Journal*, Special Issue (Nos.1-4) **68**, pp 81.

3. Censuses of Agriculture (1946, 1962, and 1982) *General Reports*. The Department of Census and Statistics, Colombo.

4. Coastal Zone Management Plan (1996) and its Revision. Coast Conservation Department, Colombo.

5. Coast Conservation Department (1992) Coastal 2000: Recommendations for a resource management strategy for Sri Lanka. (Volumes I & II), Colombo.

6. Crown Lands Encroachment Ordinance (1840) and its subsequent amendments. Govt. Press, Colombo.

7. De Silva K.M. (1981) *A History of Sri Lanka*, Oxford University Press.

8. Dharmasena P.B. (1991) Present use of land and water resources in village tank farming. *Journal of the Soil Science Society of Sri Lanka*, pp 7-17.

9. Farmer B.H. (1957) *Pioneer peasant colonization in Ceylon*. Oxford University Press.

10. Land Commission (1990) Final Report, Sessional Paper No.III, and the Interim Reports of 1985 and 1987. Govt. Press.

11. Land Reform Law (1972 and 1975), Department of Government Printing, Colombo.

12. Madduma Bandara C.M. (1982) Effect of drought on the livelihood of peasant families in the dry zone of Sri Lanka. In: *Climate, water and agriculture in Sri Lanka* (Ed. M. Yoshino) University of Tsukuba, Japan.

13. Madduma Bandara C.M. (1985) *Coastal changes of crow Island and its environs*, Coast Conservation Department, Colombo.

14. Madduma Bandara C.M. & Kuruppuarachchi T.A. (1988) *Land use change and hydrological trends in the Upper Mahaweli Basin of Sri Lanka, Symposium on the Hydrology of Natural and Man-made Forests*, GTZ, Kandy. (Republished in Report of Special Research Project on Global Environmental Change (1994) University of Tsukuba, Japan. **1**: pp 116-131.

15. Madduma Bandara C.M. (1989 a) *A Survey of the Coastal Zone of Sri Lanka*. Coast Conservation Department, Colombo.

16. Madduma Bandara C.M. (1989 b) Recent natural disasters – Wrath of Gods or responsibility of Men. *Economic Review*; Peoples Bank, **2**: pp 1-5.

17. Madduma Bandara C.M. (1989 c) *Coastal changes of Crow Island and its environs*. Coast Conservation Department, Colombo.

18. Madduma Bandara C.M. (1991) *Case studies of shoreline trends in the west coast*, Seminar on Causes of Coastal Erosion in Sri Lanka, CCD/GTZ Coast Conservation Project, Colombo.

19. Madduma Bandara C.M. (1993) Land Policy and Landscape Management in Sri Lanka. In: *Ecology and Landscape Management in Sri Lanka*. (Eds. W. Erdlen *et.al.*) Margraf Scientific Books, Germany.

20. Madduma Bandara C.M. & Wickrema Gamage P. (1996) *Land use changes in the southwest coast*. Coast Conservation Department, Colombo (unpublished).

21. National Building Research Organization (NBRO)(1994) *National Symposium on Landslides in Sri Lanka*, Ministry of Housing Construction and Urban Development, Colombo.

22. Peiris G.H. (1996) *Development and Change in Sri Lanka*, ICES Kandy; MacMillan India Ltd. Delhi.

23. Sessional Paper III (1931) Report of the Committee on Soil Erosion, Government of Ceylon, Government Press, Colombo.

24. Soil Conservation Act (1951) Government Press, Colombo.

25. Somasekaram T. (1996) *Facts about our land*. Arjuna Consulting Co. (Ltd). Dehiwala.

26. Stocking M.A. (1986) Land use planning Phase II: Sri Lanka, *Consultant Report on Soil conservation in land use planning*. UNDP/FAO Project SRL/84/032, Colombo.

27. Water Resources Board (1968) *A survey of water resources utilization and cultivation habits and practices of the NCP Peasant Cultivator in the Toruwe Tulane of the Anuradhapura District*, Government Press, Colombo.

28. Water Resources Board (1969) *Land use of stream reservations in Kumbalwela Korale*, Baddula District, Government Press, Colombo.

Courtesy: The Island.

Parakrama Samudraya

WATER RESOURCES OF SRI LANKA

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Summary

Compared with most other countries of the world, Sri Lanka is richly endowed in water resources. Rainfall that forms the source of all our water resources is high, by any standards, since on average the island receives an annual rainfall of nearly 2000 mm. However, it is highly seasonal and, unevenly distributed geographically. It is this variability in space and time that creates many challenges, as well as, opportunities regarding the utilization of water resources. Extreme weather conditions often lead to droughts and floods, which often inflict heavy damage to life and property. The government incurs heavy expenditure on relief measures.

The highest state investment has been on the development of water resources for irrigation, hydro-power generation and domestic and industrial water supply. The annual resource allocation to the water supply sector rose from nearly Rs. 0.8 billion in 1981 to almost 4 billion in 1996. The cumulative capital investment for the Mahaweli Project alone came close to Rs. 75 billion. In the energy sector, it has been estimated that Ceylon Electricity Board may need over Rs. 100 billion to meet the additional installed capacity in the future, of which hydropower accounts for the greater proportion. In a country where so much has been invested for water related development, it is imperative that greater efforts be devoted to the conservation and efficient management of water resources.

INTRODUCTION

Sri Lanka, despite her small size with a land area of only 65 525 km^2, is richly endowed in water resources. On average, the island receives an annual rainfall of nearly 2000 mm, primarily from the monsoons. The climate of Sri Lanka has no seasonal pattern similar to those in temperate zones. However, the rainfall pattern is seasonal and rainfall is unevenly distributed geographically. This varied spatial and temporal distribution pattern creates certain problems regarding the utilization of water resources. Furthermore, extreme weather conditions often lead to droughts and floods. These take a heavy toll on life and property and cause considerable expenditure by the government (Madduma Bandara, 1989) for relief and rehabilitation.

Since Independence in 1948, the highest level of state investment has been on the development of water resources for irrigation, hydropower generation and domestic and industrial water supply. The cumulative capital investment for the Mahaweli Project alone over the period 1971-1996 stood at Rs.73 billion (Central Bank, 1999). A total of about half a million hectares of paddy land has been provided with irrigation facilities by 1997, under major as well as minor, irrigation schemes. The resource allocation to the water supply sector rose from Rs.795 million in 1981 to Rs.3697 million in 1996. In the power and energy sector the Ceylon Electricity Board (CEB) alone has fixed assets worth about Rs.107 billion and much of this is in the hydropower development sector. For the future, it has been estimated that CEB may need US $ 1500 million (over Rs. 100 billion) to meet additional installed capacity of which hydropower accounts for the greater proportion. In the context of water related development, with such heavy investment, conservation and efficiency of water management is a prime imperative today.

HISTORICAL CONTEXT

Sri Lanka had the unique distinction of having developed a *hydraulic civilization* even before the beginning of the Christian Era (Leach, 1959). According to Brohier (1935), records of that time show that Sri Lankan engineers were called upon even to help solve hydraulic problems of neighbouring countries. Some hydraulic structures have survived to this day. These include long canals with imperceptible gradients, (Fig.2) *bisokotuwas* (valve-pits), *ralapanawas* (wave-breakers) and *cascades of village tank systems* (Madduma Bandara, 1985). They bear ample testimony to the high achievements in irrigation technology and management during the period of our hydraulic civilization. The water-sealed toilet systems (in Anuradhapura and Polonnaruwa), and ornamental fountains in exquisite landscape gardens at Sigiriya indicate high levels of skills in the management of urban water supply and waste disposal systems (Fig. 1).

The reasons that led to the collapse of this ancient hydraulic civilization around the 12th Century AD, are unclear. Climate change, malaria, impoverishment of soil, foreign invasions and famine are some of the reasons thought to have contributed to the collapse. Paranavitana, the veteran archaeologist and historian of Sri Lanka, believed that the breakdown of the efficient management of the irrigation systems was due to invasions from South India. As a result of these invasions the skills of the *kulinas* – the nobility who were water resource experts, was lost. These water experts had their own standards and insignia as reflected for instance by the symbol of the multi-hooded cobra, found at the sites of major ancient water works (Fig.3). Others attributed the decline to a *push and pull* process that attracted the people to wetter areas while there was a pull away from the dry zone.

Whatever the reasons may be for the collapse of the *hydraulic civilization*, the experience of its development and decay brings out several important historical features. One of these is that the development of ancient hydraulic systems was rooted in some indigenous scientific knowledge and wisdom which grew over the centuries through trial and error, experience and external inputs.

Courtesy: Geological Survey and Mines Bureau.

Figure 1: Landscape gardens at Sigiriya

Although it is likely that this knowledge would have passed down from generation to generation by word of mouth, at least some elements of it would have been recorded in inscriptions, copper plates or *ola* (palm) leaf. It appears that much of this ancient knowledge could have been destroyed or lost along with the collapse of the civilization itself. However, it is possible that, at least, a small proportion of this documentation may exist unknown in homes, temples and other places. Much of the knowledge carried by the water resources nobility was usually passed by word of mouth. A certain element of *guru musti* (secrets of craftsmen) disappeared when this group of nobility died out. Those who survived gradually went into oblivion and jungle took over the land. It is possible perhaps, that, *wannihuru*[1] *or wanniars* of the northcentral regions constitute this residual element of ancient water resources expertise (Madduma Bandara, 1985). After the collapse of the major irrigation works, *wannihuru* continued to live in the *purana* villages which were fed by the old village tanks organized into *cascading* systems that supported sustainable land use practices (Fig 4). It is obvious from this brief historical sketch that, the management of water resources during ancient times remains an area of research which is still largely unchartered.[2]

The colonial period which began in the early 16th century with the occupation of the maritime provinces by the Portuguese, and subsequently by the Dutch created a new interest in the development of water resources in the coastal areas while traditional practices continued in the interior. In the hill country where the rule of Sri Lankan Kings continued, the traditional irrigation systems that developed in the dry zone plains underwent certain interesting transformations. At first, the movement of capital cities and centres of population from the dry zone to the intermediate climatic zone led to the development of smaller tank systems suited to conditions and water shortage of shorter dry periods. Thus the highest densities of old *(purana)* village tanks are found in the interior of the northwest and in the south and southeast.

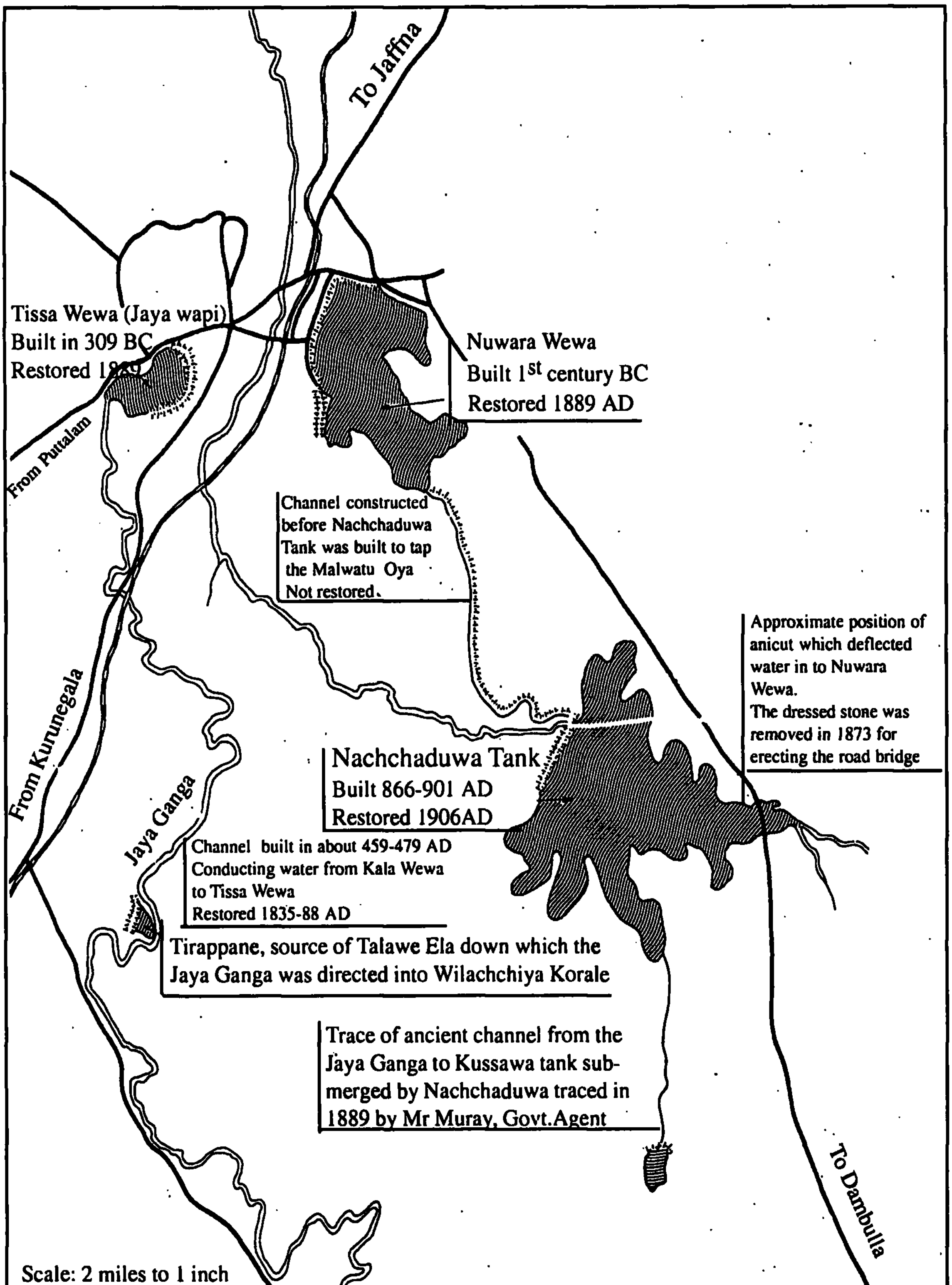
A different form of hydraulic civilization developed in the hill country where hills and their slopes were used as 'store houses' of water in place of village tanks. The canal systems that were constructed around the hills collected both ground and surface waters and conveyed them to the rice fields located in the *deniyas* (alluvial valley bottoms). They did not disappear altogether. They remain in places like Ambagamuwa (near Nawalapitiya) that are located in the highest rainfall belt in the country. Many canal systems fed by hill forests as well as by Kandyan Forest Gardens (KFG) also protected the villages from landslides (Madduma Bandara, 1994). The implications of such changing land use on hydrology and slope stability in the hill country particularly after the advent of plantation agriculture is an area which needs further research.

During the Portuguese and Dutch periods the focus of water resources development activity was on the coastal belt which each occupied, in turn, for approximately 150 years. Here the flood protection works and canal systems for navigation would have required some feasibility studies of a scientific nature. Some ecological implications become evident, subsequently, as in the case of the transformation of Muthurajawela formerly a flourishing rice field. Studies of the Portuguese and Dutch periods are important as baselines, since they represent the first attempts at bringing the western scientific knowledge into the field of water related development activities in Sri Lanka.

During the British period, particularly after the conquest of the kingdom of Kandy, the attention of the rulers shifted to the hill country, where they promoted plantation agriculture. In the latter stages of the British rule, interest in renovating ancient irrigation works particularly in the dry zone was initiated. Governors such as Henry Ward (1856) and Gregory took initiatives in this regard. Le Mersieur in his *Manual of the Nuwara Eliya Distrct* stressed the need for protection and maintenance of the intricate canal systems in the drier areas of the hill country. These initiatives marked the beginning of interest in water resources development during the British period culminating in the establishment of the Irrigation Department at the turn of the century. The

[1] The word "vanni" is usually taken to denote, a forest or a forested area; It can also be taken as "vanhi" or flowing substance as in the case of the origin of the term "vana" or the spill-way.

[2] Most of the writings on the collapse of the hydraulic civilization are in the form of descriptive writings by the historians and archaeologists. However, ancient irrigation works have attracted the attention of surveyors (such as R.L. Brohier) and more recently of engineers (such as D.L.O. Mendis).

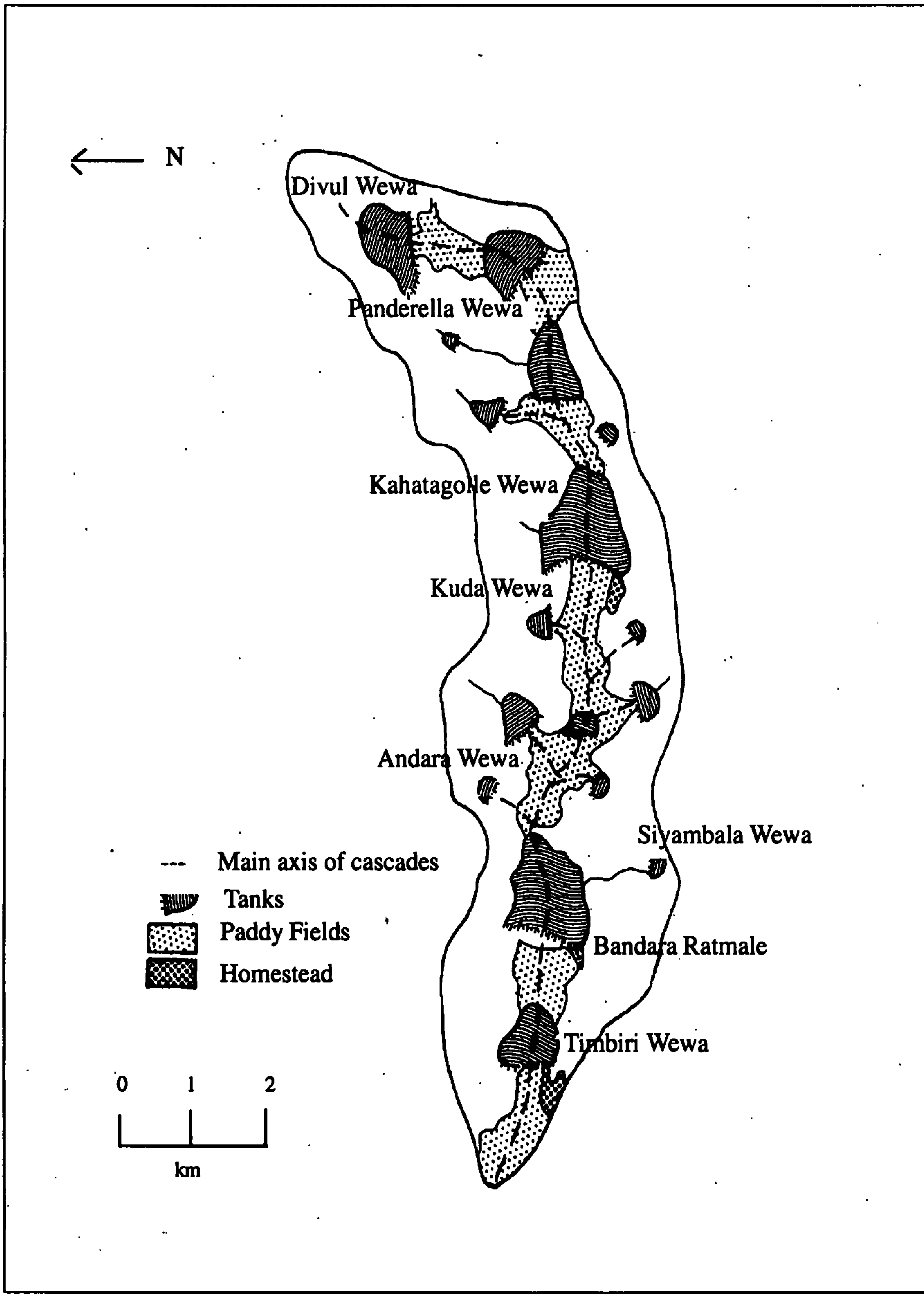


Source : Brohier R.L. (1935) Ancient Irrigation Works of Ceylon. Govt. Press.Colombo.

Figure 2 : The Ancient canal systems

Source : Sharma Prem N (Ed) 1999.

Figure 3: Multi-hooded cobra



Source: Madduma Bandara C.M. (1985).

Figure 4: Cascades of village tanks

Irrigation Department has remained in the forefront of water resources development since its inception and has contributed considerably to the development of water resources, as well as, to the expertise in the field. The Department of Agriculture, too, was established during the British period and contributed to water resource management in a different way, with contributions to the understanding of crop-water relationships. These two departments are the main repositories, today, of knowledge and expertise on water resources of Sri Lanka.

At the same time, adverse impacts of indiscriminate clearing of montane forests for plantation agriculture began to manifest themselves and gradually increased in importance. The need for conservation of land at heights above 1500 m and the high rate of soil erosion observed elsewhere, led to several studies, primarily through committees and commissions, appointed by the colonial government, from time to time. The Committee on Soil Conservation appointed in 1931 is a good example. This process was facilitated also through the Executive Committee system of the State Council, during the years before independence. The appointment of the Land Commission of 1927 and the introduction of the Land Development Ordinance of 1935, under the able guidance of Hon. D.S. Senanayake, then Minister of Agriculture and Lands, gave a much needed fillip to irrigation and water resources development (Senanayake 1935). Food shortages experienced during the period of World War II gave an impetus for the promotion of irrigation schemes, even in the hill country.

NATURAL SETTING AND WATER RESOURCE BASE

The location of the island between 6° and 10° N latitude in the Indian Ocean gives it a monsoon dominated weather pattern and a tropical climate. Lying in the northern half of the Indian Ocean, Sri Lanka is exposed to moisture laden winds from both the southwest and northeast. The northsouth spread of the land mass with its southcentral mountain massif and lying astride the path of these monsoon winds are overriding geographical determinants of patterns of rainfall and distribution. The result is the creation of a high rainfall area in the southwest (wet zone) and a more extensive relatively dry region (dry zone) in the north and east (Fig 5).

The southcentral massif rising to 2500 m above sea level, forms the hub or source from which many streams and river systems flow in a radial drainage pattern (Fig. 6). In all, there are 103 distinct natural river basins (Table 1) that cover over 90 per cent of the area of the island. The remaining area falls within 94 small coastal basins (Arumugam, 1969). The river basins originating in the wetter parts of the hill country are perennial, while many of those in the dry zone are seasonal. Only a few large river basins, such as the Mahaweli Ganga, which drains 16 per cent of the island, carry water from the wet zone to the dry zone.

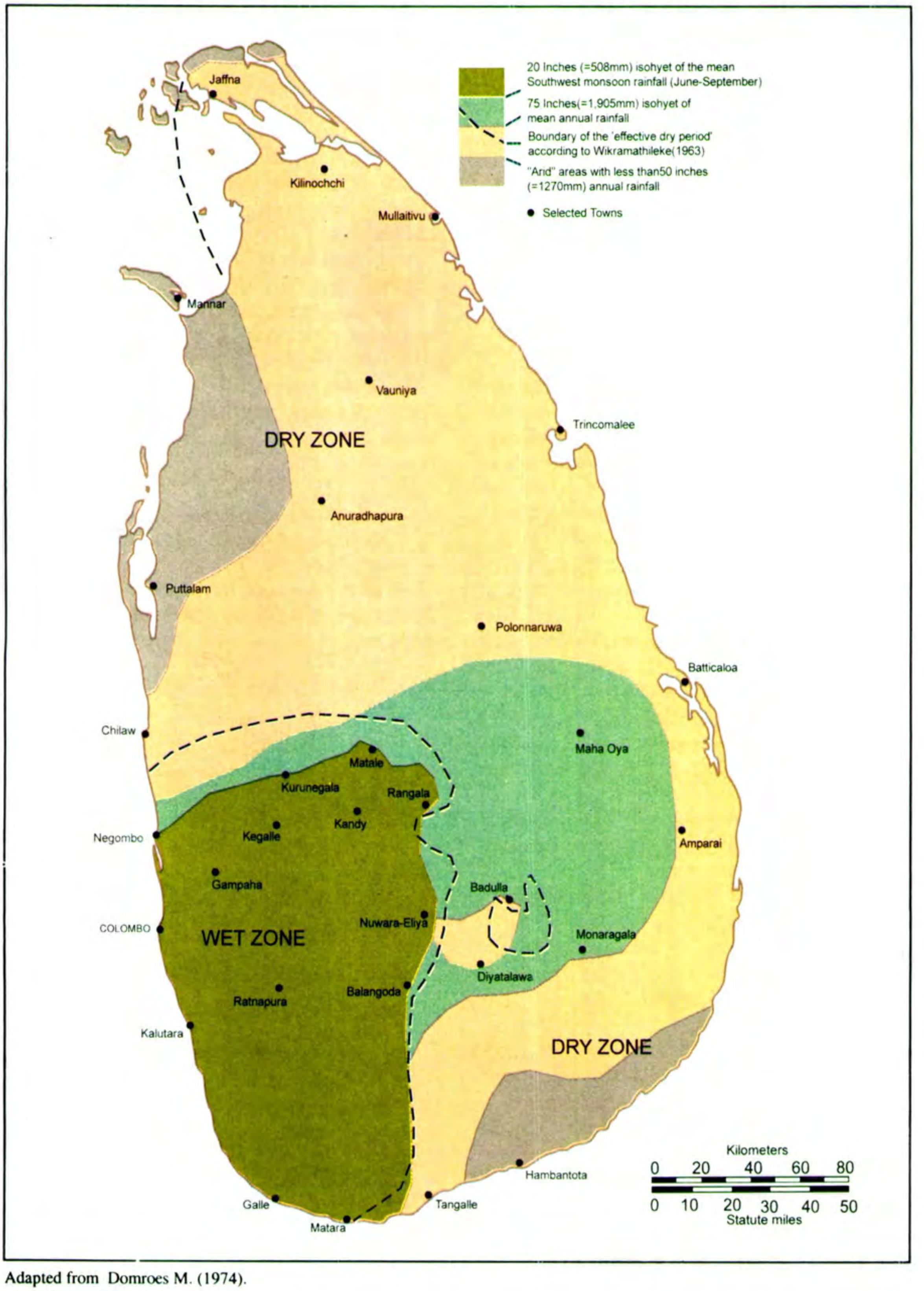
Geologically, Sri Lanka is predominantly a hard, metamorphic, crystalline land mass except in a limited area in the north and northwest. Geological formations that determine Sri Lanka's aquifer systems fall broadly into the following categories:

- Ancient crystalline hard rocks that spread over 90 per cent of the land area. These Precambrian rocks have poor primary porosities and ground water in them is often found in their joints and fissures. (Witanage, 1958; Cooray, 1967; Basnayake, 1985).

- Sedimentary formations that mainly include Miocene limestone areas of the north and northwest.

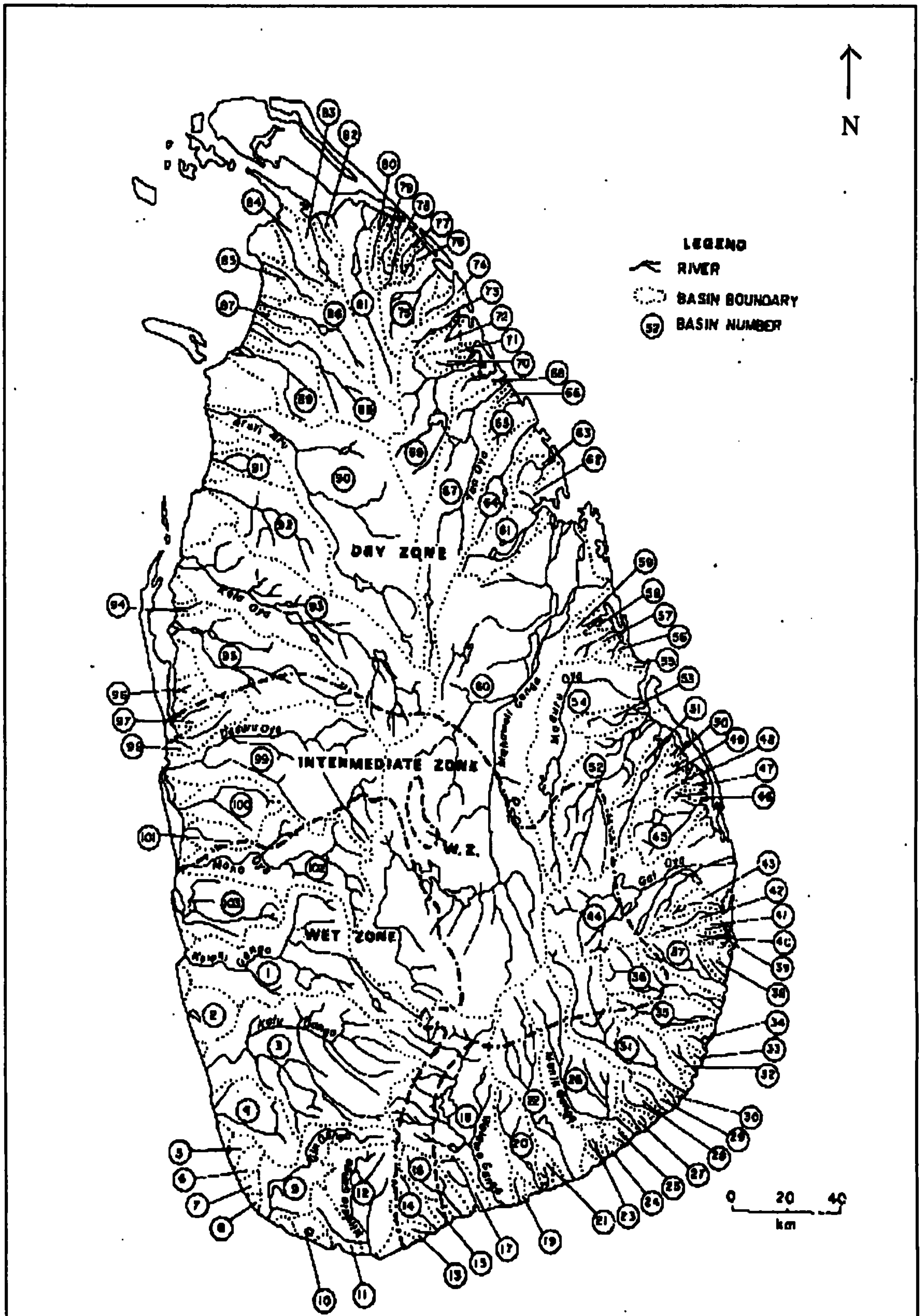
- Laterites and colluvial aquifers found mainly in the south and west. Surface alluvium, consisting of clays, sands and gravel in the riverine and coastal areas.

- The weathered over-burden in hard rock areas, which includes products of *in situ* weathering such as soil and gravelly material that form localized aquifers.



Adapted from Domroes M. (1974).

Figure 5: The boundaries between the wet zone and the dry zone in Sri Lanka, according to different criteria



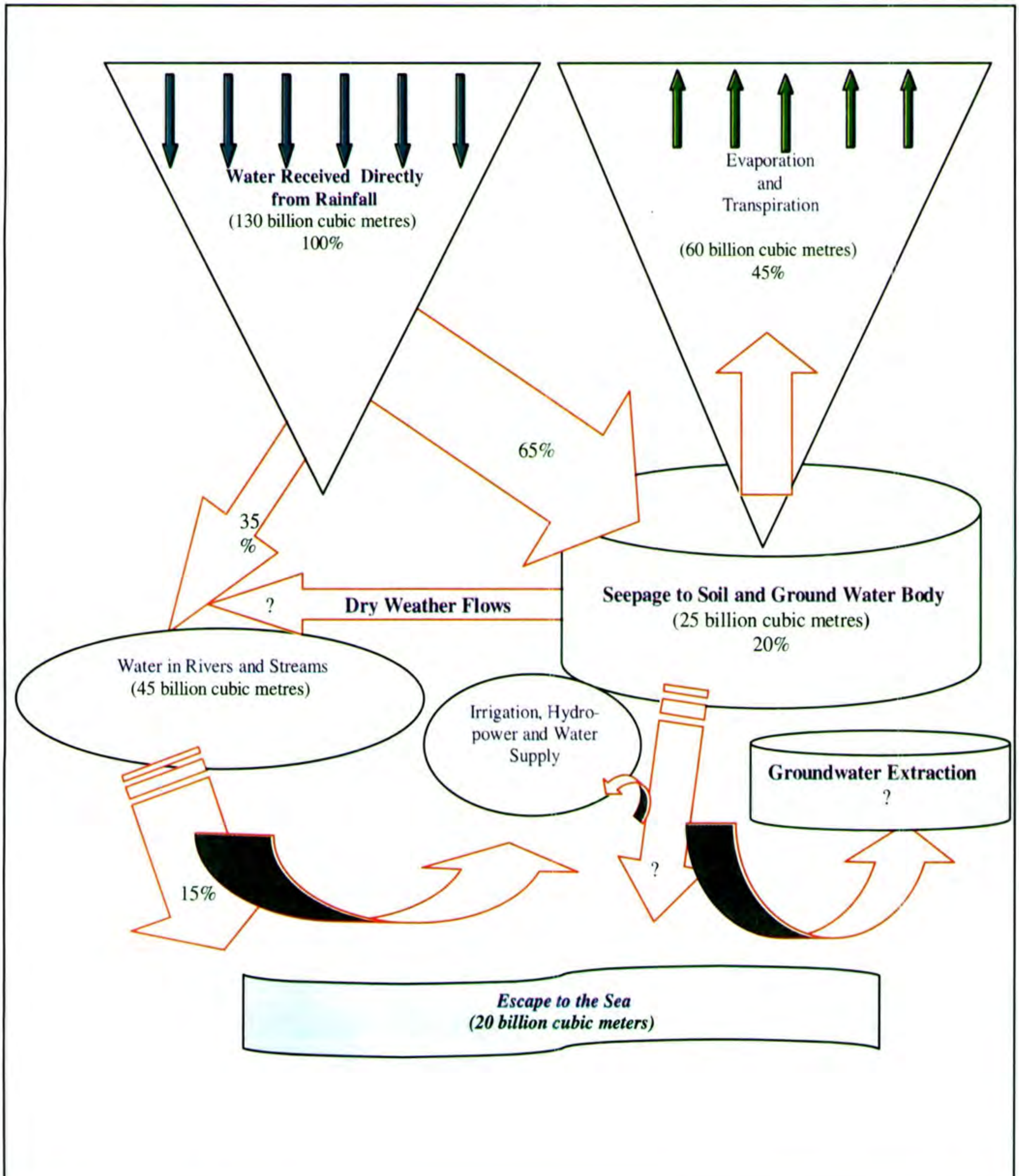
Source: Hydrology Division, Irrigation Department.

Figure 6: River basins of Sri Lanka

Table 1 : River basins of Sri Lanka

Basin No	Name of Basin	Catchment Area Km^2	Basin No.	Name of Basin	Catchment Area Km^2
1.	Kelani Ganga	2278	52	Mundeni Aru	1280
2.	Bolgoda Lake	374	53	Miyangolla Ela	225
3.	Kalu Ganga	2688	54	Maduru Oya	1541
4.	Bentota Ganga	622	55	Pulliyanpotha Aru	52
5.	Madu Ganga	59	56	Kirimechi Odai	77
6.	Madampe Lake	90	57	Bodigoda Aru	164
7.	Telwatte Ganga	51	58	Mandan Aru	13
8.	Ratgama Lake	10	59	Makarachchi Aru	37
9.	Gin Ganga	922	60	Mahaweli Ganga	10327
10.	Koggala Lake	64	61	Kantale Basin Per Ara	445
11.	Polwatta Ganga	233	62	Panna Oya	69
12.	Nilwala Ganga	960	63	Palampotta Aru	143
13.	Sinimodera Oya	38	64	Pankulam Ara	382
14.	Kirama Oya	223	65	Kanchikamban Aru	205
15.	Rekawa Oya	755	66	Palakutti Aru	20
16.	Urubhokke Oya	348	67	Yan Oya	1520
17.	Kachigala Ara	220	68	Mee Oya	90
18.	Walawe Ganga	2442	69	Ma Oya	1024
19.	Karagan Oya	58	70	Churian Aru	74
20.	Malala Oya	399	71	Chavar Aru	31
21.	Embilikala Oya	59	72	Palladi Aru	61
22.	Kirindi Oya	1165	73	Nay Ara	187
23.	Bambawe Ara	79	74	Kodalikallu Aru	74
24.	Mahasilawa Oya	13	75	Per Ara	374
25.	Butawa Oya	38	76	Pali Aru	84
26.	Menik Ganga	1272	77	Muruthapilly Aru	41
27.	Katupila Aru	86	78	Thoravil Aru	90
28.	Kurunda Ara	131	79	Piramenthal Aru	82
29.	Namadagas Ara	46	80	Nethali Aru	120
30.	Karambe Ara	46	81	Kanakarayan Aru	986
31.	Kumbukkan Oya	1218	82	Kalawalappu Aru	56
32.	Bagura Oya	92	83	Akkarayan Aru	192
33.	Girikula Oya	15	84	Mendekal Aru	297
34.	Helawa Ara	51	85	Pallarayan Kadu	159
35.	Wila Ara	484	86	Pali Aru	451
36.	Heda Oya	604	87	Chappi Aru	66
37.	Karanda Oya	422	88	Parangi Aru	832
38.	Simena Ara	51	89	Nay Aru	560
39.	Tandiadi Aru	22	90	Malvatu Oya	3246
40.	Kangikadichi Ara	56	91	Kal Ara	210
41.	Rufus Kulam	35	92	Moderagam Ara	932
42.	Pannel Oya	184	93	Kala Oya	2772
43.	Ambalam Oya	115	94	Moongil Aru	44
44.	Gal Oya	1792	95	Mi Oya	1516
45.	Andella Oya	522	96	Madurankuli Aru	62
46.	Thumpankeni Tank	9	97	Kalagamuwa Oya	151
47.	Namakada Aru	12	98	Pantampola Oya	215
48.	Mandipattua Aru	100	99	Deduru Oya	2616
49.	Pattanthe Dephue Aru	100	100	Karambala Oya	589
50.	Magalawatavan Aru	346	101	Ratmal Oya	215
51.	Vett Aru	26	102	Maha Oya	1510
			103	Attanagalu Oya	727

Source : Hydrology Division, Irrigation Department, Colombo.



Sources : Data from various sources.

Figure 7 : A generalized national water balance of Sri Lanka

Figures rounded to convey general picture only

%	=	Percentage of total water received as rainfall
?	=	Paucity of data

National Water Balance

The mean annual rainfall of Sri Lanka is around 2000 mm (Arulananthan, 1985) which would give an average volume of a little over 130 billion cubic meters of fresh water. Of the total volume of water received from rainfall, only about 35 per cent or around 45 billion cubic meters contribute to stream flow. The balance 90 billion cubic meters is used and transpired by natural vegetation and crops or evaporates from soils and water bodies or seeps into the soil to replenish the ground water. The average rate of seepage is estimated at around 20 per cent of the rainfall accounting for about 25 billion cubic meters, a part of which appears as dry weather flow in streams (Fig. 7). Although, this water balance approximation provides a general picture of the water resource base, it does not reveal the considerable variations of water resources over time and space. The damming of rivers, creation of reservoirs, and extraction of groundwater are factors that complicate the estimation of the national water balance.

Rainfall

The island receives almost all of its fresh water from rainfall. The contribution from all other forms of precipitation, such as frost, dew, clouds and hailstorms, is insignificant, except at some high elevations. Therefore, the primary source of soil moisture, stream flow and ground water is rainfall.

The southcentral highland massif standing across the path of monsoon winds is the major determinant of rainfall patterns and distribution. It causes high rainfall in the southwest quarter and relatively less in the east and north and northcentral plains that cover nearly two thirds of the island. The steeper western flanks of the massif cause a rainfall distribution pattern as shown in Figure 8.

Rainfall Regime and Distribution

Average annual rainfall varies spatially over Sri Lanka from around 1000 mm to over 5500 mm (Table 2). Maximum rainfall occurs on the windward western slopes of the central highlands as for instance in Ratnapura reflecting the strong influence of the southwest monsoon during the period from May to September. The northeast monsoon winds from November to March bring rain to the lowlands of the north and northcentral and east of the country. In between the two monsoon periods there are two inter-monsoonal periods during which convectional patterns of rainfall prevail. During the inter-monsoonal months of April-May mornings are clear while thunder-storms occur in the evenings. Tropical cyclonic activity is part of the second inter-monsoonal period. Fortunately however, Sri Lanka lies outside the main cyclone belt. Cyclones are not frequent. Some of the highest recorded rainfall events have taken place when cyclonic activity combines with other forms of rainfall (Thambiahpillay, 1959).

The 'rain shadow' effect caused by the southcentral highlands not only creates a dry area on the leeward side of the hills as in the Uva Basin, but also results in the creation of the two major climatic zones of the Island namely, the 'Dry Zone' and the 'Wet Zone' (Fig 8). The general southwest-northeast alignment of the rainfall belts, with two extra-dry coastal strips in the northwest and southeast, is another reflection of the streamlining caused by major wind systems that operate over the island, seasonally.

In addition to the two major climatic zones, an 'intermediate zone', too, is recognized based on the annual or southwest monsoon rainfall characteristics (Domroes,1974). The wet zone, which covers nearly one third of the island, receives an average rainfall of around 2500 mm annually, the dry zone around 1500 mm and the intermediate zone between 1500-2000 mm. The narrow but extra-dry zones in the coastal belts of the northwest and southeast receive around 1000 mm, as recorded at Mannar and Hambantota.

The definitions of these different climatic zones have been controversial (Domroes, 1998). An area that receives over 1000 mm, can hardly be called a 'dry zone'. So the terms 'dry zone' and 'arid zone' appear to be misnomers. The rationale is that though so much rain is received, there are long spells when these areas are subject to drought.

It is the seasonality and high evapo-transpiration losses in the context of a tropical climate, that create 'dryness' that led to the naming of different climatic zones. The seasonality is so marked that, in agriculture which depends heavily on water resources, the crop calendar has developed its own cultivation seasons namely, *yala* and *maha* that correspond to the dry and wet seasons respectively. The 'dryness' that is perceived by the agrarian communities is also due to the poor adjustment of land use to available water resources. In historical perspective, it appears that the relative extents of the dry and wet zones have remained generally unchanged throughout our history. This is reflected in the distribution and profusion of village tanks, in what is now the dry zone.

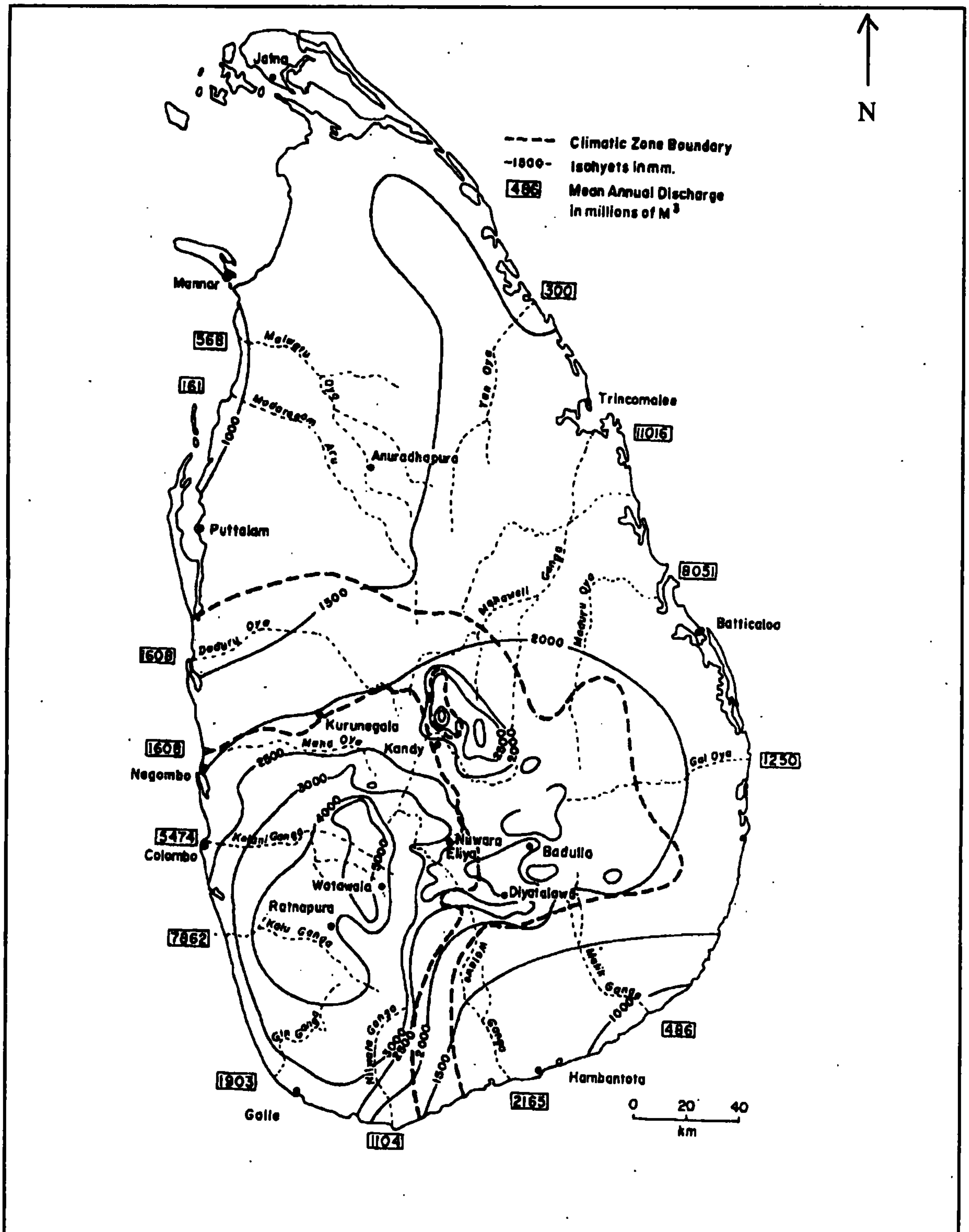
Besides the seasonality, there is also a substantial inter-annual variability in rainfall making average values somewhat misleading (Sirinanda, 1975). The inter-annual variability is, however, less in the wet zone, where it is around 10 per cent, than in the dry zone where it can be 15-20 per cent. On the other hand, the wet *maha* season rainfall is far more variable than that of the dry *yala* season due to the weaker northeast monsoon and the irregularity in the incidence of tropical depressions during the early period of the *maha* season. The general unpredictability of rainfall variations has compelled agricultural planners to rely on simple probability levels (Panabokke and Walgama, 1974). This is illustrated by the fact that annual surface water regimes of 25 agroecological regions of Sri Lanka, defined by a 75 per cent probability of monthly rainfall, deliver expected water requirements in three out of four years. Although this type of analysis has been useful in planning paddy production, monthly rainfall values just as annual values are inadequate for more specific planning purposes. There is a tendency now to use weekly rainfall values in research and planning exercises (Domroes, 1998).

In water resources management, extreme rainfall conditions often prove to have greater impacts than average conditions. It is those extreme conditions that cause floods and droughts and accelerate the processes of soil erosion and cause landslides. There are few studies available on these extreme events but information and analyses are essential for better hazard preparedness and management.

Table 2: Annual rainfall and rainy days

Selected Meteorological Stations	Annual Average (Long-term 1961-1990)		Annual Average (Last 5 years -1994-1998)	
	Rainfall (mm)	Number of Rainy Days	Rainfall (mm)	Number of Rainy Days
Anuradhapura	1285	89	1154	95
Diyatalawa	1572	129	1545	145
Colombo	2424	146	1903	158
Hambantota	1050	87	1030	100
Kandy	1840	148	1745	165
Nuwara Eliya	1905	163	2063	195
Ratnapura	3749	205	3924	221
Trincomalee	1580	86	1488	88
Averages for Sri Lanka	1927	132	1857	146

Source : Department of Meteorology.



Source: The National Atlas of Sri Lanka.

Figure 8 : Mean annual rainfall and Climatic Zones Boundary

Evapo-transpiration and Related Issues

Evaporation from soil, open water surfaces and transpiration from vegetation, together referred to as evapotranspiration are the pathways of return of water to the atmosphere, in the form of vapour. This accounts for nearly half the total volume of water received as rainfall in Sri Lanka (Fig. 7).

Since water is vital for growth of vegetation, transpiration cannot be considered as a 'loss' and evaporation from reservoirs and other water bodies cannot be prevented. In any case, evapotranspiration is an integral part of the hydrological cycle, and consumptive losses from crops and vegetation and evaporative losses from open water bodies could be optimized through scientific management. Some species of plants consume more water than others, particularly exotics like *Pinus* and *Eucalyptus* which were utilized even for drawing out water from marshy areas in plantations (Gunawardena, 1988). On the other hand 'cloud forests' at high elevations tend to trap rainfall and enhance stream flows as observed at Dambagastala Oya near Talawakele. This is an aspect which has not received adequate attention from project designers and agricultural scientists particularly in relation to catchment areas of rivers, hydropower and water supply reservoirs.

One problem in considering evapotranspiration with due importance in water resources planning is the scarcity of data available (Basnayake, 1985). Unlike rainfall records that have been maintained since the last century, evaporation measurements are few and far apart while their records also cover shorter periods, often flawed by serious gaps. Stations are mostly open-pan evaporation sites maintained by the Irrigation and Agriculture Departments at selected irrigation works or experimental farms. Moreover, analyses of available records are also relatively rare. The best estimates available for the wet zone indicate annual evapotranspiration rates of around 1450-1550 mm/year, with an upper limit at 1750 mm for Sri Lanka (Kayane & Nakagawa, 1983). In the higher montane areas of southcentral Sri Lanka, with greater cloudiness and low solar radiation, the values tend to decline to around 1000 mm.

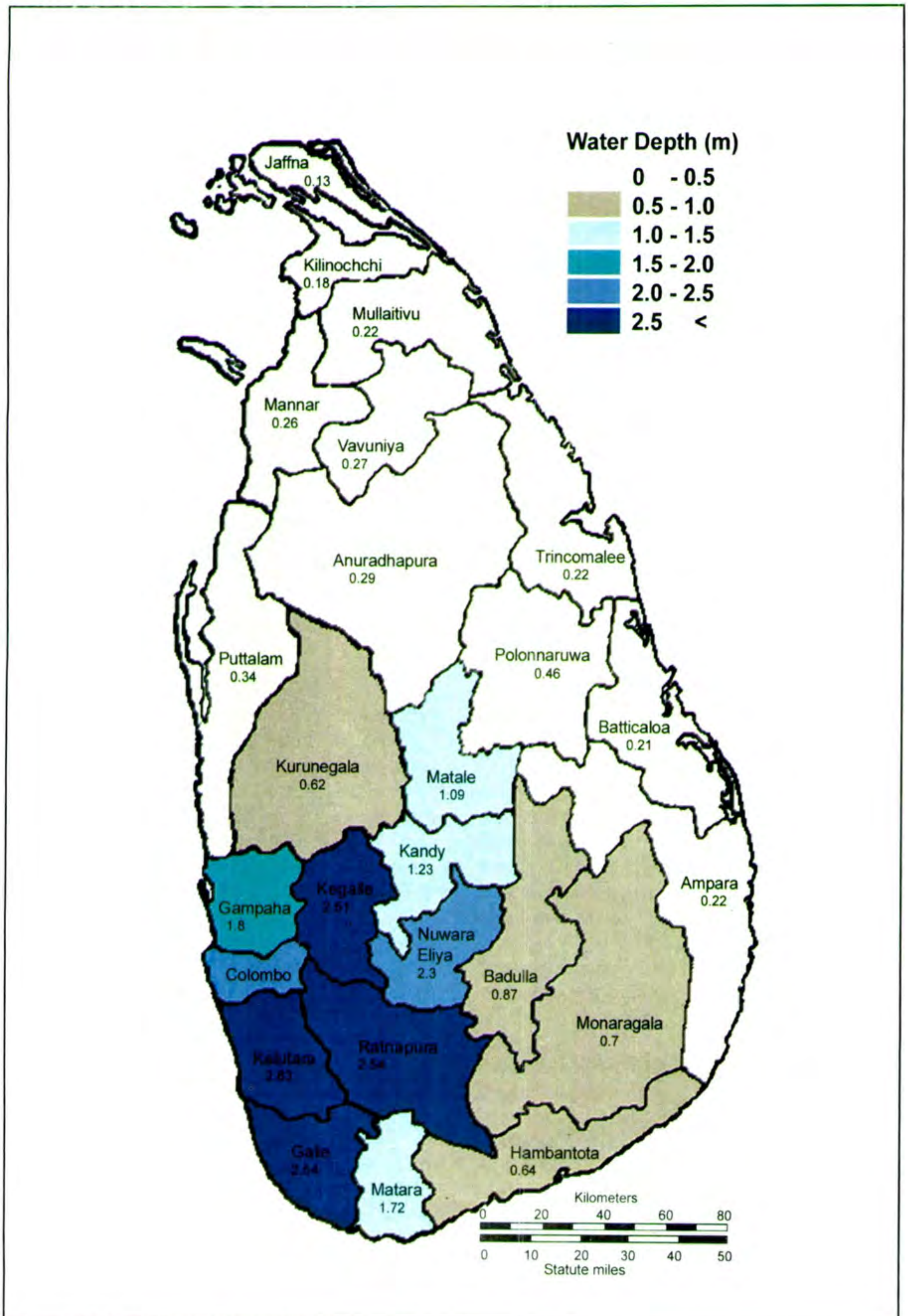
In the dry zone, evapotranspiration attains similar rates as those in the wet zone during the wet *maha* season from October to January. The rates are much lower in the dry *yala* season (May to September) in which water availability is limited. Evapotranspiration rates are also much more variable in the dry zone than in the wet zone, ranging from 1000-1400 mm/year. Evaporation rates from dry zone tanks are estimated to reach up to 2134 mm, exceeding even those in the wet zone, due to the dry climate and the advective effects on water surfaces. This tends to confirm the generally held view that, dry zone tanks are like 'evaporation pans' causing large water losses. However, their micro-climatic characteristics, and recharging effects on ground water as well as the general utility value for man and beast, may justify their existence. It was without a proper understanding of such community values that small tank systems were wiped out from some major irrigation areas such as Mahaweli in the past, considering land availability and water loss alone.

Surface Water

Surface water is a residual item that remains from rainfall after evapotranspiration and infiltration to the soil and sub-surface. The amounts are often measured in terms of units of water discharged by rivers in cubic metres per second or as units of water depth distributed over the land surface in hectare metres (HM) or acre feet (AF). Overall surface water availability at the national level is given in Figure 9.

Taking account of the various estimates made of annual surface runoff by various authorities which range from around four million HM to over five million HM (4.04 million, by IBRD,1952; 4.78 million, Bocks, 1965; 4.32 million, Walker,1962; 5.13 million, Ranatunge, 1985), it is assumed that the average total annual surface runoff in Sri Lanka is approximately 4.5 million hectare metres.

More than half the available surface water that now feeds irrigation and hydropower projects may constitute less than two million hectare metres including the waters that drain off after use and re-use in irrigation and hydropower projects. While many estimates of surface runoff in Sri Lanka are only rough approximations, there are several components



Source: Hydrology Division, Irrigation Department, Colombo.

Figure 9: Surface water potential

of it for which even such approximations are hard to find. These include the total amounts of water used by irrigation, hydropower and domestic and industrial water supply sectors. Similarly, the volume of ground water increasingly used for lift irrigation, as well as for water supply is not known. Here the problem is not just the lack of data, but lack of coordination in the compilation of data. In view of the increasing competition for available water resources, a vital need is to develop a more accurate and comprehensive national water budget. The attempt made above is only a demonstration of the path for a more comprehensive exercise.

It should be noted that, in the wet zone, over two thirds of the water that becomes surface runoff escapes to the sea, often creating floods and problems of water logging in the low lands. On the other hand, more than 50 per cent of dry zone runoff is made use of and relatively little escapes to the sea. The recent river valley development projects and particularly the Mahaweli, have reduced the volume of water escaping to the sea from the dry zone, substantially. Some early proposals to divert water from the wet zone to the dry zone, although important for flood control, as well, have not materialized (Hunting Survey, 1963). Water scarcity, particularly in the northwest, is a pressing issue, that demands early attention. Care must be taken also to avoid over exploitation of water resources in the dry zone. It now appears from experience elsewhere in the world that, exploitation of water in any river system should not exceed a limit of 20 per cent of its total resources, in order to preserve the long term ecological balance and sustainability. Where such limits have been exceeded serious problems in river behaviour have been obsereved as in South India (Madduma Bandara,1977 & 1984) which has many similarities to the dry zone of Sri Lanka (Farmer, 1956 & 1957).

Some attempts have been made by the Hydrology Division of the Irrigation Department to quantify the surface water potential of the island, based on available data on rainfall, stream flow and reservoir replenishment (Dharmasena, 1987). As summarized on a district basis in Figure 9, available surface water depth is depicted as 'surface water potential'. This indicates that, if available river discharge is spread over the respective basin areas, it can depict the overall potential. The values are adjusted to fit into district boundaries for administrative and planning convenience. However, it also indicates the problems of using existing district and provincial boundaries for water resources planning in a systematic way. Nevertheless, the surface water potential figure is useful in providing a broad guide to regional administrations relating to available potential for further development.

RAINFALL, RUNOFF AND EXTREME EVENTS

The secular rainfall trends affect the availability of water resources in several ways. Studies on island-wide climatic trends have been conducted for several decades without conclusive results (Thambiahpillay,1957), but significant local trends have been observed in the annual rainfall and in the rainfall during agriculturally critical periods. Thus a declining annual rainfall trend has been observed at high elevations such as Nuwara Eliya during the last 125 years (Hamamori,1967; Madduma Bandara & Kuruppuarachchi, 1993; Kayane, 1995). As Hamamori observed, the rainfall decline coincided with the deforestation of the hill country for plantation agriculture, but this fact alone cannot explain a decline of over 20 per cent in 100 years. It has now been established, reasonably well, that this decline is primarily associated with the decrease in southwest monsoon rains and that it may be related to the global climatic changes, specially the sea surface temperature changes in the Indian Ocean region (Kayane 1995). It is interesting to note, however, that, although the average number of rainy days during the last five years has been higher (+11%)) than that of the long term average, the average amount of rainfall received has been less (-10 per cent) (Table 2).

Annual rainfall trends do not display a uniform pattern across the island as do trends in annual temperatures which record an increasing trend at all climatological stations (Fernando & Chandrapala, 1995). Analysis of long period rainfall data at Anuradhapura does not indicate a clear trend in the annual rainfall despite the perception of the farmers that it has been declining over the years. Improper land use leading to frequent water stresses is largely responsible for such perceptions.

Photograph by C.M.Madduma Bandara.

Figure 10 : The water leak at Samanalawewa now reduced through wet-blanketing of the reservoir bed with silt

Photograph by C. M. Madduma Bandara.

Figure 11: Diwulwewa- A silting village tank in the Anuradhapura district

Table 3 : Mean Annual virgin flows of the Mahaweli Ganga (In millions of cubic meters) prior to the development of major reservoir systems

Gauging Station (Proceeding Downstream)	Basin Area km^2 (Average)	1944-1964 (Average)	1964-1976 (Average)	% Change
Morape	554	974	957	-09.82
Peradeniya	1108	2074	2137	+10.30
Randenigala	2343	3643	3822	+10.49
Weragantota	4046	5192	5594	+10.77
Manampitiya	7371	7851	8289	+10.56

Sources :UNDP/FAO (1969), Hamamori (1967) Madduma Bandara (1997).

In the hill country, rapid land use changes tend to counter-balance the effect of declining rainfall (Madduma Bandara,1993). This is revealed clearly by studies on Kirindi Oya and Mahaweli Ganga where the dry weather flow has been diminishing although the wet season flows were rising. Thus the average annual discharge of the Mahaweli Ganga over the more recent period (1964-1976) is about 10 per cent higher than the estimates of the UNDP/FAO Master Plan that was based on the 20 year period from 1944-1964. The only exception was at higher elevations above Morape (in Kotmale) where the effect of declining rainfall was felt directly (Table 3).

Although data available on sediment discharges in the rivers of Sri Lanka do not suffice for time-series analysis, increasing runoff/rainfall ratios indicate increased sediment transport from upper catchment areas and eventual increases in reservoir siltation (Puvaneswaran, 1985). High siltation rates are reported from recently constructed Mahaweli barrages as at Polgolla and Rantembe and the older water bodies such as the Kandy Lake and Lake Gregory in Nuwara Eliya. A recent study of the Polgolla reservoir indicated that 44 per cent of its capacity has been lost due to siltation within a period of less than 12 years. In many engineering projects inadequate attention given to upper watershed management has resulted in high siltation rates that affect the life span of reservoirs. Sometimes the inadequate assessment of water resources as at Kirindi Oya Basin, or the poor attention paid to geological aspects as at Kotmale and Samanalawewa have given rise to problems such as land instability and serious water leakages (Fig.10). High siltation rates are also evident in many dry zone tanks (Dharmasena 1991; Somasiri, 1992) and in some of them almost two thirds of total capacity has been lost. The net result is an increase in surface runoff and floods and creating water shortages for irrigated crops. This situation is further compounded by the increases in extents of irrigated land under village tanks. This results from the land alienation programmes based on the Land Development Ordinance. Land capacities of the tanks have been reducing progressively due to siltation and neglect. Meanwhile (Fig.11) traditional water conservation systems such as the *bethma* system (under which only a portion of the field was cultivated if the water level in the tank was low) have disappeared, gradually, aggravating the effects of siltation.

Extreme Events

Floods and droughts that often inflict heavy damages to life and property in Sri Lanka are caused primarily by extreme rainfall conditions. During the last hundred years, two drought years (1950 & 1974) and three flood years (1891, 1957and 1963) affected more than 50 per cent of the area of the country. The government has to devote sizeable amounts of funds for drought relief, landslides and floods annually. Thus in the 1980-85 period, the average annual expenditure on disaster assistance for droughts and floods alone, amounted to 88.6 and 6.35 million rupees respectively (Table 4).

Serious floods frequently recur in most wet zone rivers such as Kelani, Kalu and Nilwala while occasional floods occur in many other major rivers (Navaratne, 1985; Dharmasena, 1996). When intense rainfall from tropical depressions combine with normal monsoons, floods can devastate lowlands even in the dry zone as was seen in 1957 in the Yan Oya Basin. The silted up reservoirs and sometimes the sudden breaching of bunds can increase the magnitude of the flood volume significantly. In the wet zone, some places like Ratnapura are flooded almost every year.

Despite the significance of these extreme events, systematic scientific studies on them are hard to come by. Most studies that have been made in the past with regard to floods and flood control were for design purposes related to large engineering projects for dams, bridges and reservoirs (Walker 1962; UNDP 1969). Studies on droughts on the other hand were largely academic exercises based on monthly or annual data (Sirinanda, 1975) or those for general agronomic purposes. Attempts at forecasting or modeling of droughts are rare. This is a field of study with much potential for future research.

Global climate change is likely to accelerate the frequency and magnitude of extreme events in many countries, and Sri Lanka is no exception to this trend (ADB, USAID 1994). The results of an attempt to identify the average trend of extreme daily rainfall events based on Gumbel analysis in three selected stations are given in Figure 12 (Madduma Bandara & Pathirana, 1999). As could be seen, at Ratnapura which is frequently subject to floods, a daily rainfall as high as 550 mm, could recur in 100 years or 900 mm in 500 years. Interestingly, with the exception of Ratnapura in the wet highlands, the highest rainfall intensities are actually recorded from dry zone climatic stations such as Mullaitivu and Vavuniya in the northeast. The situation is somewhat similar in such stations where the magnitude of extreme rainfall events with long recurrence intervals is even greater. Thus in Vavuniya a daily maximum rainfall event of 600 mm could recur in 100 years and 1100 mm in 500 years. It may be noted that the highest daily rainfall in the island has been reported from Mullaitivu - a station not far from Vavuniya, with a record of a little over 800 mm. In contrast, in most highland wet zone stations extreme daily rainfall intensities are lower than those in the northeast dry zone. At Nuwara Eliya as could be seen in Figure12, intensity of extreme rainfall is relatively lower than at either Ratnapura or Vavuniya. Despite the fact that such Gumbel type estimations can often produce exceptionally high values at long recurrence intervals, they are useful indicators of the relative potential vulnerability for natural hazards such as floods and landslides.

Groundwater Resources

Groundwater resources in Sri Lanka are derived largely from direct rainwater seepage and recharge from surface water bodies such as streams, canals and reservoirs. The few studies available on recharge rate indicate that it may vary from 10-30 per cent in many areas of the dry zone with an average around 20 per cent (de Mel & Sumanasekera, 1973; Dharmasiri, 1985). The recharge from irrigation water bodies and reservoirs could be around 10 per cent of the total annual rainfall in some areas (Fernando,1973) and a part of this may be utilized for recycling (Madduma Bandara, 1979). The rates of groundwater recharge varies from one area to another depending on soil characteristics and geological formations. The poor development of surface streams in the Jaffna Peninsula and in the northwest, is indicative among other things of the higher permeability of the flat Miocene limestone terrains. In the Jaffna Peninsula, nearly half the rain water that infiltrates to the groundwater drains to the sea, the remainder being available for extraction.

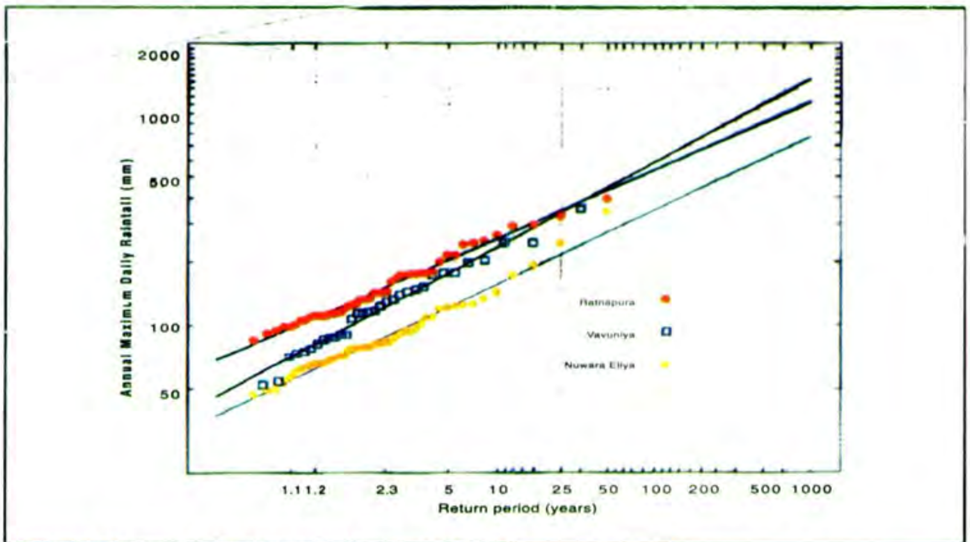
Although groundwater is in constant movement from a recharge area to a discharge area, some aquifer systems can provide good storage conditions as in the Miocene limestone belts. On the other hand, in solid metamorphic areas that cover nearly 90 per cent of the island, recharge as well as retention and storage of ground water is limited to weak zones (geological), such as joints and fractures and in alluvial formations along river valleys, and sandy soils near the coastline and in laterites.

Table 4 : Disaster Expenditure, 1981 – 1991, Sri Lanka

Year	Floods and Landslides		Droughts		Cyclones		Drinking Water		Wild Animals		Others	
	A	B	A	B	A	B	A	B	A	B	A	B
1981	15 096	2.09	186 185	41.68	255	0.19	18 026	0.97	26	0.003	3 514	0.57
1982	129 469	14.61	328 516	11.60	44	0.01	43 920	2.04			4 228	0.78
1983			410 752	8.47	204	0.05	25 174	3.17	175	0.03	4 967	0.87
1984	248 356	4.66					3 008	0.20	429	0.08	6 783	1.29
1985	17 438	254	6 481	4.26	1131	0.24	14 007	0.62	364	0.05	6 319	1.22
1986	118 336	13.59			159	0.08	5 305	0.004		0.02	3 964	0.78
1987	5 68	5.68	477 905	469.42			7 020	0.17	91	0.89	4 617	0.58
1988	2 79	2.79	652 113	285.40	105	0.007	250	0.01	140		3 683	0.64
1989	18 12	18.12	238 426	243.30	1258	0.72						
1990	37 56	37.56	203 794	6.39	512	1.13		0.32				0.31
1991	78 82	78.82	203 794	230.10		0.05		0.10		0.04		0.12

Source: Department of Social Services, 1992.

A - Number of families affected, B - Expenditure in million rupees



Source : Madduma Bandara C.M. and Pathirana (1999).

Figure 12: Distribution of extreme daily rainfall events at 3 selected stations

Miocene Aquifer Systems

Sri Lanka's largest and relatively best documented aquifers are those of the north and northwest where they extend over an area of about 250 km^2 in association with Miocene limestone terrains. In the Vanathavillu basin which was the subject of early investigations, it has been estimated that 5-20 million cubic meters of water could be extracted annually (Henreck & Sirimanne, 1968; Wijesinghe, 1985; Foster, 1976). The Murunkan and Mulankavil basins extending over an area of more than 180 km^2, to the north of Vanathavillu in the Mannar region have a significant potential for future development with deep tube wells that could yield 15-35 l/s. Tube wells around 30-40 m depth can withdraw 3-10 l/s, from some freshwater basins. However, despite the drilling of over 200 tube wells in this area they have not been fully utilized for agriculture, due to unsettled conditions.

In the Jaffna Peninsula where groundwater had been used traditionally, rates of extraction have reached their optimum limits (Balendran, 1968). In some areas signs of over-exploitation were appearing by the end of 1970s and several monitoring studies were initiated by the Water Resources Board. Although remedial measures suggested have not been implemented, the unsettled conditions that have prevailed since mid-1980s have eased, somewhat, the critical situation that was developing. With the recent return to a degree of normalcy in Jaffna, exploitation rates are again on the rise. The major problem is the accumulation of nitrates in the ground water.

Groundwater in Hard Rock Areas

The groundwater resources in the hard rock or metamorphic areas of the rest of the country were hardly exploited except for domestic use, until recent years. Early debates on their possible use for agriculture were dominated by what was then referred to as 'hard rock' thinking that over-stressed the poor aquifer characteristics of the metamorphic rocks. The deficiencies in hydro-geological data, the limited extent of local aquifers often confined to narrow crystalline limestone or quartzite bands, and the low well yields in metamorphic rocks, discouraged many early attempts. In the present context remote sensing techniques such as Electrical Resistivity surveys are able to identify deep groundwater stored in the 'hard rock'. Such resources could be exploited in the future. Deep tube wells drilled to the required depth can provide resources of sustainable groundwater.

In the Vavuniya District where exploitation of shallow groundwater began early for highland crops, reported well yields ranged from 0.1 to 0.6 l/s. Nevertheless, through proper siting and the use of local well construction technologies such as extension galleries, Vavuniya farmers could grow highland cash crops such as chillies with reasonable profits (Madduma Bandara, 1979). For other dry zone districts such as Hambantota, Trincomalee and Anuradhapura yields up to 0.5 l/s were recorded for less than one metre of draw-down in shallow dug-wells. The last two decades have witnessed a significant development of groundwater use in the dry zone hard rock areas, both for irrigation and for domestic water supply under the support of international agencies such as ADB, Agricultural Development Authority, and of provincial councils. Today, there are over 10 000 agrowells in the Anuradhapura District alone. In some areas of the Kurunegala District such as Galgamuwa, well density and groundwater pumping appears to have exceeded sustainable limits. As a result, some wells have been abandoned. Wells dug in shallow aquifers on local valley alluvium or weathered over-burden are closely associated with surface waters in streams, canals and tanks and are sensitive to water level fluctuations of the latter (Madduma Bandara, 1982). Thus the wells that have been constructed adjacent to irrigation canals were found to affect the canals adversely. Therefore, the use of shallow groundwater may be optimized only through a conjunctive approach taking into account both surface as well as groundwater and rainwater.

In the deep wells sunk into quartzite formations as at Melsiripura (Kurunegala District) and Kebitigollewa (Anuradhapura District) water yields were found to be much higher. In the wet zone, wells located in laterites, as at some sites in the Colombo District, have recorded much higher yields ranging from 1.2 to 3.5 l/s. Much of the development of deep hard rock ground water has been undertaken by the NWSDB with the support of external agencies such as DANIDA and FINNIDA. Up to 80 per cent success rates have been reported in such deep well development.

The laterites in the southwest and the coastal sands around the island also have considerable water holding capacities and are used increasingly for domestic as well as industrial water supplies. In the Colombo District well yields up to 3.5 l/s, have been reported. In Gampaha and Kalutara Districts the rapid expansion of industrial estates, small and medium enterprises and urban housing schemes and hotels is exerting much pressure on the available groundwater resources and in some areas extraction is exceeding sustainable limits. Where deeper aquifers have been tapped the inter-connection between the deep and shallow aquifers need careful monitoring and management. However, there is hardly any systematic monitoring of groundwater in these regions or in adjacent areas.

In the coastal sand aquifers, 'lenses' of fresh water float above the dense saline water and fishermen and coastal residents have used them for many centuries with much ingenuity. In areas like the Kalpitiya Peninsula, there had been intensive use of groundwater for agriculture during the last two decades. In areas to the north of Chilaw groundwater had been increasingly used for aquaculture ponds, while many tourist hotels along the coastal zone also depend on it heavily. Apart from the adverse effect on domestic dug-wells in the areas concerned, the use of coastal sand aquifers is bringing about problems of contamination, over exploitation and salinization.

Water from natural springs forms an important source of water in many rural areas particularly in the hill country. Natural springs which depend on antecedent rainfall are also affected by changes in land use. Thus some early studies by the Water Resources Board (1968), Arumugam & Ratnatunge (1974) indicated the problem of drying of springs in the Badulla District. The hot-springs of the eastern region such as those seen at Kinniya, however, derive water from relatively deeper aquifers.

Groundwater Quality

The quality of groundwater has become a matter for serious concern in many areas. Salinity intrusion as well as nitrate pollution has been reported from the Jaffna Peninsula, since 1970s. In the densely populated southwest, "point-source" discharges such as industrial effluents and leaking sewers in urban areas result in groundwater pollution. Open dug-wells in particular are more vulnerable to contamination from septic tanks and industrial effluents. An understanding of the problems associated with the quality of ground water in tube wells in different parts of the island is given in Figure 13.

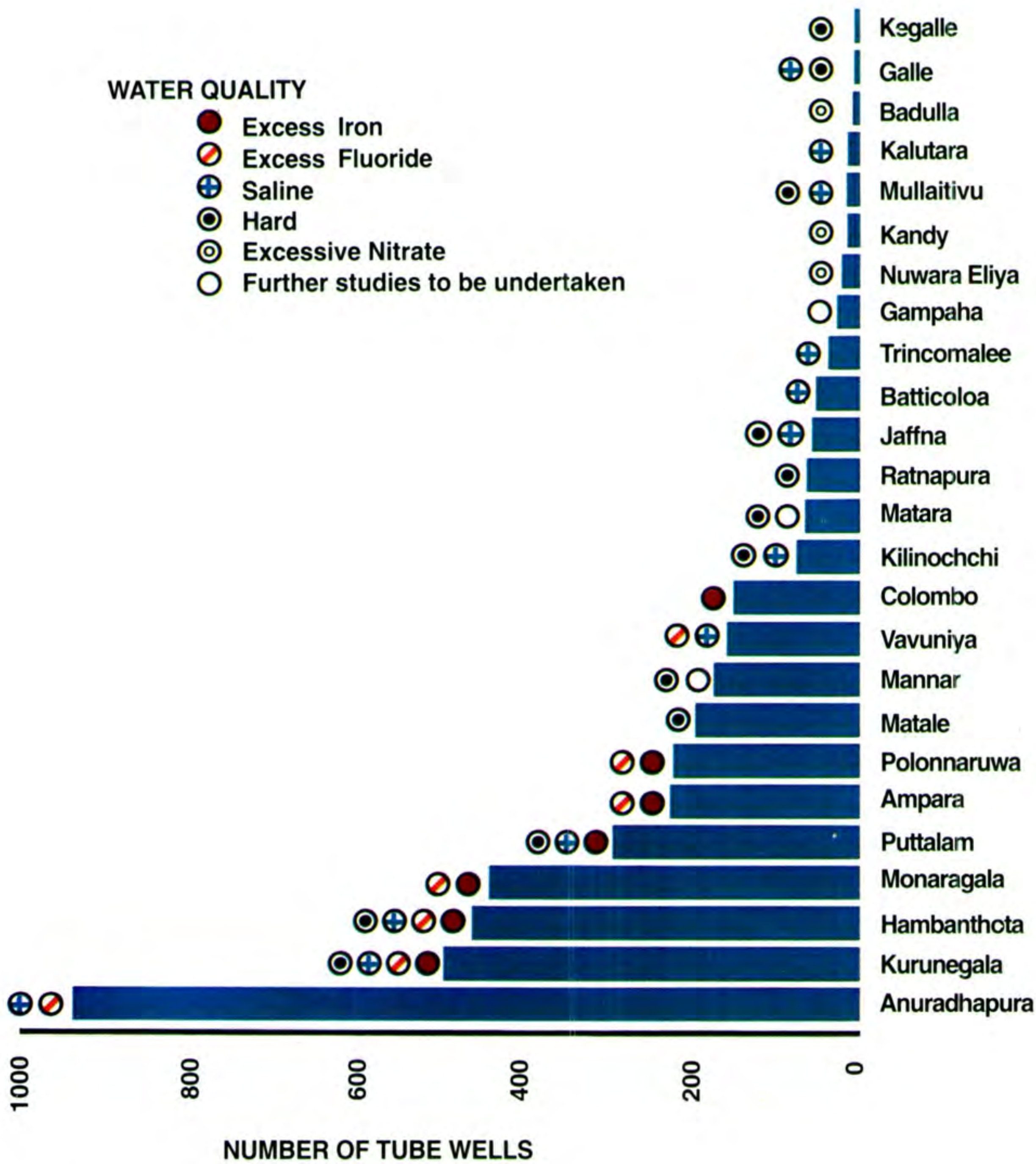
RESEARCH AND PUBLICATIONS

After Independence in 1948, a concerted effort was made on water resources development through irrigation projects such as Gal Oya, followed by Uda Walawe and subsequently Mahaweli, while little attention was paid to ground water resources. The renovation of ancient irrigation works rehabilitation of minor irrigation systems continued and even a few new ones were added. In the meantime, hydropower development, flood control, the water supply and sanitation and land reclamation programmes gained new vigour and dynamism in the post-independence years. Thus Laxapana hydropower project station, though proposed in 1918, was finally commissioned only in 1950. On the other hand, the mini hydropower plants in the plantations which were operational during the colonial period, were gradually neglected and many subsequently abandoned. Similarly the pre-occupation with large scale irrigation projects led to a relative neglect of small irrigation systems and ground water development until serious water shortages began to appear in recent times.

Research output in the field of water resources is directly or indirectly related to the development programming in the field. As D.S. Senanayake in his foreword to Brohier's work on *'Ancient irrigation'* wrote, " greater part of the contribution to our knowledge has been made by officers employed in the administration and technical branches of our public service". This is largely true in respect of resources surveys, too. International involvement in the development of water resources in Sri Lanka has been a major factor in encouraging research and publications. The development of aerial photography covering the entire island in the mid-fifties, among other things, opened many vistas for water resources research. Thus Hunting Survey Corporation which conducted the first national air surveys, was responsible for an array of reports on the resources of major river basins (Hunting Survey, 1963). This also led to the compilation and systematization of data on the hydrometeorology of Ceylon (Walker, 1962). This was followed by studies that led to the formulation of the Mahaweli Master Plan (UNDP/FAO, 1969) and data on resources of many other river basins. It resulted in several studies on Climate and Hydrology (Hamamori, 1967) and the modernization of data collection under the Hydrological Crash Programme (NEDECO, 1981).

Considerable interest in water resources research was generated during the International Hydrological Decade and its successor - International Hydrological Programme since the early 1970s. A National Committee based at the Irrigation Department was established and many research studies, seminars and conferences were held under its umbrella. However, some writings that arose from such activity did not find outlets for publication, for many years. Many research studies resulting from internationally funded water related projects too remained largely unpublished. With the opening of the economy in the late 1970s, consultancy reports became a more frequent medium of conveying research findings among other avenues. Thus the environmental assessment report for the accelerated Mahaweli Development Programme (TAMS/USAID, 1980) and the Master Plans for Forestry, Coast Conservation, and for Water Resources (ADB, 1994) were based on investigations that generated valuable information.

A large proportion of the data, as well as, other research outputs of government agencies came through Administrative Reports, and the reports of committees and commissions, such as the Land Commission, set up by the government from time to time. The reports of the Director Department of Meteorology, and publications by the Departments of Irrigation, Surveyor General and Agriculture, as well as those by the Water Resources Board and the Mahaweli Authority provide some valuable sources of information. However, much of the hard and fundamental research has come from the universities and research institutes, both local and international. The outlets for publication of research in the form of journals and occasional publications also remained largely with such institutions. The learned and professional societies such as the Sri Lanka Association for the Advancement of Science (SLAAS) and the Institution of Engineers have provided fora at which researchers could present and discuss their findings. A noticeable fact, here, is the relatively insignificant involvement of the local private sector in water resources related research despite their increasing involvement in the field.



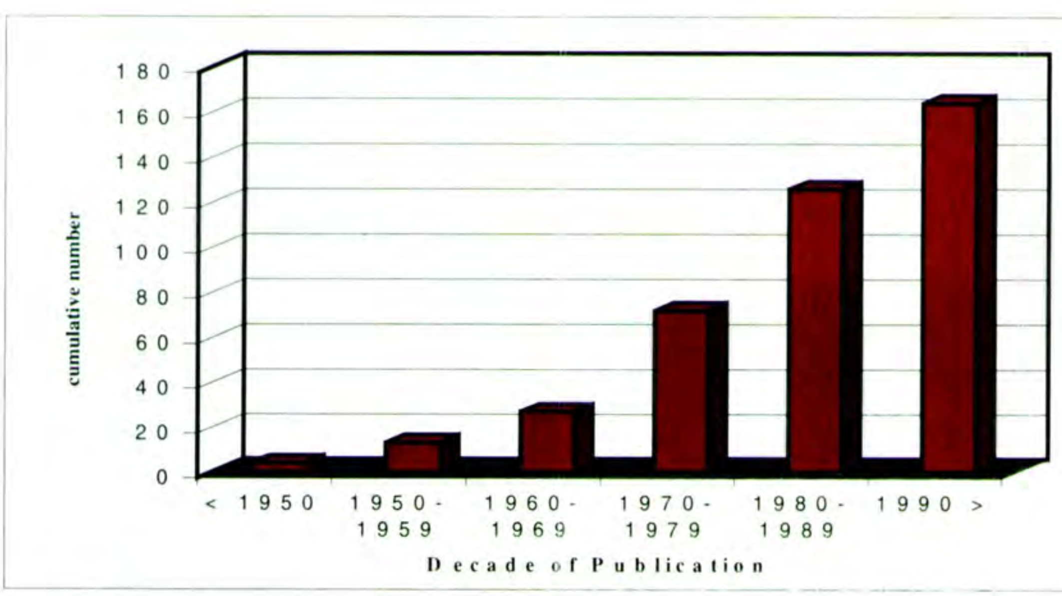
Source : The National Atlas of Sri Lanka.

Figure 13: Ground water quality by district (in tube wells constructed up to 1985)

There is hardly any comprehensive bibliography on water resources covering its manifold aspects. Bibliographies maintained by the research institutes and the universities cover some aspects. An attempt has been made to compile such a bibliography for the National Water Conference held in November 1998 (Madduma Bandara 1998). Since this was only a preliminary step, it is anticipated that a comprehensive bibliography on water resources of Sri Lanka will eventually be developed by some interested agency.

Despite its limitations and the incomplete nature, an analysis of the available bibliographic information indicates certain interesting features. The first is that, there are hardly any journals in Sri Lanka specifically devoted to the publication of papers arising from water resources research. There are, however, newsletters, and popular magazines published by different ministries, departments and corporations which carry papers of informative and educational value related to water. The most common local water outlets for research seem to be in the journals published by NARESA (now NSF), Department of Agriculture, the Institution of Engineers, SLAAS and some of the Universities. At the Universities many postgraduate dissertations related to water research seem to remain in unpublished form, although some papers arising from them have been published, elsewhere. Among the International research organizations the International Irrigation Management Institute (IIMI, also referred to as IMI or now IWMI) has published extensively on aspects related to irrigation water management.

It is of interest to note the progressive increase in the volume of publications related to water resources of Sri Lanka since National Independence (Fig.14). Although no claim is made to the completeness of the bibliography on which it is based, it is assumed that the growth of publications since Independence has been steady and significant. The take-off in the 1960s may be attributed among other things to the impact of the activities of the Hunting Survey, Mahaweli Project Planning activities and the International Hydrological Decade.



Source: The National Water Conference, Colombo (1998).

Figure 14: The growth of publications related to water resources

POLICIES, PLANNING AND LEGISLATION IN THE WATER SECTOR

Water policy denotes all major lines of public action designed to improve the use of water resources and the conditions of water rights traditionally enjoyed by the people, in Sri Lanka. Water as a vital asset for the economy and social well-being of the nation, has been predominantly under the control and care of the government or the monarch since ancient times. Water continues to remain as common public property except where it is defined otherwise in law. In ancient times there are records of persons who owned village tanks (*vapi hamika*), although water in general came under the purview of the monarch through his minister in-charge of the subject – *daka pathi* or *udaka pathi*[3]. It may be noted that, the original Irrigation Ordinance of 1856 enacted by the British colonial government was designed "to facilitate the revival and enforcement of ancient customs regarding the irrigation and cultivation of paddy lands".

The Crown Lands Ordinance (CLO of 1947) defines a public stream as any stream, lake or *ela* flowing into or from a natural channel where the source and the entire course of such stream is not situated in a private land. When it is located entirely within a private land it becomes a matter of private right. Under section 72 of the CLO the state is vested with the right to use, manage and control water in any public water body. Since large scale private land ownership is restricted in Sri Lanka, almost all fresh water comes under the control of the government without prejudice to any already granted rights. A similar principle appears to be upheld in the recent devolution of power to the provincial councils under the 13th Amendment to the Constitution, through which all inter-provincial river systems and irrigation projects continue to remain under the central government while all others come under provincial councils. However groundwater tapped from wells located in private lands continue to enjoy the rights of private property. With the expansion of groundwater in recent decades there is a growing need to redefine the conditions of these rights.

Since water is largely common public property as noted above, water policy in Sri Lanka was always synonymous with government policy. The government policy since the latter part of colonial rule had been directed to develop water resources for land development and agriculture as well as for domestic consumption. Thus some of the first major irrigation renovation projects such as Kalawewa and Tissawewa were commenced towards the end of the last century. This trend continued after Independence without any change and with even greater vigour and dynamism. The culmination of this policy was seen in the Mahaweli Project that began in the early 1970s and has been continued into the early 1990s. At present, almost all suitable sites for major irrigation projects in the dry zone, appear to have been utilized. Future potential, if any, lies in the wet zone from which water may be diverted to the dry zone or utilized for hydropower generation.

In the post-Mahaweli era the government policies appear to be increasingly directed towards some new goals:

- greater efficiency in irrigation water management in existing schemes through farmer participation,
- increasing productivity in existing irrigated lands through crop diversification and higher cropping intensities,
- groundwater development for agriculture and domestic use,
- drainage and flood protection improvement,
- development of small scale irrigation systems and hydropower plants,
- systematic watershed management and
- improvement of industrial and domestic pipe-borne water supply systems.

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[3] The folklore maintains that if the bund of a vital reservoir like Kalawewa breached due to neglect, the responsible Minister (or Udakapathi) had hardly any choice than to sacrifice his life by plunging himself into the spate. This is also related to the worship of Kadawara – the deity who protected the big tanks. On the other hand the kings who built great tanks like Mahasen were deified by the people and worshipped through the generations.

The Presidential Land Commission of 1985 stressed the need for formulating a Water Master Plan and the establishment of a Watershed Management Authority (GOSL,1990). In pursuance of this recommendation a proposal was made to partner-donor agencies in 1992 to carry out a water resource master plan study. As a result, with assistance from the Asian Development Bank, a study was completed and a report on " Strategic Framework and an Action Plan for Comprehensive Water Resources Management" was published (ADB/USAID, 1994). This Action Plan stressed the need for development of a national water resources policy, recommended the establishment of a permanent institutional arrangement for water sector coordination, to enact a National Water Resources Act and to amend the water related legislation. It also urged the establishment of systems needed to provide the data and information required by the decision makers and carry out comprehensive planning in selected watersheds. In pursuance of this report the government formally established a Water Resources Council and a Water Resources Secretariat in. 1996. In the meantime FAO supported a 'Water Law and Policy Advisory Programme' which is developing water legislation and assisting with groundwater policy. Some institutional recommendations involving a new National Water Resources Authority and a permanent Water Resources Council have been developed along with draft legislation. The national water resources policy and institutional arrangements have received cabinet approval in March 2000.

The overall objective of the National Water Policy is to ensure the use of water resources in an efficient and equitable manner, consistent with the social, economic and environmental needs of the present and future generations. Its scope extends to cover all fresh and brackish water in Sri Lanka but excludes marine water. The National Water Resources Policy will also be based on the principle that all surface and groundwater are owned by the state and managed, by the government in partnership with water users on behalf of all Sri Lankans. It also gives much prominence to the management of groundwater in view of its increasing use for both irrigation and other purposes. The proposed policy also takes an integrated approach covering all aspects of water resources management in coordination with other national policies and natural resources management agencies (Water Resources Secretariat, 1998).

The implementation of legislation both existing as well as proposed is beset with many constraints. The multiplicity of existing pieces of legislation related to water, some running back to the last century, have developed their own inertia and continue to serve various specific purposes. It has been reported that there are over 40 such pieces of legislation and even a greater number of institutions dealing with water (GOSL, 1986). They spread over half the present cabinet ministries. Some of the more prominent legislative enactments are :

Irrigation Ordinance No.32 of 1946 and its amendments.
Agrarian Services Act of 1979 and its amendments.
Crown Lands Ordinance No.8 of 1947 and its amendments.
Land Development Ordinance No.19 of 1935 and its amendments.
Water Resources Board Act No.29 of 1964.
Land Reform Law of 1972 and its amendments.
Mahaweli Authority Act No. 23 of 1979 and 59 of 1993.
Ceylon Electricity Board Act of 1956 and 1969.
National Environment Act of 1980 and its amendments.
Coast Conservation Act No.57 of 1981 and its amendments.
National Water Supply and Drainage Board Law No.2 of 1974 and No.13 of 1992.
Fisheries and Aquatic Resources Act No. 2 of 1996.

The 13th Amendment to the Constitution of the Republic of Sri Lanka also has implications for water management.

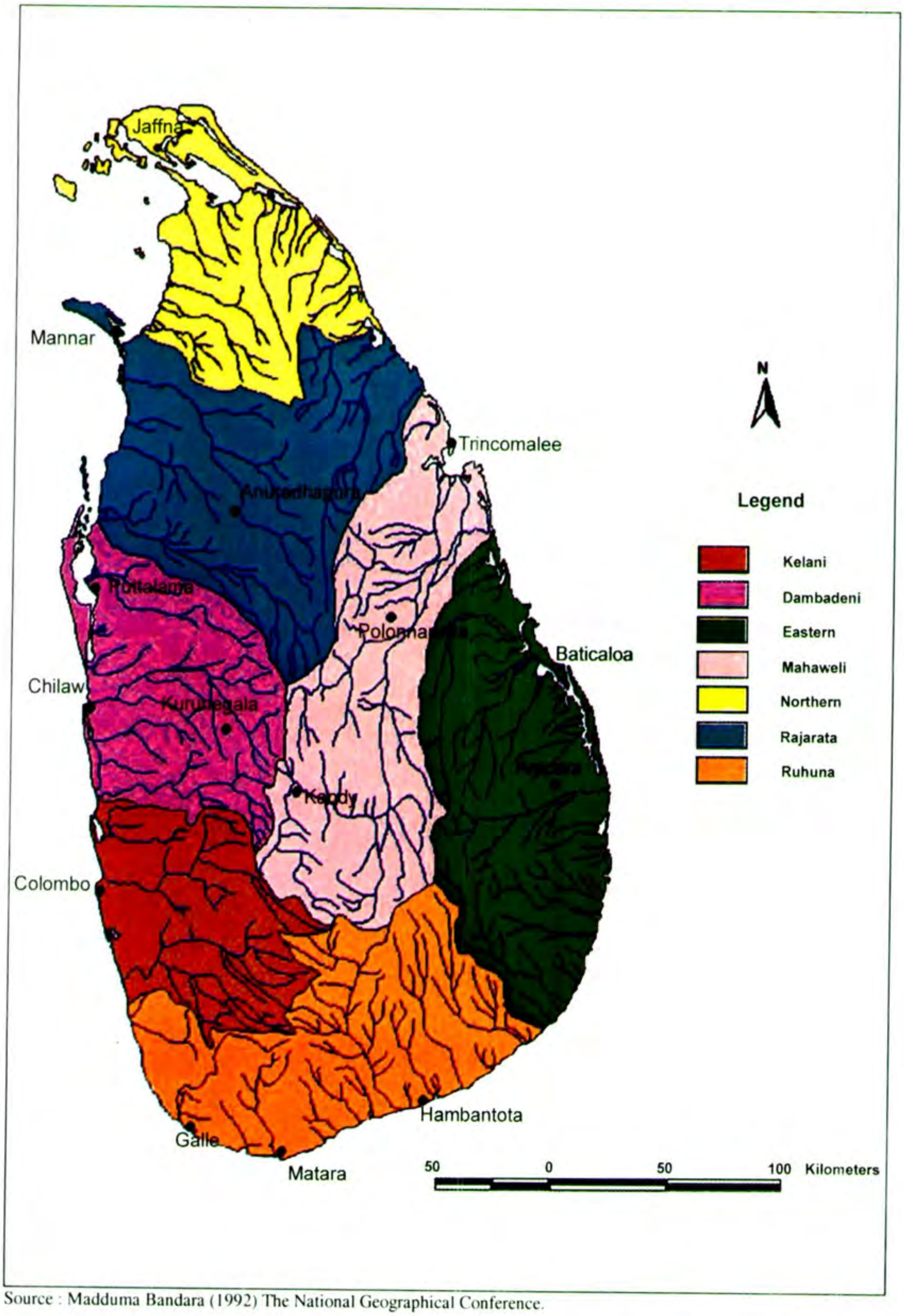
The implementation of different pieces of legislation are entrusted with a large number of government departments, public corporations, provincial councils and local bodies. For example the provisions of the Crown Lands Ordinance were implemented through the government agents since its inception. However, over the decades the vigilance exercised by the Government Agents had become less and less due to several reasons. The powers of the Government Agents also diminished with more legislation and new institutions were created. With the establishment of the provincial councils, the situation had become even more confused. The maintenance of stream and reservoir reservations which is a vital necessity for the conservation of water resources, had been virtually neglected since it had become increasingly difficult to eject the unlawful occupants. Thus in critical water source areas like Nuwara Eliya, much of the vegetable cultivation is on the stream reservations and the Government Agent can do very little about it although regulations under the CLO defines specific widths of riparian land that should be maintained as stream reservations depending on the size of the stream. The neglect of the conservation of land above 5000 ft (1500 m) - a policy continuing from colonial times, will have serious adverse impacts on water resources, particularly in the light of declining rainfall trends at high elevations.

Similarly, under administrative arrangements based on the Irrigation Ordinance, all reservoirs should have a belt of reserved land around them defined by the bund-top level or the spill level contour, so that they are protected from damage, siltation and pollution. This has been largely neglected and even some government land alienation programmes have overlooked this requirement in the past. It has been estimated that at least 290 000 ha of land should be set apart for streams and their reservations alone (Somasekeram, 1996). The inland reservoirs both large and small will inundate at least 130 300 ha, and they will need at least a similar extent of additional land for their catchment conservation.

Just as there had been an increasing neglect of provisions under different Acts and Ordinances, there are also areas of duplication and conflict of interest. This is exemplified by the construction of hotels for tourist development in the catchments of reservoirs that generated much controversy in recent years, as at Kandalama, Rajawella (in Victoria Catchment) and Batalagoda (near Kurunegala). Different government agencies often attempt to focus on their own interests overlooking the needs of other sectors. This state of affairs has developed due to the lack of a central decision making body which can make decisions based on a broader vision.

Escalating water conflicts from individual to state agency level will soon require 'water tribunals' that can adjudicate on such issues.

With the devolution of power to the provinces that were demarcated over a hundred years ago by the colonial rulers for their own needs, much potential for inter-regional water conflict has been created as witnessed frequently in South India between the states of Karnataka and Tamilnadu. Proposals have been made to re-demarcate provincial boundaries on the basis of river basin watersheds (Madduma Bandara, 1991) so that land and water conservation could be carried out more efficiently and at the same time avoid most future up-stream and down-stream conflicts (Fig. 15). If the provision of the 13^{th} amendment to the Constitution to create a National Land Commission had been implemented that would have reconciled at least some of the issues related to land needed for stream and reservoir reservations. The main challenge before the proposed National Water Resources Act is to embrace and supercede many provisions in the fragmented legislation related to water resources management. It should also take into account the delineation and rationalization of functions of numerous institutions and particularly between the central government and the provincial councils. It may be prudent to base all water resources planning on natural river basin watersheds not only for the sake of conservation of water resources, but also to optimize the returns from massive investments made by the government over the decades for water related projects.



Source : Madduma Bandara (1992) The National Geographical Conference.

Figure 15 : New development regions based on river basins

REFERENCES

1. ADB/USAID (1994) *Comprehensive water resources management in Sri Lanka*: Technical Assistance Project TA1918-Sri. Vols.1-2.

2. Arulananthan J.T. (1985) Regional Study on Global Environmental Issues. In: *Climate change in Asia: Sri Lanka country report;* Asian Development Bank.

3. Arumugam S. (1969) *Water resources of Ceylon: utilization and development*, Water Resources Board, Colombo.

4. Arumugam S. and Ratnatunge P.U. (1974) *Springs of Sri Lanka*. Vol.1. Water Resources Board, Colombo.

5. Balendran V.S. (1968) *Groundwater in Jaffna.* Water Resources Board, Colombo.

6. Basnayake B.K. (1985) Evapotranspiration. In: *Some aspects of the water resources of Sri Lanka* (Eds. C.M. Madduma Bandara and N.M.G. Navaratne) Irrigation Department, Colombo.

7. Basnayake B.M.S.B & Madduma Bandara C.M. (1985) *Groundwater in hard rock areas;* In: *Some aspects of the water resources of Sri Lanka* (Eds. C.M. Madduma Bandara & N.M.G. Navaratne) Irrigation Department, Colombo.

8. Bocks S. (1965) *Water resources of Ceylon*, Irrigation Department, Colombo.

9. Brohier R.L. (1935) *Ancient Irrigation works in Ceylon*. Parts I, II & III.Ceylon Government Press, Colombo.

10. Central Bank of Sri Lanka (1999) *Annual Report* for 1998, Colombo.

11. CLO (1947) *Crown Lands Ordinance* No.8. Govt. Press, Colombo.

12. Cooray P.G. (1967) *An Introduction to the geology of Ceylon*; National Museums of Ceylon, Colombo.

13. De Mel I.D.T & Sumanasekera P. (1973) Groundwater recharge at Yala; *Journ. of the Nat. Sci. Coun. of Sri Lanka*, Vol.I.

14. Dharmasena G.T. (1987) *Evidence given at the Presidential Land Commission* (1990).

15. Dharmasena G.T. (1996) Nilwala Ganga Flood Protection Scheme: Post-mortem of a Post-mortem; *Hydro. Ann.* 1994/1995.

16. Dharmasena P.B. (1991) Present use of land and water resources in village tank farming. *J.S.Sc.Soc.of SL.* Vol.7.

17. Dharmasiri J.K., Dharmawardhana K.G. & de Mel I.D.T. (1985) Groundwater recharge in Sri Lanka In: *Some aspects of the water resources of Sri Lanka* (Eds. C.M. Madduma Bandara and N.M.G. Navaratne) Irrigation Department, Colombo.

18. Domroes M. (1974) *The Agroclimate of Ceylon*, Wiesbaden, Germany.

19. Domroes M., Gunadasa J.M. & Ranatunge E.R. (1998) Intra-seasonal rainfall variation and the cultivation of rice under rainfed farming in Sri Lanka. *Petermanns Geographische Mitteilungen*, Vol.142.

20. Domroes M. (1998) Variabilities of the temporal and spatial organization of rainfall in Sri Lanka. In: *Sri Lanka: past and present.* (Eds. M. Domroes & H. Roth) Margraf Verlag, Germany.

21. Farmer B.H. (1956) Rainfall and water supply in the dry zone of Ceylon, In : *Geographical. essays on British Tropical Lands* (Eds. R.W. Steel & S.A. Fisher) George Philip & Sons.Ltd. London.

22. Farmer B.H. (1957) Land use lessons learnt in Madras and applicable to the dry zone of Ceylon. *Bull.Cey.Geogr.Soc.* Vol.10.

23. Fernando A.D.N. (1973) *Groundwater resources of Sri Lanka*; Ministry of Irrigation, Power and Highways, Colombo.

24. Fernando T.K. & Chandrapala L. (1995) Climate variability in Sri Lanka: a study on trends of air temperature, rainfall and thunder activity. In: *Climate and life in the Pacific* (Ed. K.U. Sriyananda) University of Brunei Darussalam.

25. Foster S.S.D., Yearwood Y.D.F. & Carruthers I.D. (1976) *Groundwater for agricultural development in Sri Lanka: resources and economics.* Ministry of Overseas Development, U.K.

26. GOSL (1986) First Interim Report of the Land Commission, *Sessional Paper*, Govt. Press, Colombo.

27. GOSL (1987) *The 13th Amendment to the Constitution*; Parliament of Sri Lanka.Govt. Press, Colombo.

28. GOSL (1990) Final Report of the Presidential Land Commission, *Sessional Paper*, Govt.Press Colombo.

29. Gunawardena E.R.N. (1988) Hydrological and Soil Erosion Studies in Sri Lanka; In: *Reforestation with Pinus in* (Eds. H.P.M. Gunasena). Godamunne & Sons, Kandy.

30. Hamamori A. (1967) *Mahaweli Ganga Irrigation and Hydro-power Survey*; Vol.II: Climate and Hydrology; FAO and Irrigation Department, Colombo.

31. Henreck R. & Sirimanne C.H.L. (1968) *Geology and groundwater resources in the Vanathavillu Area*, Puttalam, Irrigation Department, Groundwater Division. Colombo.

32. Hunting Survey Corporation (1963) *Report on fifteen river basins of northwest Ceylon*; Surveyor General's Department, Colombo.

33. IBRD (1952) *Economic development of Ceylon*; World Bank Mission to Sri Lanka.

34. Kayane I. & Nakagawa S. (1983) Evapotranspiration and water balance in Sri Lanka. In: *Climate, water and agriculture in Sri Lanka*, (Eds. M. Yoshino) University of Tsukuba, Japan.

35. Kayane I. (1995) Climatological data in Sri Lanka and southwest India *IGBP Activities in Japan*, Science Council of Japan.

36. Leach E.R. (1959) *Hydraulic society of Ceylon; past and present*, Vol.15.

37. Madduma Bandara C.M. (1977) Hydrological consequences of agrarian change; In: *Green Revolution*? (Ed. B.H. Farmer) MacMillans, London.

38. Madduma Bandara C.M. (1979) A study of the practice of well irrigation in the country around Vavuniya in Northern Sri Lanka. *Sri Lanka Journal of Social Sciences*, Vol.2.

39. Madduma Bandara C.M. (1982) Behaviour of the groundwater table in the vicinity of selected major irrigation reservoirs in the dry zone of Sri Lanka. In: *Beitrage Zur Hydrologie* (Ed. Rainer Keller), Germany.

40. Madduma Bandara C.M. (1984) Green revolution and water demand: irrigation and groundwater in *Sri Lanka and Tamil Nadu, South India;* In: (Eds. T. Baylis-Smith & S. Wanmali) *Cambridge University* Press.

41. Madduma Bandara C.M. (1985) Catchment ecosystems and village tank cascades in the dry zone of Sri Lanka; In: *Strategies for river basin development*, (Ed. J. Lundqvist) Reidel Publishing Company, Germany.

42. Madduma Bandara C.M. & Nawaratne N.M. (1985) Some Aspects of the Water Resources of Sri Lanka, Hydrology Division, Irrigation Department, Colombo.

43. Madduma Bandara C.M. (1989) Recent natural disasters: wrath of Gods or responsibility of men; *Economic Review*, Peoples Bank, Colombo. Vol 15.

44. Madduma Bandara C.M. (Ed.) (1989) *Hydrology of the natural and man made forests*; GTZ, UMWMP, Kandy.

45. Madduma Bandara C.M. (1991) Re-structuring the provincial system, *National Geography Conference*, Golden Jubilee, University of Peradeniya;

46. Madduma Bandara C.M. & Kuruppuarachchi T.A. (1993) Land use change and hydrological trends in the Upper Mahaweli Basin; *Report of the Special Project on Global Climatic Change*; Science Council of Japan.

47. Madduma Bandara C.M. (1994) *Restructuring the Provinces*, OPA, Colombo.

48. Madduma Bandara C.M. (1997) Land use changes and Tropical Stream Hydrology. In: *Process and Form in Geomorphology* (Ed. D. Stoddart) Rontledge of London, Newyork.

49. Madduma Bandara C. M. (1998) Status of water resources research in Sri Lanka; Paper presented at the *National Water Conference*. Nov.1998, Water Resources Management Secretariat, Colombo.

50. Madduma Bandara C.M. & Pathirana A (1999) Extreme rainfall events in Sri Lanka: Some statistical aspects and societal impacts. A Paper presented to the *International Conference on Climate Change and Variability*. Tokyo Metropolitan University, Japan.

51. Navaratne N.M.G. (1985) Floods and flood control, In: *Some aspects of the water resources of Sri Lanka* (Eds. C.M. Madduma Bandara and N.M.G. Navaratne) Irrigation Department, Colombo.

52. NEDECO (1981) *Hydrological crash programme*, Mahaweli Development Project; Vol.1-18; Hydrology Division, Irrigation Department, Colombo.

53. Panabokke C.R. & Walgama A. (1974) The Application of rainfall confidence limits to agriculture in the dry zone of Sri Lanka; *J.of Nat.Sc.Coun.of.Sl*; Vol.2.

54. Puvaneswaran P. (1985) Assessment of relationships between runoff and the load in the Mahaweli Ganga, Basin, Sri Lanka. In: *Beitrage Zur Hydrologie*, Kircharten, Germany.

55. Ranatunge D.G.L. (1985) Surface water resources; In : *Some aspects of the water resources of Sri Lanka* (Eds. C.M. Madduma Bandara and N.M.G. Navaratne) Irrigation Department, Colombo.

56. Senanayake D.S. (1935) *Agriculture and Patriotism*, Lake House, Colombo.

57. Sharma P.N. (Ed) (1999) Some Indigenous Technology and Practices for watershed management in Sri Lanka, University of Peradeniya.

58. Sirinanda K.U. (1975) Pattern of drought in the dry zone of Sri Lanka: A Study in water balance climatology. *Bull.Cey.Geog. Soc.*Vol.21.

59. Somasekeram T. (1996) *Facts about our land*; Arjuna Consulting Co. Dehiwala.

60. Somasiri S. (1992) Water conservation in small and medium tanks for agriculture; *Trop.Agric*. Vol.149.

61. TAMS/USAID (1980) *Environmental assessment:* Accelerated Mahaweli Development Programme. New York, Vols. I-IV.

62. Thambiahpillay G. (1957) Climatic fluctuations in Ceylon; *Ph.D. Dissertation* (Unpub.)University of Cambridge, U.K.

63. Thambiahpillay G. (1959) Tropical cyclones and the climate of Ceylon; *University of Ceylon Review*, Vol.17, Peradeniya.

64. UNDP/FAO (1969) *Mahaweli Ganga irrigation and hydropower survey*; Vols. I-III, Rome.

65. Walker R.L. (1962) *The Hydrometeorology of Ceylon*; Parts I & II. Hunting Survey Corporation, Canada & the Irrigation Department Colombo.

66. Ward H. (1856) *The Second minute on the Eastern Province*, Govt. Press.

67. Water Resources Board (1968) A Survey of Water Resources Utilization and Cultivation Habits and Practices of the NCP Peasant Cultivator in the Toruwe Tulane of the Anuradhapura District; Government Press, Colombo.

68. Water Resources Secretariat (1998) *National Water Resources Policy*; Government of Sri Lanka (Discussion Draft), Colombo.

69. Wijesinghe M.W.P. (1985) The Geohydrology of miocene aquifers: A study of the Murunkan Basin in northwest Sri Lanka; In: *Some aspects of the water resources of Sri Lanka* (Eds. C.M. Madduma Bandara and N.M.G. Navaratne) Irrigation Department, Colombo.

70. Witanage P.W. (1958) Geology and water supply in the country around Polonnaruwa; *Cey.Geog.Soc.*Vol.12.

Photograph by C. V. S. Gunatilleke

Victoria Dam Across the Mahaweli Ganga at Spill Level

ENERGY RESOURCES

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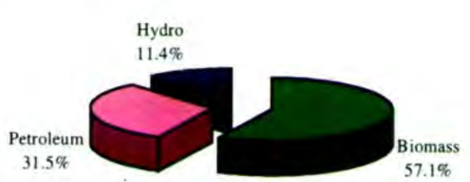
Summary

Per capita energy consumption in Sri Lanka is at a relatively low level at present. Biomass contributes a large component. The other indigenous resource is hydropower already exploited to 50 per cent of total potential. Present average level of electrification is about 50 per cent with 98 per cent in Colombo and less than 10 per cent in some remote areas. Estimated annual growth in electricity demand is about 9 per cent to 10 per cent. Currently, this is being met by thermal plants. Coal fired, plants are being planned. Increase in petroleum consumption is taking place rapidly with expansion in transport and industry, growing at about seven per cent over the next 10 years. Biomass seems to be the main alternative energy resource that could be expanded in the near future. Other options are solar energy, wind energy and microhydro plants. Their potential needs to be explored. A programme of restructuring the energy sector is envisaged, splitting functions vertically and horizontally. Private sector participation will also be encouraged. A balanced system ensuring regular supply, clean environment and cost effectiveness will be evolved.

INTRODUCTION

Energy supply in Sri Lanka is mainly based on three primary sources, namely hydroelectricity, biomass and petroleum. In 1996, hydroelectricity and biomass accounted for approximately 780 thousand Tonnes of Oil Equivalent[1] (TOE) and 3930 thousand TOE respectively. Approximately 2 170 thousand TOE came from petroleum crude and oil products giving an aggregate primary energy supply of approximately 6 880 thousand TOE. These correspond to 11.4 per cent from hydroelectricity, 57.1 per cent from biomass and 31.5 per cent from petroleum oil products (Figure 1).



Source : Sri Lankan Energy Balance, 1996
Energy Conservation Fund, Sri Lanka.

Figure 1: Primary energy supply in Sri Lanka (1996)

The energy accounted here does not include solar energy used in processes such as drying of agricultural produce, making dried fish, extracting salt from sea

[1] Electrical energy is usually measured in kilowatt hours (kWh) which is the same as 'units' of electricity used in household terminology. For comparison and evaluation purposes, kWh of electricity can be expressed in equivalent tonnes of oil (TOE). Likewise biomass (fuelwood) is normally measured in tonnes, but can be expressed in terms of TOE. The conversion factors generally used are 1 unit of electricity = 1kWh = 0.086 TOE and 1 tonne of fuelwood = 0.38 TOE. A tonne is 1000 kilogrammes and is slightly higher in weight (1.016) than a tonne (20 cwt.)

Table 1: Per capita energy consumption in selected countries and groups of countries by income

Country or 'country group'	Commercial Energy Consumption (kg of oil equivalent per capita)	
	1980	*1995*
Bangladesh	32	67
India	137	260
Nepal	12	33
Pakistan	139	243
Sri Lanka	**96**	**136**
Thailand	259	878
Low income country group	133	198
Middle income country group	953-1536	1030-1579
High income country group	4808	5118

Source: World Development Report, World Bank, 1998.

water etc., as such use is usually classified as 'non-commercial' energy. Draught and manpower used in transporting goods, agricultural practices and timber harvesting have also been excluded in the above energy account. Commercial use of renewable energy sources such as wind power and solar electricity is estimated to be at an insignificant level compared to energy from these major sources. Use of coal is also insignificant.

The energy supply is expected to increase to 11.5 million TOE approximately by the year 2010 at an annual growth rate of four per cent to eight per cent in different sub sectors. Hydropower and biomass based energy supplies will remain virtually fixed during this period (because the developmental efforts focussed and exerted on these primary energy sources are only very modest), while petroleum oil and coal consumption will gradually increase giving rise to a requirement of greater emphasis on mitigation of environmental impacts.

Table 1 gives a comparison of commercial energy usage in different countries in the region, from which it can be seen that the consumption in Sri Lanka stands at a considerably low level even compared to the average consumption level in the low income country group.

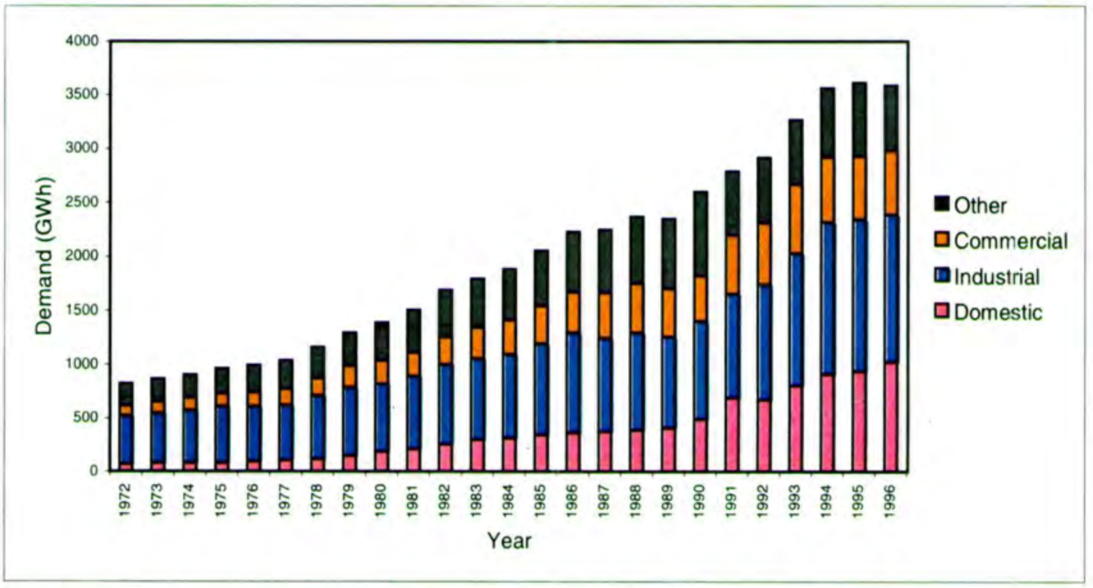
INDIGENOUS RESOURCES AND IMPORTED SOURCES

Hydroelectricity and biomass are considered to be the only large scale indigenous primary energy sources available in Sri Lanka. All petroleum, oil and gas requirements are imported. No fossil fuel deposits have been discovered in Sri Lanka or within its extended economic zone. However, India has discovered petroleum deposits at the Cauvery basin, a few kilometers outside Sri Lanka's maritime boundary. Sri Lanka has not carried out adequate exploration in this region within its boundary. The only 'fossil fuel resource' found within Sri Lanka to date is peat; a meagre quantity of only 285 kilo tonnes of peat, of little use, has been identified at Muthurajawela.

ELECTRICITY

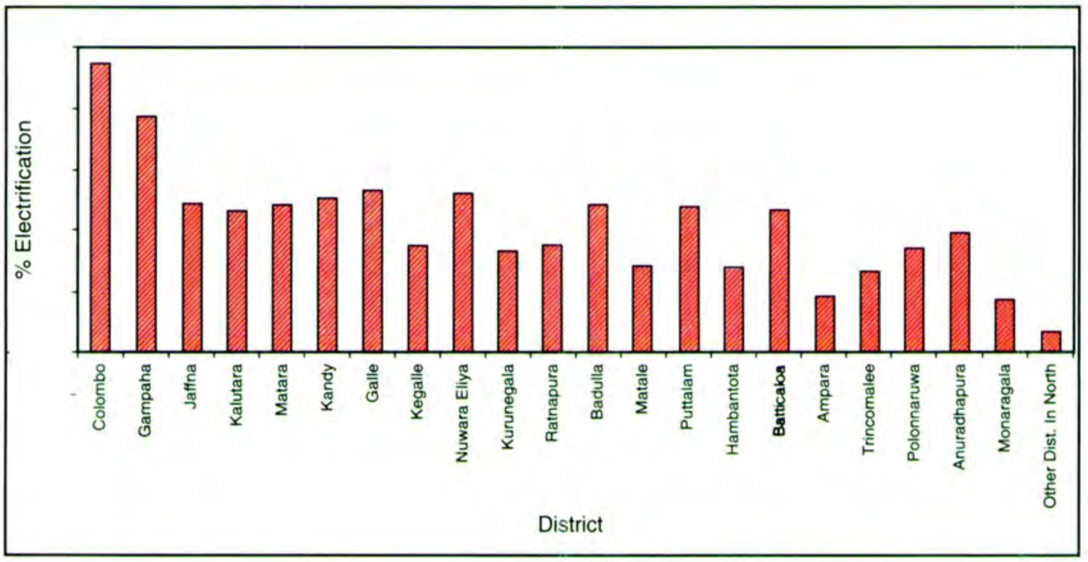
Demand

The historical growth of electricity demand is shown in Figure 2. The overall annual electricity demand grew from 823 million units in 1972 to 3588 million units in 1996 at an annual compound growth rate of 6.8 per cent. The growth during the period 1972-1977 recorded an average annual rate of 4.7 per cent while it rose sharply to 10 per cent per annum in the early 1980s. However, between 1982 and 1989, the growth rate dropped to 4.9 per cent and increased again to 8.9 per cent from 1989 to 1994.



Source: Long Term Generation Expansion Planning Studies 1996-2010, Ceylon Electricity Board, 1996.

Figure 2: Growth of electricity sales over the period 1972 - 1996



Source : Pre-electrification Unit, Ceylon Electricity Board, 1998.

Figure 3: Electrification levels in different districts

A sharp increase in the sales to the 'Domestic' category during early 1990s, and a concurrent decrease of the 'Other' category can be seen in electricity sales. This is mainly because of the transfer from the Local Authority electricity distribution systems to the Ceylon Electricity Board (CEB) with the taking over of those distribution areas; Domestic consumers previously identified under 'Other' category had thereafter been categorized as Domestic consumers. In addition, the implementation of a large number of rural electrification schemes is partially responsible for the increase of the demand in the domestic sector. The countrywide electrification level stands (1998) at approximately 50 per cent of the households in the country with a relatively large

Photographs by Priyantha Wijayatunga.

Figures 4 & 5: Samanalawewa hydro reservoir and its rock-fill dam

percentage of rural households not being connected to the national grid.

This low electrification level in the rural domestic sector can be attributed to inadequate electricity supply lines and the inability of these non-electrified households to pay for electricity connections and/or monthly electricity bills. Figure 3 shows the district wise distribution of electrification level in 1998. It can be seen that in the Colombo District where the national electricity grid has penetrated to all the areas, the electrification level stands at around 98 per cent while rural districts such as Ampara and Monaragala are poorly electrified with less than 20 per cent of the households connected to the grid.

Per capita electricity consumption levels in different countries in the region are given in Table 2. It can be seen that the per capita consumption in Sri Lanka in 1995 which stands at 208 units per annum is relatively low in comparison to other countries while its average growth of per capita consumption is the lowest in the group.

Generation

The demand on electricity generation is higher than the electricity sale figures by about 15 per cent to 20 per cent because the generators also have to supply the inevitable power losses in the transmission and the distribution of electricity.

The use of hydroelectricity depends largely on the extent of effective installed capacity and rainfall in catchment areas. In general, the shortfall to meet the demand (after utilizing hydroelectricity) is supplied by oil-fired thermal plants, at present.

The total hydroelectricity generation from existing power stations (1996) amounted to approximately 3 250 million units per annum (which is equivalent to 300 thousand TOE). There are other potential hydroelectric sites which can be developed, more than doubling current output but their development is constrained by economic factors to approximately, a further 3 500 million units of annual supply.

Installed capacity and energy supply from hydroelectric stations in Sri Lanka have been increased progressively through commissioning of hydropower stations as depicted in figures 4 & 5. The total installed capacity of hydropower stations in 1999 adds up to 1 135 MW and an average generation capability of approximately 3 500 million units (Table 3) excluding Kukule. This could be compared with the projected demand of 6 481 million units for 1999. The shortfall of about 2 981 million units has to be covered by the thermal power stations, tabulated in Table 4.

Table 2: Per capita electricity consumption in selected countries and groups of countries by income

Country	Electricity Consumption (kWh per capita)	
	1980	*1995*
Bangladesh	16	57
India	130	339
Nepal	13	39
Pakistan	125	304
Sri Lanka	**96**	**208**
Thailand	279	1199
Low income country group	159	269
Middle income country group	811-1376	991-1962
High income country group	5557	7748

Source: World Development Report, World Bank, 1998.

Table 3: Existing and committed hydropower generation

Plant	Installed Capacity MW		Generation (million units/yr)	Commissioning
Laxapana Complex				
Canyon	2x30	60	137.3	Unit 1 March 1983 Unit 2 1988
Wimalasurendra	2x25	50	122.1	Jan 1965
Old Laxapana	3x8.33	50	260.8	Dec 1950
	2x12.5			Dec 1958
New Laxapana	2x50	100	465.8	Unit 1 Feb 1974 Unit 2 Mar 1974
Polpitiya	2x37.5	75	396.8	April 1969
Laxapana Total		**335**	**1382.8**	
Mahaweli Complex				
Victoria	3x70	210	663.7	Unit 1 Jan 1985 Unit 2 Oct 1985 Unit 3 Feb 1986
Kotmale	3x67	201	445.13	Unit 1 April 1985 Unit 2 Feb 1988 Unit 3 Feb 1988
Randenigala	2x61	122	326.4	July 1986
Ukuwela	2x19	38	164.4	Unit 1 July 1976 Unit 2 Aug 1976
Bowatenna	1x40	40	48.8	Jan 1981
Rantambe	2x24.5	49	189.1	Jan 1990
Mahaweli Total		**660**	**1837.53**	

Contd.... Table 3

Contd.... Table 3

Plant	Installed Capacity MW		Generation (million units/yr)	Commissioning
Samanalawewa	2x60	120	277.3	Oct 1992
Small Hydroplants				
Inginiyagala	2x2.475 2x3.15	11	26.8	June 1963
Uda Walawe	3x2	6	7.6	April 1969
Nilambe	2x1.6	3	11.6	July 1988
		20		
Under Construction				
Kukule	2x35	70	306	Jan 2002
Total Hydro		**1205**	**3803.63**	

Source : Long Term Generation Expansion Planning Studies 1996-2000, Ceylon Electricity Board, 1996.

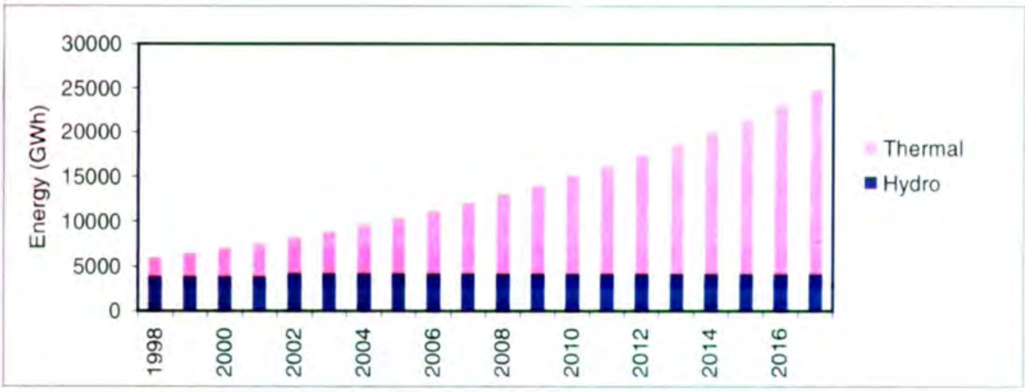
Table 4: Thermal power plants in Sri Lanka

Plant	Installed Capacity (MW)		Commissioning
Kelanitissa Gas Turbines	6x20	120	Nov 1980 - Mar 1982
	1x115	115	August 1997
Kelanitissa Steam	2x22	44	June 1962 & Sep 1963
Sapugaskanda Diesel	4x18	72	May 1984 to Oct 1984
Sapugaskanda Diesel Extension	4x10	40	Sep 1997
Lakdanavi Diesel (BOO)		22.5	Late 1997
Asia Power Diesel (BOO)		51	Mid 1998
Under Construction			
Kelanitissa Combined Cycle	1x150	150	Late 1999 to 2000
Sapugaskanda Diesel Extension	4x10	40	Early 1999
Total Thermal		**654.5**	

Source: Long Term Generation Expansion Planning Studies1996-2010, Ceylon Electricity Board, 1996.

The forecasts of Annual Electrical Energy Generation required, for the period 1998 to 2017 are given in Figure 6. The expansion of the hydroelectric system during this period is limited to 70MW and 306 million units. This implies that there will be a significant shortfall between the demand and hydropower output, which needs to be bridged; the present power-sector plan is to bridge this through thermal plants.

Additional thermal electricity sources as presently planned by CEB, are all either oil or coal based. If one considers that this requirement is to be supplied entirely by oil, additional oil required per annum for power generation alone by the year 2010 will amount to more than three times what is used in thermal power stations at present. Even if the thermal electricity generation is partly through coal fired plants, the tonnage of (imported) fuel would be higher; at perhaps, a slightly lower cost. In any case, it would be a severe drain on the foreign exchange resources of Sri Lanka. Moreover, it will have adverse environmental effects. The only large scale long term alternative that can help to minimize such imported energy resources can come from fuelwood grown on energy plantations. A strategy for thermal electricity generation based on fuelwood has been proposed. Thermal electricity from fuelwood has the advantage of (a) being indigenous (local), (b) having price stability even if oil/coal prices fluctuate, (c) having a net zero carbon dioxide



Source : Long Term Generation Expansion Planning Studies 1996 – 2010, Ceylon Electricity Board 1996.

Figure 6 : Growth of the electricity generation sector 1988-2017

emission (during the growing of a tree it will absorb carbon dioxide from the atmosphere which will be later released during the process of power generation or other energy production), (d) being able to provide large scale employment during the growing process of energy forests, (e) being able to increase greenery and positive environmental effects and (f) being stable against shortages and price fluctuations during periods of war and other international disturbances.

Courtesy: Lanka Transformers Ltd.

Figure 7 : Lakdanavi thermal based electricity generation station, Sapugaskanda

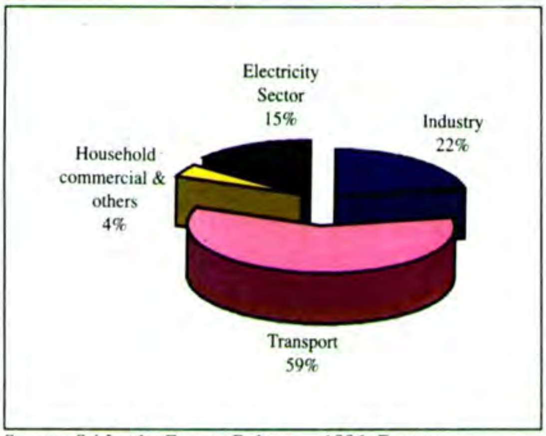
Tariffs

The present electricity tariff structure differentiates the selling price for different consumer categories; religious purpose, domestic, low voltage general purpose, low voltage industrial purpose, industrial time-of-day, and street lighting. Also lower tariffs are given for bulk supplies of more than 50kVA capacity. Electricity consumption at medium voltage (11kVto 33 kV) also enjoys certain benefits. The present electricity tariff, which has been effective from September 1997, provides an average energy charge of Rs. 4.00 for domestic consumers, Rs. 5.50 per kWh for general purpose consumers and Rs 4.10 per kWh for industrial consumers.

PETROLEUM

Petroleum oil products with an annual supply of approximately two million TOE, contributed to 31.5 per cent (1996) of the primary energy supply in Sri Lanka at a cost of Rs. 18.3 billion. This is supplied through the output of the local refinery at Sapugaskanda, with an annual refining capacity of 2.2 million tonnes of crude oil and from direct importation of refined products. Imported crude oil is processed at the Sapugaskanda refinery into petrol (gasoline), kerosene, diesel fuel, aviation fuel and liquid Petroleum Gas and sold through a well established distribution network. Shortfall of refinery capacity is met through direct import of finished products.

Of particular significance is the importation of kerosene oil and liquid petroleum gas. Figure 8 shows that the major user of petroleum product is the transport sector, followed by industrial and electricity sectors. The historical demand for petroleum products in Sri Lanka is shown in Figure 9. During the period 1972 to 1977, the consumption of all petroleum products except liquid petroleum gas (LPG) and auto diesel had shown a decline. This was as a result of low economic growth coupled with the near trebling of prices. Since 1977, demand for most petroleum



Source: Sri Lanka Energy Balance – 1996, Energy Conservation Fund, Sri Lanka

Figure 8: Composition of petroleum products consumption (1996)

products has been increasing, particularly that for auto-diesel and LPG. The demand for heavy diesel and fuel oil shows a marked increase whenever there is a heavy demand on thermal electricity usually resulting from dry years where hydro-generation capability is at its minimum; years 1982 and 1983 are examples.

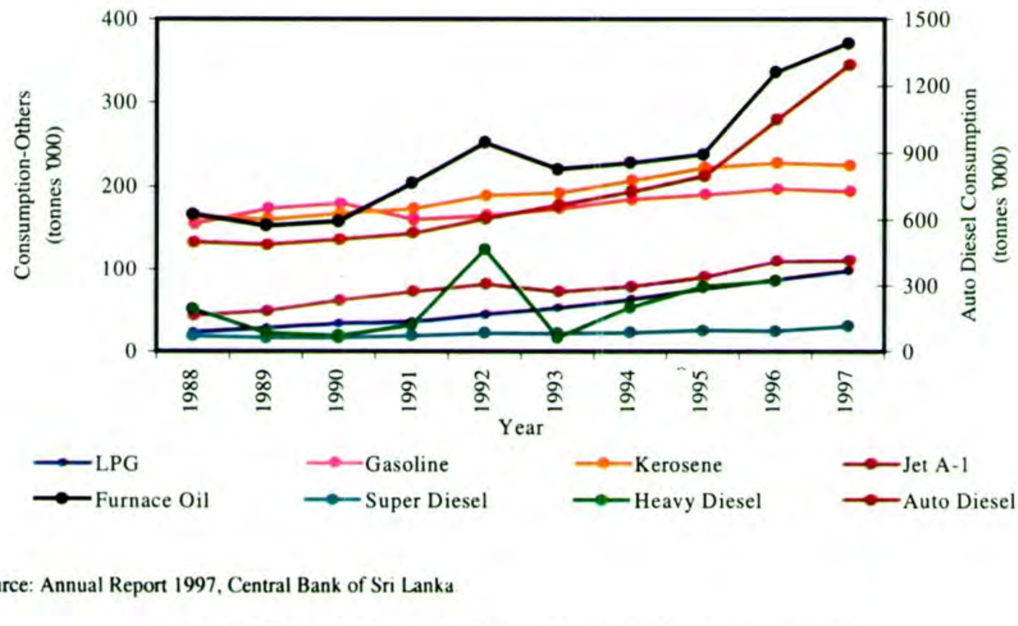
In the year 2000, the only oil refinery in Sri Lanka (at Sapugaskanda) is expected to saturate at its capacity of 2.2 million tonnes of crude oil per annum. Further, the present (1998) annual consumption of two million TOE of petroleum is expected to grow up to 4.9 million TOE by the year 2010 mainly as a result of increased direct consumption in the transport and industrial sectors, recording an average annual growth rate of seven per cent in this sector. The expected growth in consumption is shown in Figure 10.

Government levies, which reach around 50 per cent of the border prices on imported petroleum oil and oil products, are generally uniform except in the case of LPG where the import tax has been removed.

BIOMASS

Biomass is the most widely used source of primary energy in Sri Lanka with total consumption standing at approximately 10 million tonnes in the year 1996 and shared among domestic, commercial and industrial sectors. Most of the biomass is derived from non-forest resources.

Biomass generally implies fuelwood, agrowaste through forest and non-forest sectors including twigs, branches and roots. Biomass, though generally classified as 'non-commercial'

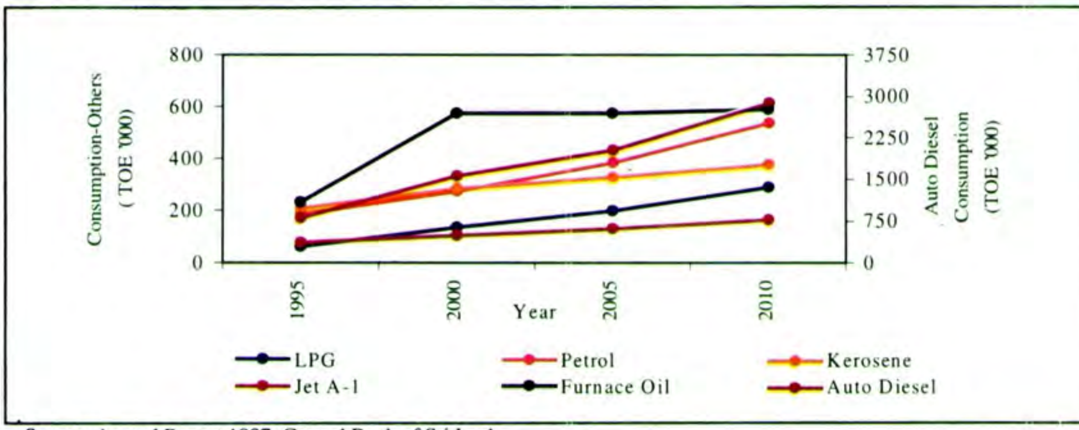


Source: Annual Report 1997, Central Bank of Sri Lanka

Figure 9: Historical growth in petroleum product consumption

has a market place and is traded freely. Perhaps it should be now classified as 'commercial'. In the context of Sri Lanka, commercial activity in fuelwood production, sale and use needs to be encouraged.

industries, use mainly fuelwood as their source of energy supply. Bagasse resulting from sugar production is almost completely utilized for electricity generation within the sugar factories

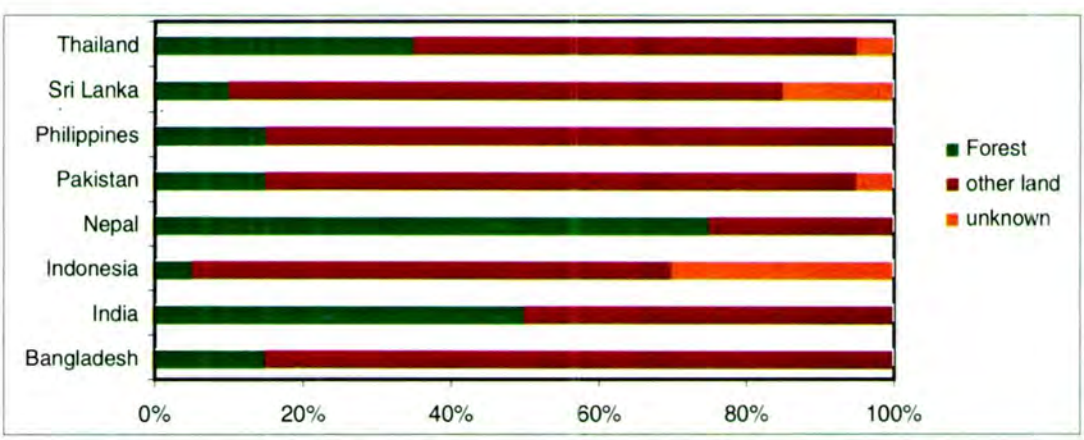


Source: Annual Report 1997, Central Bank of Sri Lanka.

Figure 10: Expected growth in petroleum product consumption

The annual biomass availability is estimated to be between 10 900 to 16 500 kilo tonnes corresponding to 4 142 thousand TOE and 6 270 thousand TOE. Although the biomass availability over demand for the whole country is positive, there are some regional deficits. If forest fuelwood management programmes are carried out carefully, it is possible to obtain an excess of supply over demand, at least, until the year 2020. Fuelwood and other biomass such as coconut residues, paddy husk and saw dust are largely used for domestic cooking. Small manufacturing industries such as bakeries, tile and brick making themselves. Rice husk is being used increasingly in rice mills and in tobacco barns as a major energy source during processing.

At present (1999), fuelwood is purchased by industries such as Tea, Tile and Brick industries at Rs. 1 500 per tonne, i.e. Rs. 1.50 per kg. When the lower energy capability of fuelwood in terms of TOE is taken into account, the effective price for the same energy as given by a litre of fuel oil works out to Rs. 4.50, which compares with Rs. 14.00 per litre of diesel or Rs. 13.00 per litre of kerosene oil in the petroleum product market.



Source : Sources of Wood Energy, FAO-RWEDP, 1999.

Figure 11: Fuelwood supply in the region from different sources

The present retail price of fuelwood may not be a realistic indicator of prices fuelwood would fetch if trees are grown specifically for energy purposes. It has been postulated that if the price could be reasonable and cheaper than oil or coal for heating purposes such as drying of tea and firing of tiles and bricks in kilns, fuelwood could be used to replace oil to a considerable extent. However, the proof of this can only be through experimental growing and utilization.

Presently there are 12 experimental plots of land being cultivated under a European Commission (EC) funded Energy Forest pilot project in Sri Lanka. The Ministry of Science and Technology, with the assistance of the Energy Conservation Fund and the Department of Forests is carrying out this project mainly to determine the optimum parameters such as species to be planted and planting regimes appropriate for energy plantations. Also the Energy Forum has recently completed a study to ascertain the feasibility of fuelwood based electricity generation in Sri Lanka considering issues such as land availability and the use of short period rotation plant species. If the results are encouraging, plans should be developed to include generation of electricity from fuelwood, to some extent.

The Forestry master plan has identified 1.6 million hectares of scrub land and chena land, which urgently need some form of 'cover' to prevent degradation. Energy plantations may be introduced on some of these lands. If one third of this available land is used for an energy plantation, around 10 million tonnes of fuelwood will be produced annually. This quantity of fuelwood, if used for electricity generation, can produce 10 000 MWh of energy per annum, which amounts to almost twice the exploitable hydropower potential in Sri Lanka. In addition, it is estimated that such energy plantations covering 500 000 hectares will provide employment opportunities for 150 000 rural families giving an average monthly income of Rs. 10 000 to each family.

Although biomass (including fuelwood) accounts for about 57 per cent of the total energy supply in the country, the biomass sector operates without adequate policy support from the government. Increase in fuelwood production and lowering production cost (together with popularization of easy wood-burning non-polluting stoves, backed by R&D would result in the creation of employment opportunities and possible voluntary substitution by consumers of imported fuels such as fuel oil and LPG in certain applications. The existing laws and regulations in respect of felling of trees and transport of logs are in fact a hindrance to commercial biomass energy development. About 1.6 million hectares of marginal lands, which could be used readily for fuelwood plantations, could be leased out to the private sector for energy plantations. As stated above, plantations can provide 10 million tonnes of fuelwood which is equivalent to 3.8 million tonnes of oil. This quantity of fuelwood could supply more than the entire energy generated from oil at present.

These factors led to a proposal for a biomass energy agency to promote and consolidate production, marketing and efficient use of fuelwood. It has been stated that such an institution will also be responsible for liberalizing, commercializing and promoting growing of trees for energy and encouraging substitution of imported energy sources where technically feasible and economically viable.

Table 5: Fuelwood supply demand balance

Period	Annual Availability '000 tonnes	Annual Demand '000 tonnes	Excess Supply '000 tonnes
1986 - 1990	11375	9675	1700
1991 - 1995	11629	10359	1270
1996 - 2000	10959	10950	9

Source: Energy Status in Sri Lanka: Issues –Policy Suggestions, Institute of Policy Studies, 1989.

Further, it has been pointed out that the government will not have to incur additional capital expenditure for these activities. It will be able to earn some revenue through leasing hitherto unutilized land. An agency as proposed above appears necessary in Sri Lanka to develop and fully utilize biomass potential for energy generation.

OTHER ENERGY SOURCES

Source : Ceylon Electricity Board.

Figure 12: Pilot wind farm at Hambantota

Wind Energy

At present, wind power is a mature renewable energy technology for application in large scale electricity generation. Commercial scale production of wind turbine plants with moderate power generation commenced in some countries around 1984. The worldwide wind plant installed capacity has now exceeded 5 000 MW. There is an installed wind turbine capacity of over 500 MW in India alone.

In Sri Lanka systematic studies on the development of wind energy were commenced in 1988 by the CEB. These studies revealed that the coastal belt from Hambantota to Kirinda offered an exploitable total wind turbine capacity of 200 MW with an annual yield of 350 million units. (These capacities may be viewed in the context of an annual demand increase of about 100MW at present). However, cost effectiveness has been found to be deficient, unless environmental considerations are given a value to enable wind plants to become competitive with diesel plants. It is further known that significant wind energy potential is available on the coastal belts from Puttalam to Jaffna and from Jaffna to Trincomalee. These have not been systematically studied or feasibility worked out. In addition, certain areas of the hill country such as Ambewela and the Uva basin experience strong wind speeds.

In most locations of the southern coastal belt, an annual average wind speed of only around 6 m/s to 6.5 m/s is experienced. Further, there is a mismatch between the wind speed variation and the daily as well as annual demand for additional generation. Due to these factors wind energy becomes economically viable in these areas only if the cost of the wind turbine, tower and associated system is below US$ 1 000 per kW, at present alternative costs.

CEB has embarked on a pilot wind farm of three MW capacity consisting of five 600 kW turbines in Hambantota. This was commissioned and connected to the national grid in early 1999. Some private sector institutions also have expressed their interest in establishing grid-connected wind turbine plants in the southern coastal belt.

Though there are some negative features, wind generated power is a supplementary option to be considered in long term future power development. Turbine costs are decreasing with technological advances. Further, wind energy is unaffected by external markets making it more attractive for the local economy.

Micro-hydropower

The highlands of Sri Lanka experience rain for around nine months of the year. The topography is such that many rivers and streams descend via small waterfalls. Rivers are being tapped for large scale hydropower generation. Many of the small streams flow through vast areas of tea country.

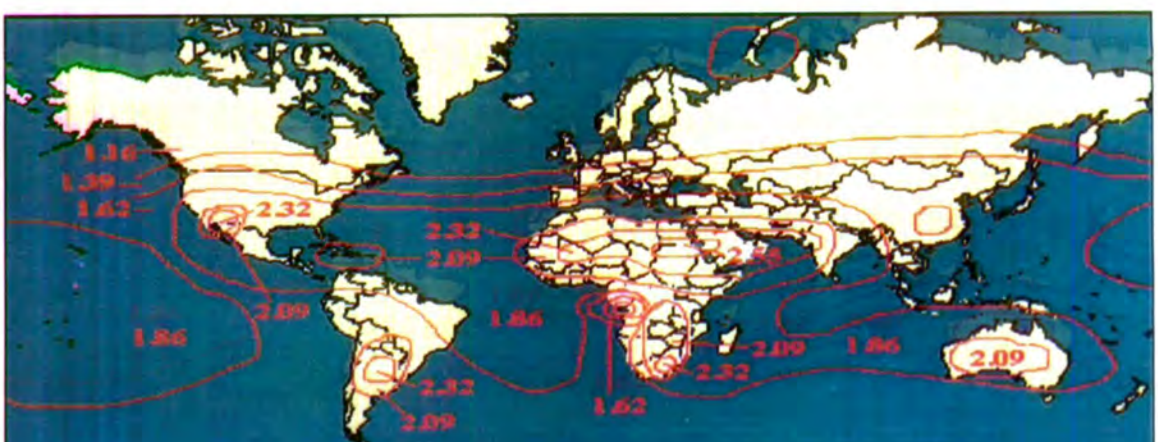
In the early part of this century these streams had been used for micro-scale power generation mainly to fulfil the electricity requirement of individual tea factories. Most of them were abandoned with grid electricity penetrating into tea estates in the early nineteen sixties. Records reveal that there had been around 500 micro-hydroplants with capacities varying from 10 kW to 250 kW providing a combined capacity of around 20 MW. The potential capacity at these sites may be as high as 40 MW. When other potential larger scale sites are also considered the total exploitable small hydro potential on the country is estimated at around 100 MW to 120 MW with an annual energy output of around 350 million units.

Photograph by Priyantha Wijayatunga.

Figure 13: Weir and the channel of typical micro hydropower unit

The CEB now allows grid connection of small hydroplants and offers to buy all the energy injected into the system by such plants at a pre-published power purchase tariff, meant specifically for small power producers. As the initial capital investment required on micro- hydro plants is now reduced and comparable with investment in conventional electricity generation systems, a considerable interest among private investors has been created for this activity. Presently, studies are being carried out on the development of many of the sites identified in the Electricity Master Plan of 1987. Two such small hydroplants have already been connected to the national grid during the last three years.

Also, the Intermediate Technology Development Group (ITDG) and other Non-Governmental Organizations (NGOs) have been involved in developing stand-alone small hydro plants in remote villages which have no access to grid electricity. These plants have capacities in the order of 1 kW to 25 kW. The villagers themselves, with technical and financial assistance from sponsoring institutions, generally implement and manage these schemes. In general, each household in these schemes is provided with 100 W to 200 W of capacity for lighting and other low capacity household requirements. Other end use activities such as rice milling and battery charging are carried out during daytime. With the introduction of the Energy Services Delivery Project (ESD) of the World Bank, more of these stand-alone village hydrosystems are encouraged



Source : Web site http:// www.chatlink.com/nsolthern/insol.htm:, International Solar Collectors, Inc.1996.

Figure 14 : Global distribution of the annual average solar radiation (TWh per km^2)

with grant funding made available for technical support and to cover part of the investment cost.

Photograph by Aruna Ranaweera

Figure 15: Solar PV based water scheme in Monaragala District

Solar power

Solar insolation in Sri Lanka is considerably high, at an annual rate of 1.86 TWh $/km^2$ on average (Figure 14). Therefore it is important to examine the use of solar energy based power supply systems in the Sri Lanka context.

In Sri Lanka, traditionally solar power has been used directly in day to day activities mainly in drying processes. Solar drying of various agricultural products such as rice, chilli and many others has been the largest single consumer in this area. In recent times, solar hot water systems designed to capture direct solar radiation for water heating, have been used by a few affluent households and tourist hotels in the country, mainly motivated by increasing electricity costs. Also, there are ongoing research and development activities addressing the use of solar thermal systems in the industrial sector as a means of cheaper and cleaner energy supply.

In 1980, with the formation of the Energy Unit at the CEB, Sri Lanka started promotion of solar photo-voltaic (PV) systems for rural domestic use. Since then many private sector companies have been involved in assembling and marketing solar PV systems in the country. However, the solar photo-voltaic cells are all imported.

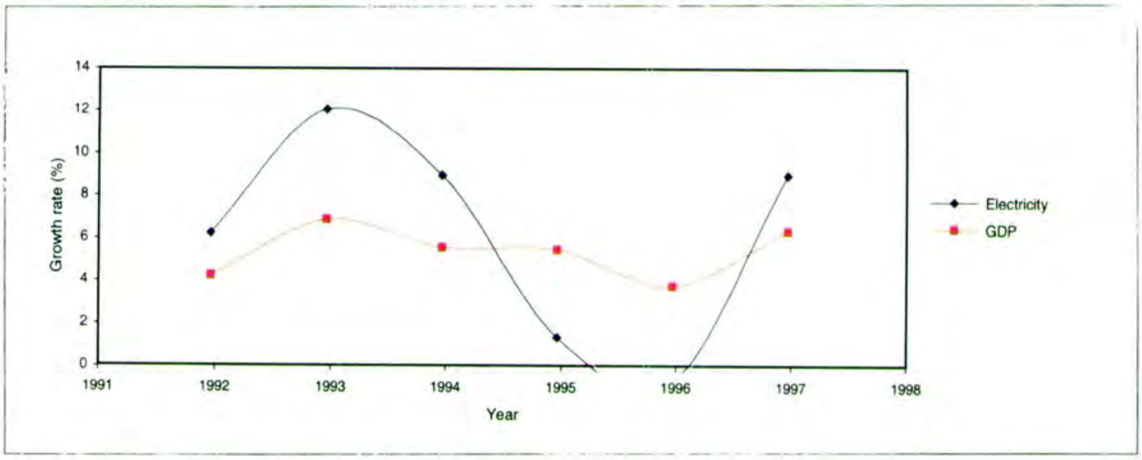
The main solar PV applications identified for Sri Lanka are in domestic lighting, operating radios and television sets in remote rural areas. Also, there are around 20 solar PV based water-pumping schemes in Monaragala and Badulla Districts, established with grant funding from the Australian government.

A typical 40 W solar PV system can be used to operate around four eight W lamps, radio and a black & white television set. A system of this capacity costs around Rs. 25 000 including all the accessories for internal wiring and a local battery. If this is financed through a normal bank loan, the monthly repayment is so heavy that the rural poor find it hard to repay, unless the venture is coupled with an income generation opportunity.

In general, solar photo-voltaic systems are not economically viable for large or moderate power applications.

ENERGY – ECONOMY RELATIONSHIP

Increasing energy consumption is coupled closely with economic growth, population growth and energy prices. With liberalization of the economy in the late 1970s, the demand for energy and its rate of growth increased significantly. The growth rate of energy consumption during the period 1977 to 1982 had been approximately six per cent per annum while the gross domestic product (GDP) growth rate during the same period was 6.8 per cent. From 1982 to 1989, the annual energy consumption rate declined to 1.3 per cent, while the GDP growth rate had dropped to 3.7 per cent, mainly due to economic and social instability resulting from the insurgency experienced at that time. The above energy growth rate figures refer to the total commercial energy supplies which include petroleum oil and electricity. In the electricity sector itself the growth rate is higher and usually corresponds to about 1.4 to 1.5 times the growth rate of GDP, in the case of Sri Lanka, as shown in Figure 16. Petroleum consumption has grown at the same rate as that of the GDP.

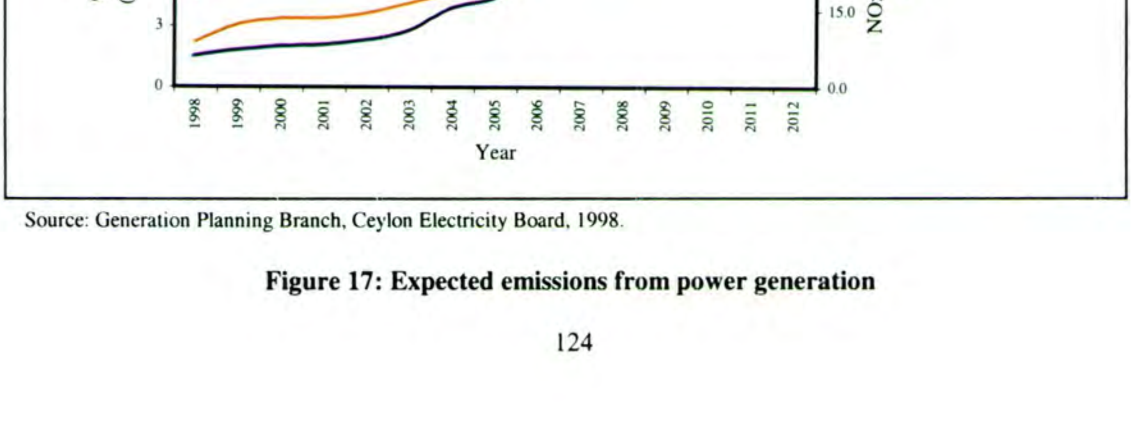


Source: Annual Report 1997, Central Bank of Sri Lanka.

Figure 16: Growth rate of GDP and electricity demand

ENERGY AND ENVIRONMENT

Increased energy generation and utilization have become a necessity in most countries to support economic development. This is because of industrial development in the manufacturing and agricultural sectors and increased demands for energy by transport, tourism, hotels, banking and support services. Although careful planning and re-structuring can slow down the growth rate of energy required by a country, additional energy is required every year to meet development needs. Increased energy usage has become synonymous with development, with increased pollution and degradation of the environment. The global factors among these are increased emission of carbon dioxide, sulphur oxides and nitrogen oxides, all of which are associated with the combustion of fuels. In a local context, particulate materials such as unburnt carbon from coal or oil fired boilers are of immediate concern. Acid rain which may contain sulphuric acid is also of concern in a country having large coal or oil fired power stations. Also, carbon monoxide and particulate material emitted from motor vehicles and trains are a major concern, particularly in cities where there is heavy traffic and high population density.



Source: Generation Planning Branch, Ceylon Electricity Board, 1998.

Figure 17: Expected emissions from power generation

Hydropower stations too have their own negative environmental impacts. Large scale inundation of populated areas or forests are generally detrimental to the local environment. These can be minimized by proper planning and by using these reservoirs to an advantage where possible. In general, the environmental impact of large hydropower stations is relatively low when compared to fossil fuel based power stations of equivalent capacities.

Wood fired boilers for industrial purpose or for power generation have a direct advantage over coal or oil fired boilers in terms of environmental impacts, provided such usage is coupled with energy plantations established for that purpose. **This is because growing of trees and burning of resulting fuelwood is a net zero carbon dioxide emission process; it does not add extra carbon dioxide to the atmosphere. This may be compared with coal or oil fired stations which release large quantities of carbon dioxide, releasing carbon which had been trapped for millions of years in the form of oil or coal.**

It can be seen that the present level of greenhouse gas emissions in Sri Lanka stands at a considerably lower value compared to other countries in the region as given in Table 6.

Relevant government, as well as, non-governmental institutions have been promoting energy efficiency improvement in different sub-sectors in various forms. The Energy Conservation Fund embarked on a large scale field study on the performance of Compact Fluorescent Lamps (CFL) in Sri Lanka with the assistance of the CEB and the University of Moratuwa. Later CEB successfully completed a major programme on popularizing CFLs by distributing lamps at duty-free prices. Currently the CEB is implementing another programme where CFLs are distributed to the consumers on monthly cost recovery basis at no interest. In addition, energy auditing has penetrated, rapidly into the industrial and commercial environments during the last decade, with increasing number of institutions seeking for energy efficiency improvement and related advice.

Table 6 : Per capita CO_2 emissions in selected countries and groups of countries by income

Country	Per capita CO_2 emissions in 1980 (t)	Per capita CO_2 emissions in 1995 (t)
Bangladesh	0.1	0.2
India	0.5	1.0
Nepal	0.0	0.1
Pakistan	0.4	0.7
Sri Lanka	**0.2**	**0.3**
Thailand	0.9	2.9
Low income country group	0.4	0.7
Middle income country group	1.6-4.3	3.5-4.5
High income country group	12.0	12.5

Source : World Development Report, World Bank, 1998.

Although electricity generation does not produce much pollution now, according to present generation plans it will become a large contributor to air pollution in Sri Lanka in the future, as shown in Figure 17.

EDUCATION, RESEARCH & DEVELOPMENT

Research activities in the energy sector vary widely from specialized technical areas such as development of efficient local turbines for small hydroplants, to policy level studies like development of an energy policy for Sri Lanka or establishing linkages between providing energy services and poverty alleviation in developing countries.

The institutions involved in education, research & development in the field of energy can be grouped into two main categories. There are some large organizations such as the Ceylon Electricity Board engaged in studies, training and research & development purely aiming at their own development programme. These include investigations for future thermal and hydropower plants involving feasibility studies and detailed investigations such as locating suitable dam sites, after geological investigations. The second category consists of those directly involved in research activities either as pure research or catering to the requirements of development programmes in other institutions. These efforts are not coordinated and are handled by several organizations. These organizations include the National Science Foundation (formerly NARESA), the Energy Conservation Fund (which is a Statutory Board presently under the Ministry of Power & Energy), the National Engineering Research & Development Centre (within the Ministry of Science & Technology), the Sri Lanka Energy Managers' Association (SLEMA) set up by an Act of Parliament, and Lanka International Forum on Environment and Sustainable Development (LIFE). Funding for these research activities are made available by the government through an allocation in the annual budget or by other national and international agencies such as UNDP, USAID, World Bank, ADB, SIDA and Asian & Pacific Development Centre (APDC).

The Universities and Research & Development Institutions also carry out a certain amount of research and development activity either through their own funding or funding from other sources such as the National Science Foundation, Energy Conservation Fund, or funds from foreign organizations. The Ministry of Science & Technology, itself, through its Alternate Energy Division, has embarked on a pilot project involving energy plantations with the assistance of the European Union. There are 12 plantations being established (1999) under this programme. Although there is informal coordination of the various activities associated with research and development in the energy sector, there is a need to formalize some degree of coordination and dissemination. Perhaps these coordinating and monitoring efforts would become a subject of the newly (1998) established National Science & Technology Commission (NASTEC), which is the apex body for Science & Technology.

INSTITUTIONAL FRAMEWORK

The Energy Sector is handled mainly by the Ministry of Irrigation & Power under which large institutions such as the CEB, the Ceylon Petroleum Corporation and the Energy Conservation Fund function. In addition, the Lanka Electricity Company, which is a public sector company (with CEB holding a majority share), handles a part of the electricity distribution.

Liquid Petroleum Gas, also, was handled earlier by the public sector through a competent authority, but was later converted to the Gas Company. In 1994, this company was transferred to the private sector having a majority foreign share holding and is presently operating as Shell Gas Lanka Ltd.

Biomass, which includes fuelwood, is the largest energy source used in Sri Lanka but is not formally within the patronage of any government ministry for active development and marketing and for seeking private sector participation.

The electricity sector is under regulation of the Chief Electrical Inspector who reports directly to the Minister in charge of electrical power. The Chief Electrical Inspector is responsible for functions such as issue of electricity generation and distribution of licenses and approving their tariff (provided it is outside the CEB). However, developmental activities are not adequately covered by this mechanism.

In addition, Ministries of Science and Technology and Forestry & Environment also have a stake in the energy sector, mainly arising from their involvement in Research & Development aspects and in the development of renewable energy sources, as well as, their concerns in terms of environmental impacts of energy sector development activities.

Presently there is a major drive for energy sector reforms which is addressing the electricity sector. Under the auspices of the ADB and World Bank, it has been proposed that the electricity utility industry be split into strategic business units such as hydropower, thermal generation, transmission and regional distribution systems. A reform manager is expected to be in place shortly, to organize and implement the proposed restructuring process.

ENERGY SECTOR REFORMS

Traditionally, the energy sector in Sri Lanka has been dominated by state owned monopolies such as Ceylon Electricity Board and Ceylon Petroleum Corporation (CPC). With increased emphasis on private sector participation in the energy sector throughout the world, during the last few years Sri Lanka has been compelled to revisit its strategy towards the development of its own energy sector. Restructuring of the energy sector has become even more important with dwindling financial assistance from donor agencies for its development.

Electricity Sector

Sri Lanka government strategy on the development of the electricity sector has been highlighted in the recently published "*Power Sector Policy Directions*". It is expected that the electricity demand will double every seven years requiring approximately US$ 1.5 billion for generation capacity expansion. Further US$ one billion is required for transmission and distribution expansion. The private sector is expected to play an important role in financing the major part of the generation system expansion, where such investment can be easily attracted.

Only solicited proposals will be accommodated for future generation projects on a Build Operate and Own (BOO) or Build Operate and Transfer (BOT) basis. However, even unsolicited proposals will be considered if such proposals accompany setting up of nationally important large scale manufacturing projects or industrial parks.

The power sector is to be restructured to encourage competition and facilitate private sector participation by decentralizing the existing vertically integrated electricity industry, where generation, transmission and distribution of electricity is largely carried out by one state owned utility. During this process, generation, transmission and distribution functions will be separated and generation and distribution will be subdivided horizontally to form a number of entities. Transmission of electricity will be handled by a separate publicly owned transmission authority. It has been proposed that the government establish a transparent regulatory framework and enact legislation to provide a sound basis for power sector economic, financial, environmental and service policies.

Power sector planning will be based on the framework of integrated resource planning where least cost system development methodologies will be adopted. Government will make necessary institutional and financial arrangements to ensure successful implementation of rural electrification projects and establishment of an electricity tariff policy encompassing economic, technical and social requirements.

Petroleum Sector

Although commitment to restructuring of the petroleum sector is not as strong as that in the electricity sector, it has been widely discussed and debated. It has been proposed to remove the monopoly of the CPC in the petroleum sector, allowing new importers, distributors and new refineries to compete with the CPC in those sub-sectors. Before embarking on such a reorganization process within the petroleum sector, it is important that the anomalies in the tax structures within the sector are removed. These anomalies have resulted in unfair competition between different petroleum fuels such as gasoline and liquid petroleum gas and gasoline and diesel. Private sector participation in the petroleum sector can be secured by providing a level playing field for all the parties involved in the sector through uniform tax structures and other financial incentives across the sector.

Biomass

Though biomass accounts for a large percentage of total energy supply in the country, this sector has been operating without any government involvement or encouragement to date. It has been proposed that necessary action be taken to commercialize utilization of biomass by encouraging establishment of private sector energy plantations along with the use of wood fuel in traditional sectors such as domestic cooking, tea industry and small and medium scale industries. Further, biomass based electricity generation with accompanying energy plantations should also be encouraged.

In view of its significant contribution, it has been proposed that a "Biomass Energy Agency" be established to coordinate and promote production, marketing and efficient use of biomass. This agency is expected to facilitate the functions such as leasing of unproductive marginal land to "tree farmers" at a nominal rate while providing technical know-how involving establishment and operation of energy plantations and power plants.

CONCLUSION

At present, Sri Lanka is heavily dependent on imported petroleum to satisfy its commercial energy needs. As indicated, petroleum consumption is expected to grow rapidly if the present energy consumption pattern continues into the future. The increase of imported fossil fuel consumption will be even more drastic with the planned scenario where thermally generated electricity growth is much more than the growth of hydroelectricity. The alternative to this scenario has to come from a system where non-conventional or renewable energy sources such as wind, solar, hydro and biomass will play a major role. The economically exploitable wind energy is extremely limited; even the recently (1999) commissioned limited capacity (3 MW) wind energy plants at Hambantota deliver electricity at a higher price than electricity from diesel and other conventional methods. With the limited extent of further hydropower resources that can be economically exploited, biomass remains the only local large scale energy supply which can be developed to an appreciable extent in Sri Lanka. Though a large extent of solar insolation falls on Sri Lanka, electricity through solar cells for generalized power generation is prohibitively capital heavy, and thus expensive. Therefore, the encouragement of the commercial establishment of energy plantations and the competitive use of biomass so created for direct burning for heat energy and for electricity generation where possible, will be of long term benefit to Sri Lanka in the 21st century. This is the most economic method of exploiting solar energy, which will also increase greenery and is environment friendly.

Restructuring of the energy sector in a manner so as to maximize the economic and technical efficiency within the sector, while giving due attention to locally available resources which have the capability to provide large scale energy inputs is needed. It is important to choose a balanced path to the energy sector development with the objective of minimizing unavoidable adverse environmental impacts while ensuring continuous supply of energy requirements of the population.

Research and development in the energy sector should continue with more emphasis on locally available energy resources while giving due consideration to field implementation of these research outputs. Special attention is required in adaptation of technology developed abroad, to suit the local energy sector environment.

REFERENCES

1. *Annual Report 1997* (1998) Central Bank of Sri Lanka, April.

2. Danapala K., Wijayatunga P.D.C., Fernando W.J.L.S., Ariyadasa L., Joseph P. J., Fernando S. (1998) Environmental & Economic impact of using Micro-hydro and Biomass power in the Tea plantation sector in Sri Lanka. *Research Report*, Ministry of Forestry and Environment.

3. Daranagama U., Wijayatunga P.D.C., Ariyadasa K.P., Kumarasiri H.K. (1999) Feasibility of Dendro Power Based Electricity Generation in Sri Lanka, *Research Report, Energy Forum*, Sri Lanka, January.

4. *Energy Sector Strategy Study* (1998) *Asian Development Bank,* TA 2795-Sri, Ministry of Irrigation, Power and Energy.

5. Fernando K.S. (1996) Small Thoughts and Experiences on Wind and Micro Hydro Power, *Economic Review*, August.

6. Gunaratne L. (1994) Solar Photovoltaics in Sri Lanka: a Short History, *Progress in Photovoltaics: Research and Applications*, Vol-2.

7. *Long Term Generation Expansion Planning Studies:1996-2010* (1996) Generation planning Branch, CEB.

8. Meier P. and Munasinghe M. (1994) Incorporating Environmental Concerns into Power Sector Decision Making: A Case Study for Sri Lanka, *World Bank Environment Paper.* No 5, The World Bank.

9. Perera K.K.Y.W. (1992) *Energy Status in Sri Lanka: Issues-Policy-Suggestions.* Institute of Policy Studies, Sri Lanka.

10. Perera K.K.Y.W. (1997) *Energy Policy for Sri Lanka*, National Energy Committee Report to the Hon. Minister of Irrigation Power and Energy, Sri Lanka.

11. *Power Sector Policy Directions* (1998) Ministry of Irrigation and Power, October.

12. *Report of the Regional Workshop on Selection of Pilot Projects* (1997) Asian and Pacific Development Centre, Malaysia, August.

13. Wijewardena R. & Joseph P.G. (1997) Energy Plantations: Complementing hydropower for sustainable thermal energy and rural employment in Sri Lanka, *Achievers*, September.

14. Wijayatunga P.D.C. (1998) Prospects of Renewable Energy Sources in Sri Lanka: Pricing and Other Issues, *Workshop on Energy and Environment*, LIFE/German Cultural Institute, January , Colombo, Sri Lanka.

15. *World Development Report 1998/99* (1998) World Bank.

Courtesy : Geological Survey & mines Bureau.

Mineral Resources

MINERAL RESOURCES

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Summary

Sri Lanka in relation to its size is reasonably well endowed with mineral resources, particularly of the non-metallic type such as gems, graphite, phosphate and clay. Even though the mineral industry has recently shown signs of an upward trend, it falls far short of its potential for growth.The non-addition of value to the mineral products, is one of the major reasons for its hitherto mediocre performance. Further, the development of small and medium scale industries has to be addressed as a national priority. However, there has been a major improvement in the geological mapping programme conducted by the Geological Survey and Mines Bureau (GSMB) and this should facilitate potential mineral investors. The mining of mineral resources has always raised environmental concerns, notably in gem and sand mining. The National Environmental Action Plan has introduced stringent measures to protect the environment from these mining activities. Better coordination among the GSMB and the geo-scientific research organizations, particularly the universities, would undoubtedly prove to be a boon to the development of the mineral sector of Sri Lanka.

INTRODUCTION

Sri Lanka, for its size, is reasonably well endowed with mineral resources especially of industrial minerals and rocks. The earliest attempts at studying the geology and mineral resources of the country were made by the Imperial Institute of London, which carried out mineral surveys during the period 1903-1918. The Mineral Survey of Ceylon was established under the Imperial Institute in 1903 and its first Mineral Surveyor, Ananda Coomaraswamy, made many significant discoveries of valuable mineral occurrences. These included gemstones, gold and graphite. Even after several decades, his mineral discoveries formed the basis of economic mineral exploration.

Several others who followed Ananda Coomaraswamy also made useful contributions on minerals of economic importance to Sri Lanka. Foremost among them were D.N.Wadia, E.J.Wayland, J.S.Coates, J.D.Fernando, P.W.Vitanage, D.B.Pattiarachchi and P.G.Cooray. The history of the Geological Survey Department is discussed in detail in the publications of Herath (1995) and Seneviratne (1997) and the reader is referred to these sources for further information. The Geology of Sri Lanka is presented comprehensively in the book "An Introduction to the Geology of Sri Lanka" (Cooray 1984).

The Department of Mineralogy, which was set up in 1938 as the successor to the Mineral Survey of Ceylon, began systematic mapping of the geology of the island on the scale of 1 inch = 1 mile in 1952. Mapping continued until the seventies, when the geological survey of most of the island on a reconnaissance basis was completed. The Memoirs, Professional Papers and Administration Reports and other reports of that Department and of its successor the Geological Survey Department (from 1962) contain much useful information on the geology and mineral resources of the island. These data have contributed much to the initiation and development of the flourishing mineral-based industries of Sri Lanka. They also contain a great deal of information on the groundwater resources of the island and on the geotechnical engineering problems faced and solved by the Geological Survey Department (GSD) in those early years.

The first large scale geological map of Sri Lanka was in black and white (Cooray, 1967) and the first coloured geological map (8 inches = 1 mile) was published by the GSD in 1982. The geology and mineral resources of Sri Lanka began to be better understood after 1980, when several groups of Japanese and German geologists visited the island and published the results of their work in international and local journals.

The Department of Geology at the University of Peradeniya, also provided an impetus to research on minerals in Sri Lanka, specially with regard to graphite, gems and phosphates.

With the introduction of the new Mines and Minerals Act No. 33, which began operating in 1993, the Geological Survey Department was re-named as Geological Survey and Mines Bureau (GSMB) with Dr N.P.Wijayananda as its first Director. With this change, the GSMB made remarkable progress, particularly in its mapping programme with the assistance of the British Geological Survey under an aid programme. Modern and up to-date geological maps of the scale 1: 100 000 and 1: 250 000 are now available and the mineral sector holds much promise for the year 2000 and beyond.

It has been estimated that mineral exports account for only about five per cent of the nation's export earnings. Even though Sri Lanka does not possess large metallic ore deposits, the above figure is far below the potential of the mineral sector to contribute to the national development of Sri Lanka. Most of our minerals are exported in the raw state, at present. The lack of viable, mineral industries capable of value addition has resulted in poor performance, except in the cement and ceramic industries. Among the minerals that could be value added, still exported in the raw state are graphite, mica, and some mineral sands. Further, many of the non-metallic types of minerals of Sri Lanka are yet to be studied for their potential economic value. Therefore, there is under-utilization of these valuable mineral resources.

MINERAL RESOURCES OF SRI LANKA

Referring to our mineral resources in general, it could be stated that we have very little by way of energy minerals, slightly more significant quantities of metallic minerals, but have major resources of non – metallic minerals (Table 1). Among the latter are graphite, gemstones, mica, ceramic and other clays, quartz, feldspar, limestone, mineral sands, marbles, building and ornamental stones, and phosphate, all of which have industrial applications.

Figure 1 illustrates the locations of the mineral resources of Sri Lanka

Table 1 : Classification of Mineral Resources of Sri Lanka

Energy Minerals Uranium Thorium Peat	Siliceous Minerals Vein quarts Silica sand Quartzites
Ferrous and Ferroalloy Minerals Iron ore Copper Iron deposit Nickel bearing serpentinites	Precious Minerals Gemstones Gold
Products of Weathering Clays Bauxites Laterites	Fertilizers Rock Phosphate
Calcareous Minerals Limestones Corals and shells Dolomitic rocks	Carbon Minerals Graphite
Minerals Sands Ilmenite Monazite Rutile Zircon Sillimanite Garnet	Others Feldspar Mica

Source: Herath, 1995.

Gemstones

Sri Lanka has been known for over 2000 years for gemstones unique in quality and variety, and today they are the country's most renowned and important mineral resource. Over the years, Sri Lanka has risen to the prestigious position of being the producer of the world's best sapphires, some of which even adorn the crown of British monarchs. Considering the abundance and numerous varieties that are now found, it could be stated that nowhere else in the world is there such a variety, abundance and concentration of gem minerals in a comparatively small area, as in Sri Lanka.

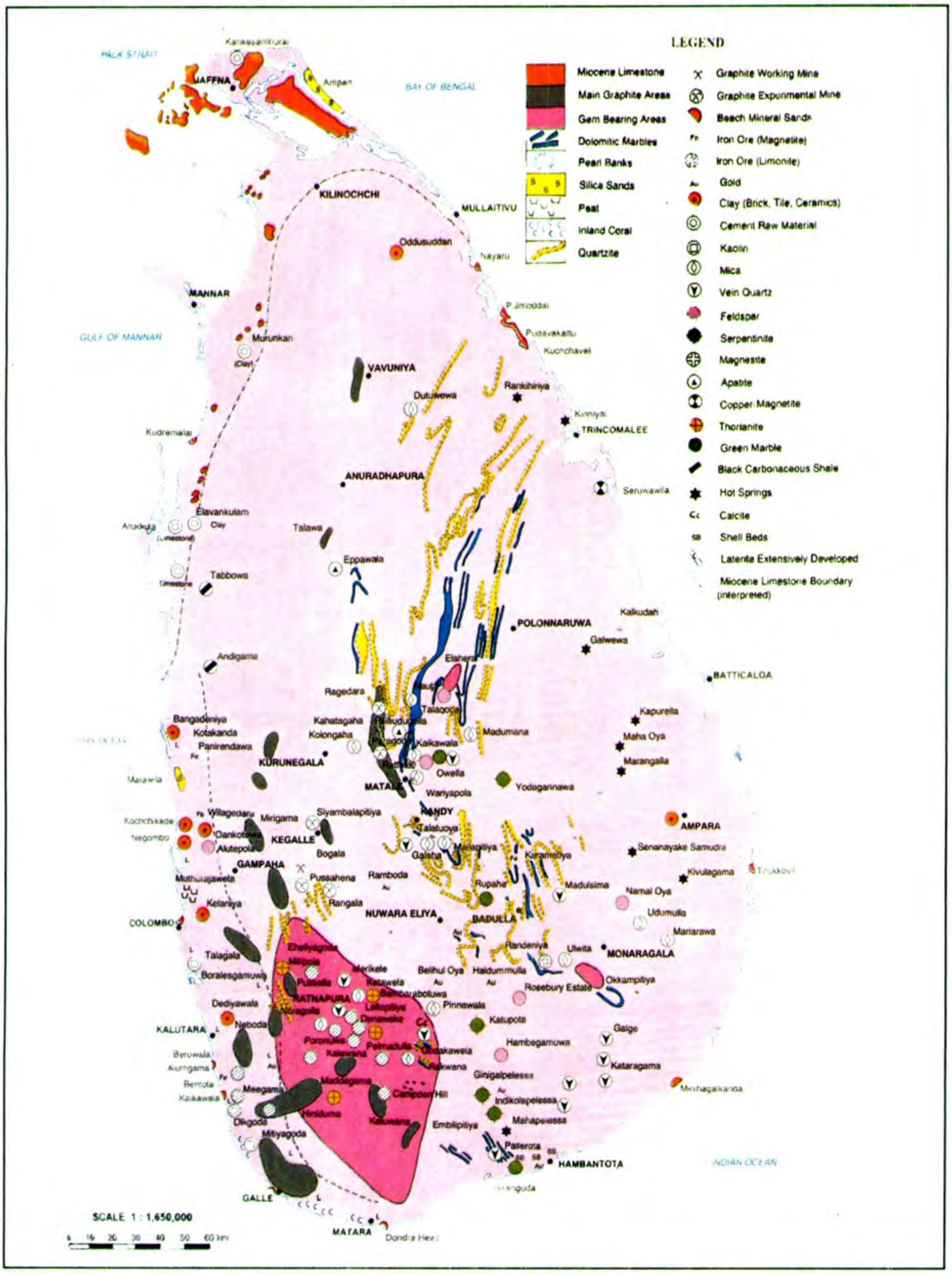
Gemstone deposits lie within a geologically narrow zone (240x64 km^2). Recent geological surveys suggest that the gemstone resource is about 50 per cent higher than hitherto expected. Many new gem fields have been located in the central highlands and in southwestern geological formations.

Gem minerals are obtained from eluvial, alluvial and residual formations. The Sabaragamuwa Province, with Ratnapura as its leading centre, has approximately 80 per cent of the gem mines, but even in areas peripheral to the main gem fields, there is a high potential for gems.

In their natural state, the gem minerals occur in thin layers of gravel and sand termed *"illam"* (Sinhala) in river beds and alluvial flood plains, as rounded pebbles and worn fragments. Most gem pits contain several layers of *illam* that lie above the underlying decomposed bedrock termed *malawa*.

Gem mining

Most gem mining practices have changed little in Sri Lanka since mining first commenced. The most common method is small scale pit mining with lateral tunnelling. Riverbed mining is also



Adapted from Arjuna's Atlas of Sri Lanka, 1997.

Figure 1: Mineral resources map of Sri Lanka

Table 2 : Annual Export of Gemstones 1993 – 1998

	1993		1994		1995		1996		1997		1998	
	Qty	Value	Qty	Value	Qty	Value	Qty	Value	Qty	Value	Qty	Value
Blue sapphire	35.9	370.7	52.8	442.8	64.0	432.0	39.9	317.1	79.5	714.5	95.2	1150.7
Star sapphire	461.3	517.6	360.5	291.5	435.4	356.5	278.0	285.4	525.3	597.6	92.3	181.6
Ruby	1.3	38.2	0.8	26.4	2.2	30.1	1.9	32.0	3.0	96.0	6.4	55.4
Star ruby	5.1	69.2	3.5	49.2	3.1	42.8	71.5	30.7	11.5	90.6	7.5	33.5
Cat's eye	28.2	323.4	27.8	324.3	42.6	400.7	32.3	311.5	61.8	686.4	24.0	315.1
Others	4 022.1	670.7	5 070.3	861.3	3 560.7	728.7	4 070.1	522.1	16 469.5	1 409.0	12 081.5	1 161.6
Total Exports	4 553.9	1 989.8	2 516.7	1 995.5	4 108.0	1 990.8	4 493.7	1 498.8	17 150.6	3 594.1	12 306.8	2898.0

Source : National Gem & Jewellery Authority.
Qty – Thousand Karats
Value – Million Rupees

common. Pit mining, by far the most common method, involves construction of vertical mines as deep as 30 m, with horizontal tunnels averaging about 10 m in length. Gem gravel is removed from the *illam*, washed and sorted in wicker baskets, placed in water. The swirling motion during washing separates unwanted lighter materials from the heavier gem materials that are then collected and identified. Mechanical equipment is largely limited to the pumps required for removing water that accumulates in the gem pits. Relatively inexpensive and easily available labour has made this simple, almost primitive, method viable.

Stream bed mining involves the damming of streams and small rivers by logs, sandbags and other materials. Workers use long shovels and mammoties to drag streambed material on to the dam. The heavy mineral fraction, which includes gemstones, is separated out and stored for later washing and sorting. Stream banks are also worked in this manner. Large scale mechanized mining is prohibited, particularly on the river beds, on account of the obvious environmental damage that will be caused.

The Gem industry

It is an established fact that even though Sri Lanka's gem mineral resources are substantial, the gem industry has performed below its full potential, due to various constraints and weaknesses in its organizational structure. In the mineral sector which brings in only five per cent of foreign exchange earnings, 60 per cent is derived from the export of gemstones (Table 2). One of the main suggestions for the enhancement of the income generating capacity of the industry is to utilize the precious gem materials in their raw state to produce finished goods locally by value addition, such as cutting and polishing to suit the customers' requirements. The establishment of a marketing organization to channel the natural gemstones into foreign markets through legitimate channels is another important proposal.

The National Gem and Jewellery Authority, which was established in 1993, is the state organization responsible for the development of the gem industry and was the successor to the State Gem Corporation, established in 1971. Its main functions are to: (a) regulate gem mining and the gem trade; (b) undertake research, development and training; (c) engage in market research, market development and trade promotion. However, it will not engage in trading of gems or manufacture of jewellery.

Table 2 shows the varieties of gemstones of Sri Lanka that are now exported and the income generated .One of the main weaknesses in the gem industry at present is the lack of infrastructure for collection, evaluation and grading and the lack of systematic channeling of the gemstones into legitimate markets. Furthermore, there is a clear need for improvement of the marketing strategy to explore markets abroad.

The Sri Lanka Gem Traders' Association recently proposed an agenda for the development of the Gem and Jewellery Sector in Sri Lanka. They showed that in order to improve the present situation of the gem and jewellery industry, the following measures must be taken into consideration:

1. Reconsideration of the policy which governs gem mining, with particular regard to promoting mechanized mining techniques, which will use gem deposits that cannot be accessed by labour intensive methods. Formulation of suitable controls to avoid or mitigate environmental impacts of such projects.

2. Development of infrastructure for identification, evaluation and grading of rough gems produced, including the modification of taxation methods to re-divert gems from illegal to legal markets.

3. Development of financing methods to facilitate large scale heat treatment, colour diffusion and other methods of value enhancement of calibrated *geudas*.

4. Development of calibrated cutting practices and adherence to international standards.

5. Creation of special incentives to facilitate large scale jewellery manufacture and development of a specialist market in Sri Lanka for high value gems and jewellery.

6. Proper identification, evaluation and grading of finished goods .
7. Identification of markets and formulation of a suitable strategy for export marketing.
8. Further liberalization of gem imports to engage gem cutters and to sustain the local lapidary and gem and jewellery industry.

In view of the fact that the gem and jewellery industry consists of a large number of small enterprises which have vast combined potential to create employment and additional income, the 1998 parliamentary budget proposals exempted the gold, gem and the jewellery industry from income tax as well from the National Security Levy. The importation of gems and gold were also granted duty free status. All licensed banks were permitted to operate specialized branches for gem trading. The National Gem and Jewellery Authority regulates the industry and issues mining licences for gemming in definite places. It was also proposed that the Authority collects a fee of one per cent on the sale of rough stones and use such sale proceeds to provide insurance cover to gem miners.

Graphite

Sri Lanka has also been renowned for its graphite. Graphite is the world's source of high quality microcrystalline carbon material. The Sri Lankan graphite has unparalleled purity of over 99 per cent carbon. The occurrence of graphite as massive veins occupying natural fissures in rocks allows relatively easy mining. Nearly 6000 shallow pits and small mines operated during each of the two world wars. The reason for increased demand during those years is unclear. However, the numbers have dwindled markedly over the years due to serious problems of marketing. The two main deep underground graphite mines in operation today are the Kahatagaha and Bogala mines. Even though there is a good demand for Sri Lankan graphite, the industry cannot compete in the international market due to the high cost of production. It has been suggested that more attention should be paid to the exploration and development of shallow graphite deposits.

The graphite industry of Sri Lanka which had its beginning in the early part of the 18th century had a period of intense activity during 1869 to 1918. It was during this period that a very large number of graphite mines were in operation, particularly in the southwestern parts of Sri Lanka. In 1995, however, there was only one graphite mine in operation and that, too,was not running at a profit. The share of Sri Lankan graphite in the world market, which figured prominently at 35 per cent prior to 1912, had dropped to two per cent in 1980, and by 1995 it was only a mere fraction.

The collapse of the graphite industry of the country was entirely due to poor marketing strategies. The price of Sri Lankan graphite was increased by a factor of almost three from US $ 375 in 1978 to US $ 1100 in 1981. This change naturally resulted in a marked decrease in demand and the 11 163 tonnes exported in 1978 dwindled to 3025 in 1982.

Serious efforts are now being made to revive and revitalize the Sri Lankan graphite industry and at present the two main underground graphite mines, namely Kahatagaha and Bogala, are both in operation. Production figures indicate that for the Bogala mines, recovery has been achieved in a relatively short time of 17 months from November 1994 .

Plans are now being made to open small mines and develop shallow graphite deposits. Furthermore, the establishment of a semi colloidal graphite project is now being worked out, bearing in mind the almost negligible value addition to our graphite. The development of a large number of small mines scattered in some parts of the country (Fig.1), would allow greater employment generation with enhanced economic productivity .

Ceramic Raw Materials

The ceramic industry is the country's largest industrial concern dependent on local mineral raw materials. Ceramic raw materials include quartz, feldspar, calcite, dolomite, red or ferruginous clay, zircon, ball clay, kaolin and graphite. These are available in quantities adequate to meet the ceramic requirements over the next two or three decades.

The ceramic industry of Sri Lanka has shown remarkable progress over the last two decades. With the establishment of Lanka Ceramics Limited in 1991 as the successor to Ceylon Ceramics Corporation, very high quality Sri Lankan ceramic products are now in the international market. Among these are porcelain and wall tiles. Sri Lanka's annual ceramicware exports are worth over US $ 35 million and reach some 65 countries. The high grade raw materials found in Sri Lanka, coupled with modern Japanese technology, has resulted in this major achievement. Among the major contributors to this achievement are industrial concerns such as Noritake, Lanka Wall Tiles and Royal Ceramics.

Industrial Clays

Sri Lanka has significant clay deposits and these have been divided into three clay mineral provinces, based on the frequency distribution of clay and associated minerals in the alluvial and residual soils. Herath (1973) and Herath and Grimshaw (1971), have described the three clay mineral provinces as:-

Wet Zone Clay Mineral Province

Mainly kaolinitic clay (china clay)

Kaolinite-gibbsite-boehmite clays with mixed layer mineral and vermiculite (ball clay)

Kaolinite-gibbsite-goethite clays with mica, mixed layer mineral and vermiculite (brick and tile clays)

Dry Zone Clay Mineral Province

Kaolinite-montmorillonite clays devoid of gibbsite but with calcareous material (brick and tile clays)

Intermediate Zone Clay Mineral Province

Kaolinitic clays relatively low in gibbsite and montmorillonite (brick and tile clays)

It has been shown that Sri Lanka has adequate clay deposits to sustain a viable ceramic industry. The tile industry of Sri Lanka has clearly benefitted due to the presence of good quality clays. Over 80 per cent of the tile industry is concentrated in the lower reaches of the Maha Oya around Kochchikade, where there are over 100 tile factories (Herath 1995). He has shown that for a factory to produce one million tiles per annum, three acre – feet of clay (about 4200 tonnes) are required. Accordingly, for a production of 50 million tiles, over 15 acres of land to a depth of more than 10 feet, have to be mined for the recovery of over 200 000 tonnes of clay .

The brick industry, mostly a widely distributed cottage industry, produces over 90 per cent of the requirements of the country for building construction. Further uses are seen in the manufacture of pottery, clay stoves and floor tiles.

Mineral Sands

The beaches of Sri Lanka are rich in sands containing minerals such as ilmenite, rutile, monazite and zircon . At Pulmoddai, 77 km north of Trincomalee , a beach placer deposit along about 8 km of the coast contains about 6 million tonnes of raw mineral sands containing 70 – 72 per

Table 3 : Annual production of Mineral Sands

	1994		1995		1996		1997		1998	
Commodity	Qty	Value	Qty	Value	Qty	Value	Qty	Value	Qty	Value
Ilmenite	59 911	65.1	50 250	62.9	62 810	23.5	17 969	7.1	34 118	na
Rutile	2 411	5.9	2 884	5.4	3 532	6.4	2 968	5.3	1 930	na
Zircon	22 321	40.2	21 971	48.8	15 863	28.6	12 454	22.4	8 814	na
Hi Ti Imenite	5 547	na	4 061	9.5	3 646	na	4 564	8.2	3 030	na

Source : Lanka Mineral Sands Ltd.
Qty - tonnes
Value – Million Rupees
na- Not available

cent ilmenite, 8 – 10 per cent zircon, eight per cent rutile, 0.3 per cent monazite and one per cent sillimanite. Among several other concentrations of mineral sands scattered along various beaches in the country, the most significant are at Kaikawela, Polkotuwa and Kudremalai Point. Large mineral sand deposits may exist south of Trincomalee and off the shores of Beruwala, where a large deposit of monazite has been discovered. Investigations for offshore monazite are being carried out with the assistance of the UN Revolving Fund.

Table 3 shows the production of ilmenite and rutile in Sri Lanka. The Mineral Sands Corporation was established in 1957, for mining, separation, processing and sale of mineral sand deposits in the northeast Sri Lanka, around Pulmoddai. Rutile and zircon production began in 1967. The organization was converted into a public company – Lanka Mineral Sands Ltd – in 1992. The Company has a plant with a capacity to produce 150 000 tonnes of ilmenite, 10 000 tonnes of rutile and 6000 tonnes of zircon per annum. The richness of the Pulmoddai deposit is shown by the fact that the mineral content in the sand is 40–70 per cent, whereas in Australia even sands with only five per cent heavy minerals are mined. The Pulmoddai deposit has earned US $ 25 million with an operational profit of US $ 19 million during the period 1987 – 1990. Yet, in spite of being such a potentially profitable industry, there had been no expansion or modernization. Sri Lanka's mineral sands industry still depends on ore deposits and that too, only on the export of raw materials. A development programme which aims at value addition is, undoubtedly, a national need.

Rock Phosphate

Sri Lanka imports its requirement of fertilizers at a cost of about US $ 40 million, annually. 15 to 20 per cent are phosphates – rock phosphate and superphosphate. 26 000 tonnes of rock phosphate and 55 700 tonnes of triple superphosphate were imported in 1986. Local production of rock phosphate was 15 000 tonnes in 1986.

The Eppawala phosphate deposit, discovered in 1971 by the then Geological Survey Department, has reserves estimated at 40 million tonnes for the northern part. The phosphate reserves for the southern part have not been fully estimated (Dinalankara, 1995).

Mineralogically, the phosphate ore is rich both in primary as well as secondary phosphate minerals, the major primary mineral being the greenish, chlorine rich fluorapatite. Among the secondary minerals present in the matrix are francolite, crandalite and wavellite .

Table 4 shows chemical analyses for five Eppawala phosphate samples carried out by various research organizations.

One of the most important considerations relating to the Eppawala phosphate is its low solubility. Table 5 gives the average solubility levels. Even though the ore grade is relatively high, its solubility for the production of fertilizer is rather low. It has been reported that the major cause for this insufficient solubility is the high chloride and high R_2O_3 contents.

At present, the phosphate from Eppawala is used only in its raw state as a fertilizer. The government of Sri Lanka has now considered entering into a joint venture with a foreign company to mine and process the Eppawala phosphate to produce soluble phosphate fertilizer material. In view of the facilities available at the Trincomalee harbour, plans are presently being made for the establishment of the chemical plant at Trincomalee. It is expected that through this foreign collaboration, there would be substantial income generation and income accrued to the country. Environmental concerns, however, have been expressed and a detailed Environmental Impact Assessment on the Eppawala phosphate mining should be carried out on the basis of which decisions beneficial to the country could be made.

Table 4 : Chemical Analysis of Eppawala (Sri Lanka) Phosphate

Wt%

Constituents	IFDC L-Ore	GSD L-Ore	LPL HERP	IFS Crystal	IFS Matrix
P_2O_5	37.00	36.04	40.41	40.57	33.24
Al_2O_3	1.38	2.23	0.68	0.05	1.45
Fe_2O_3	4.29	2.30	0.09	0.33	11.94
MgO	0.05	0.23	0.25	0.08	0.18
MnO_2	0.44	-	0.04	0.02	0.23
TiO_2	0.90	0.78	0.01	0.01	1.03
Cl	0.63	1.04	2.00	1.87	1.12
F	2.40	2.43	1.80	2.03	2.07
CaO	49.10	51.60	54.27	54.50	43.89
SiO_2	1.03	0.30	0.50	0.18	0.15
SrO	0.04	0.65	0.86	-	-
BaO	0.01	0.26	-	-	-
Na_2O	0.14	0.08	0.18	0.14	0.20
K_2O	0.03	0	0.03	0.01	0.01
CO_2	1.14	-	-	-	-
ThO_2	-	0.03	-	-	-
H_2O	-	2.65	-	-	-
Cr	0.01	-	-	-	-
Cu	0.01	-	-	-	-
V	0.001	-	-	0.28	0.20
Tot. S	0.11	-	-	-	-
NAC Sol.	2.80	-	-	-	-
Total	101.5	100.62	101.12	100.46	96.49
CaO/P_2O_5	1.32	1.43	1.34	1.34	1.32
R_2O_3 + MgO/P_2O_5	0.15	0.13	0.02	0.01	0.40

IFDC – International Fertilizer Development Centre
Source: Dinalankara, 1995.

Table 5 : Average Solubility levels – Eppawala Phosphate

	P_2O_5 (wt%)	Water % P_2O_5	CA % P_2O_5	NAC P_2O_5
Apatite	40.0	0.2	6.0	NA
Matrix (francolite crandalite)	35.0	0.1	3.2	NA
Ore (apatite +matrix)	33.0	0.1	3.5	NA
Ore	37.0	-	NA	2.8

Source: : Dinalankara, 1995.
NA – Not analyzed

Calcareous Materials

The major calcareous minerals of Sri Lanka could be grouped into four categories, namely:

1. Sedimentary limestone of the Miocene age ,
2. Inland coral ,
3. Shell deposits ,
4. Marble.

Table 6 shows the reserves and supply position for the industry. Sedimentary limestones of the Miocene age are found in the Jaffna Peninsula and in a northwestern belt extending towards Puttalam (Fig. 1). The $CaCO_3$ content of some of these limestone deposits is over 95 per cent; They support the cement factories at Kankesanthurai and Puttalam.

Table 6 : Limestone reserves and supply position for industry ('000 tonnes)

Commodity	Reserve (Measured)	Reserve (Indicated)	Reserve (Inferred)	Mineral Supply position from measured and indicated reserves
Miocene limestone	10 000	50 000	200 000	60 years (million tonnes of cement per annum)
Coral (Inland unrestricted areas)	na	300	400-600	12 years
Shell (Unrestricted area)	na	100	150	15 years
Calcite	na	40	60	30 years
Dolomite	na	200 000	500 000	Unlimited over next century

na – Not available
After Herath (1991).

The inland coral deposits found in the southwestern coastal region from Ambalangoda to Matara are not of major industrial importance. Private investors, however, have occasionally shown interest in these deposits. These coral deposits have supported, according to reports, 303 lime kilns from Akurala to Hambantota in the past. The Geological Survey and Mines Bureau has recorded a figure of 48 000 to 50 000 tonnes of coral that had been mined to produce approximately 25 000 tonnes of lime per annum.

The shell deposits are abundant in the Hungama region and extend up to Bundala, covering a distance of about 40 km. About 150 000 tonnes of reserves have been estimated for the Hungama shell deposits.

The marbles are of Precambrian age and are found in the Central Highland regions of Sri Lanka. These form thin prominent discontinuous bands, which run in a north-south direction (Fig. 1). Excellent exposures are observed in Matale, Kandy, Badulla and Habarana regions. The marbles are largely dolomitic and contain varying amounts of magnesia as $MgCO_3$. These dolomitic marbles are used as fertilizers for long term crops like tea, rubber and coconut, and all marbles are the raw materials for the manufacture of building lime.

Coral reefs are found in many coastal regions of Sri Lanka, particularly in the southwestern, northwestern, northern and northeastern coasts. The most extensive occurrences are at the coastal stretch extending from Ambalangoda to Matara. Surveys have shown that coral reef complexes form natural breakwaters off the coast, particularly at Akurala, Hikkaduwa and Polhena .

The corals are of different kinds, the dominant type being *Acropora,* which makes up about 75 per cent. Loosely packed finger corals are associated with heavy blocks of massive corals in these coral reefs.

Coral reefs have been mined for the purpose of producing high quality lime for the building industry. This has resulted in heavy damage to the reefs which are very valuable reservoirs of biodiversity. Reef destruction contributes to coastal erosion. Mining of these coral reefs has now been banned, and efforts are being made by the National Science Foundation (NSF) to encourage the development and use of alternatives to coral-based lime.

Rocks for Building Materials, Roads and Dimension Stone

Sri Lanka has a variety of rocks that can be used as road metal, building material and as dimension stone. Common granite, as exemplified by the granites found around Tonigala and Ambagaspitiya, is particularly well suited for dimension stone. Several other rock types belonging to the high grade metamorphic varieties are also found, and these occur in a variety of colours ranging from white to black. There are hundreds of metal quarries scattered throughout the country. These produce the crushed stone of varying sizes necessary for the construction of buildings and roads. Herath (1995) estimates that at least two million tonnes of stone, valued at nearly Rs. one billion are used in the building industry.

Ornamental and dimension stones, in particular, have a significant world demand and this appears to increase annually. Among the countries which import dimension stone from Sri Lanka are USA, Japan, Germany, Canada, Switzerland, Italy, Thailand and Singapore. Sri Lanka earns over Rs. 60 million annually from this trade.

In recent years, there has been a significant development in the import, cutting and polishing of ornamental stone for export as a BOI protected industry.

Siliceous Materials

Among the siliceous materials of economic importance in Sri Lanka are silica sand, vein quartz, river sand and quartzite. Good quality silica sands are found in areas around Madampe and at Marawila and Nattandiya . It has been estimated that the total extent of these silica sand deposits is over 100 hectares.

In some areas of the central highlands, notably in Galaha, Ratnapura, Rattota, Pussella, Pelmadulla and Opanayake, good deposits of vein quartz have been found . Some of them are known to contain nearly 100 per cent silica. The best known deposits at Ambalamana and at Akarella are estimated to contain over 20 million tonnes of quartz. Some vein quartz are exported. However, the present system of mining vein quartz is extremely wasteful and there should be more control over the industry.

Mining of river sand is widespread and is commonly seen in the Kelani Ganga and Maha Oya. A survey carried out in 1992 by the National Sand Study for Sri Lanka has shown that over five million tonnes of sand have been mined in these areas. Herath (1995), estimates that island-wide about eight million tonnes of sand worth Rs. 600 million are extracted each year. The environmental effects of this activity are serious, and alternative sources of building sand should be found.

Salt

In Sri Lanka, the salterns are located at Elephant Pass, Kurunchativu and Irupalai in the northern region, Palavi and Puttalam in the western region and Hambantota, Maha Lewaya and Palatupana in the southern region.

The production of salt in the northern region has been halted due to civil strife. The total salt production of around 100 000 tonnes per annum is by Lanka Salt Limited and Puttalam Salt Limited.

INSTITUTIONAL AND LEGISLATIVE FRAMEWORK

The Geological Survey And Mines Bureau (GSMB)

The Geological Survey and Mines Bureau (GSMB) which was established in 1993 under the Mines and Minerals Act No. 33 of 1992, replaced the former Geological Survey Department. The Functions of the GSMB are:

1. To undertake the systematic geological mapping of Sri Lanka and the preparation of geological maps;
2. To identify and assess the mineral resources of Sri Lanka;
3. To evaluate the commercial viability of mining for, processing and export of, such minerals ;

4. To regulate the exploration and mining for minerals and the processing, trading and export of such minerals, by the issue of licenses ;

5. To advise the Minister on measures to be adopted for the promotion of the extraction and production of minerals, on a commercial basis .

During the last 50 years, the Geological Survey Department carried out several exploration projects that eventually resulted in the establishment of some mineral-based industries. One of the truly significant achievements of the GSMB is the publication of the modern geological maps of Sri Lanka. These are of vital importance in any future geo-scientific investigation. A second major achievement is the publication of the first "Minerals Year Book for 1999", which has been called "An Excellent First Effort". This annual publication will be eagerly awaited in future years.

The Mines and Minerals Act No. 33 of 1992

The above Act was introduced by the government to liberalize the mineral sector and to attract investments .The Act has also provided for re-structuring of the former Geological Survey Department and the establishment of the GSMB to administer the Act. In order to regulate the mineral industry, the GSMB was authorized to issue the following licences:

1. Exploration Licence
2. Artisanal Mining Licence
3. Reserved Mineral Licence
4. Trading Licence
5. Transport Licence
6. Export permit

The Ministry of Industrial Development has just published (1999) the government's "Mineral Policy" which sets out to encourage more value addition to minerals locally.

Laws enacted are aimed mainly at exploitation and revenue collection. Little attention has been paid to environment restoration or, if this is a requirement, to its implementation.

Exploration Licence

The island has been divided into 1 km^2 grid units, all of which are numbered and the maps for which are available at the GSMB. Any individual or business organization, local or foreign, who can prove its technical and financial capabilities to carry out the work, is eligible to apply for a licence, the area for which is identified by the grid numbers. A licence is initially valid for two years and can be extended to a maximum of 10 years. Figure. 2 shows the areas reserved for mineral exploration as at the end of March 1998.

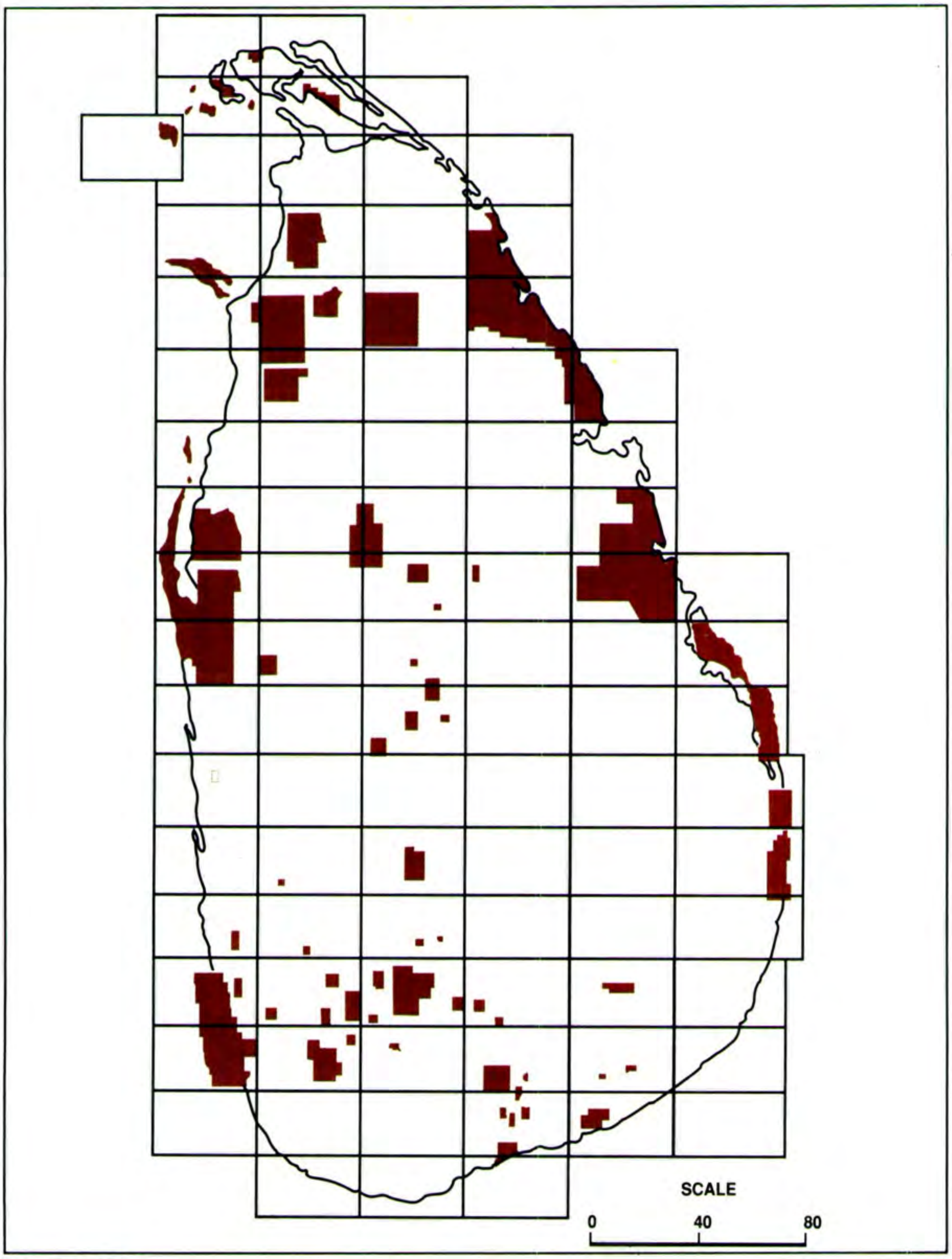
Mining Licences

There are three types of mining licences issued by the GSMB, namely, Industrial Mining Licences (IML), Artisanal Mining Licences (AML) and Reserved Mineral Licences (RML). Table 7 shows the number of applications received for licences up to 1998.

Sri Lanka Export Development Board

The Sri Lanka Export Development Board is the organization empowered to prepare the National Export Development Plan. In general, the objectives of the National Export Plan are to:

1. Identify constraints inhibiting exports ,
2. Set macro and sectoral growth targets for exports and assess the levels of investment that will be required to achieve such growth rates ,
3. Identify strategies, priorities and criteria that should be adopted to overcome the constraints identified ,
4. Prepare a Work Plan incorporating incentives and policies that would be necessary to implement the above mentioned strategies and priorities, as well as measures that should be adopted to increase / improve the supply base and diversify/expand markets.



Source : GSMB

Figure 2: Areas reserved for mineral exploration as at 31st March 1997

Table 7 : Issue of licences

	1995	1996	1997	1998
Artisanal Mining Licences (AML)				
No. of applications received	827	1 586	1 182	2 076
No. of licences issued	512	1 012	1 050	1 626
AML Renewals				
No. of applications received	68	215	556	670
No. of licences issued	41	189	494	628
Industrial Mining Licences (IML)				
No. of applications received	52	26	190	310
No. of licences issued	18	21	131	242
Renewals				
No. of applications received	16	30	55	53
No. of licences issued	14	37	43	31
Exploration Licences (EL)				
No. of applications received	53	34	87	17
No. of licences issued	39	12	08	17
El Renewals				
No. of applications received	-	03	09	12
No. of licences issued	-	01	02	04
Reserved Mineral Licences (RML)				
No. of applications received	22	22	13	11
No. of licences issued	11	13	14	13
Trading Licences (TDL)				
No. of applications received	19	33	26	36
No. of licences issued	15	31	25	26
TDL Renewals				
No. of applications received	03	06	05	07
No. of licences issued	01	02	05	04
Transport Licences				
No. of applications received	953	2 482	6 648	7 452
No. of licences issued	935	2 451	6 566	7 229

Source : GSMB.

Exploration licences

Commodity	Number of Applications	Area (km^2)
Mineral sands	24	1216
Silica sand	03	09
Gold	07	113
Ceramic raw materials	42	461
Apatite	04	125
Limestone	26	736
Graphite	07	54
Other minerals	186	5629
Total	299	8343

Source : GSMB.

The Sri Lanka Export Development Board deals with the export of the mineral commodities and works in close collaboration with other organizations in the mineral sector, such as the National Gem and Jewellery Authority and the Geological Survey and Mines Bureau.

TRENDS IN THE MINERAL INDUSTRY

Sri Lanka is not a major mineral producing country and therefore, its mineral industry is, heavily dependent on the marketing strategies and mineral policies of the more powerful consumer countries and large international organizations. The world demand for minerals has, indeed, increased in recent times and many countries are entering the mineral market now, with greater enthusiasm. This has resulted in Sri Lanka facing strong competition from these countries, as is clearly evident in the gem industry, where Sri Lanka once held a unique position. A clear trend observed in the global mineral industry is the dominant role played by international trading organizations. Sri Lanka's minerals may also find more marketing opportunities through international agreements.

All future mineral-based industries of Sri Lanka must depend necessarily on the availability of good quality raw material and one of the first priorities of a promotional strategy should be the commencement of a major, islandwide, mineral exploration programme. There is at present over dependence on the present mineral resources, which in many cases may not last for more than two decades. As in the case of other technical skills needed by the industry, foreign collaboration and expertise could be used to advantage in such a mineral exploration programme.

An analysis of the future mineral-based industrial development shows that the government has laid emphasis on the following:

1. Use of local raw material and local labour.

2. Use of foreign capital, technology and expertise in the development of the mineral sector through joint ventures.

3. Provision of many facilities for the small scale industrialists to commence mineral-based development projects; these facilities include financial and technological assistance.

4. Establishment of clear marketing and promotional strategies prior to the development of new mineral industrial ventures.

5. Value addition and wherever possible, avoidance of the export of materials in the unprocessed state.

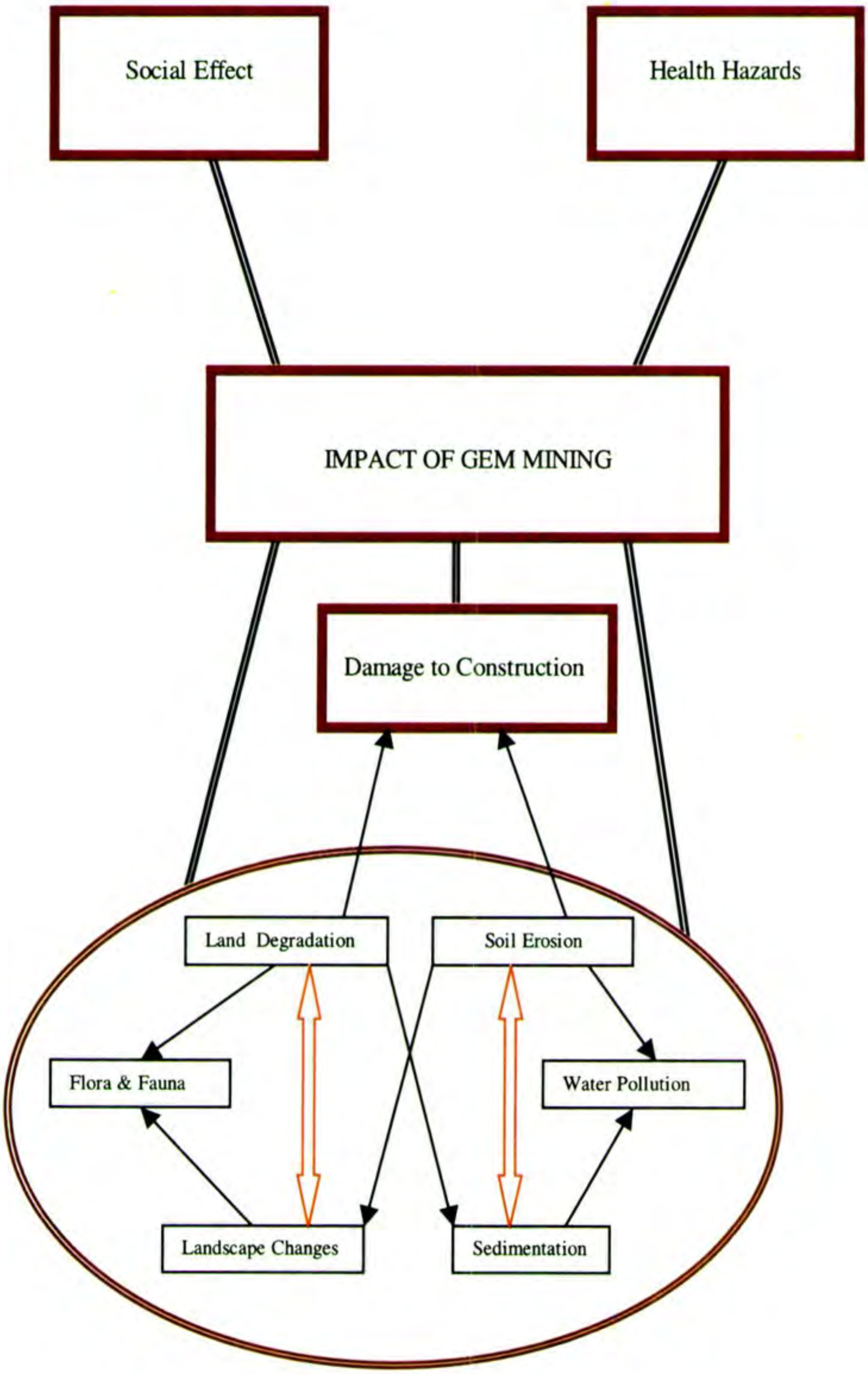
With the firm establishment of the open economy, and the greater role played by the private sector, Sri Lanka's mineral industry is showing signs of an upward trend.

MINING AND THE ENVIRONMENT

The National Environmental Action Plan

The National Environmental Action Plan (NEAP) has formulated proposals for the protection of the environment damaged by the action of mining activities. In general, all mining activities, whether they are artisanal or large scale mechanized, will produce variable environmental degradation. The general environmental issues associated with the minerals programme as outlined by NEAP are water quality, sedimentation, stream flows, land degradation, land deformation, effects on habitats and health.

All large scale organized mining prescribed under the National Environmental Act (NEA) requires a mandatory Environmental Impact Assessment (EIA) prior to the granting of approval and commencement of any field mining activity. The GSMB is expected to develop the institutional capacity to monitor effectively and control island wide mining operations.



After Rupasinghe and Cooray (1993).

Figure 3: Schematic diagram showing environmental impact of gem mining

Gem Mining

Figure 3 gives a diagrammatic representation of the impact of gem mining on the environment. The gem bearing gravels of Sri Lanka are mostly found as discontinuous lenses at depth in palaeo-alluvial sediments in wide strike valleys or as streambed deposits. Mining methods vary from deep mining and tunnel mining to shallow, open pit mining and riverbed mining. Mechanized gem mining is totally prohibited in Sri Lanka.

Along with its relatively high economic return and social benefits, gem mining can cause environmental damage, depending on the type and location of the mine. Surface, pit and streambed mining involve different types and amounts of waste gravel, water use, and reclamation costs (Rupasinghe & Cooray, 1993).

Large numbers of mines contribute to the environmental problems of mining. The National Gem and Jewellery Authority issues about 5000 gemming licences each year, allowing each licence holder to dig from two to four gem pits at a time. Approximately 10 000 to 15 000 gem pits operate legally in the Island; an equal number is illegal. Traditional gem pits are worked by six persons and approximately 60 000 to 90 000 persons are engaged in gem mining. Adding the illegal mines, the total number of people directly involved in gem mining is about 135 000.

A detailed study of the environmental impact of gem mining in the Ratnapura District, the main gem producing region of Sri Lanka, has revealed useful information on mining impacts and controls. Gem mining is one of the chief contributors to soil erosion and sedimentation in the Ratnapura district. Among the interrelated factors are:

1. Stream bank mining ,
2. Removal of vegetation cover for gemming,
3. The process of washing gem *illam* in water bodies where clay and silt particles are added to rivers , streams or canals ,
4. Deposit of sediments in rivers, streams and canals when mine waters are discharged from working mines ,
5. Erosion of soils from unstable soil heaps (mine spoils) that are accumulated around gem pits.

A highly visible environmental effect is the change of landforms. Large areas are pockmarked with craters, often filled with turbid water, and collapsed and subsided terrain. Stream banks have caved in due to the construction of horizontal tunnels. Mine filling is virtually never done properly. As a result, land subsidence and water pools occur in areas nearly 300 m in diameter. Stream banks in some instances have been expanded laterally by as much as 38 m. The extent and impact of these changes on land productivity need more precise assessment in order that appropriate preventive and remedial action, may be taken.

There is circumstantial evidence that gem mining has contributed to a resurgence of malaria in Sri Lanka. Abandoned gem pits that form stagnant pools of water are breeding grounds for the mosquito. Quantitative data on the problem is still lacking, but resurgence of malaria in the main gem mining areas of Elahera and Ratnapura does not appear coincidental.

Sand mining

Sand that comes down in rivers is necessary to maintain coastal beaches. When a section of the beach loses sand by littoral drift and other phenomena, this loss is made good by sand transported by rivers. Hence, if sand mining from the bed of Kelani and other rivers exceeds their annual deposit, coastal beaches will not receive their necessary replenishment. It has been estimated that the total quantity of sand coming down the Kelani annually may be around 1.4 million tonnes, while a 1984 survey estimated the annual extraction at 916 000 tonnes.

Uncontrolled mining of river sand often leads to the collapse of riverbanks. Large scale sand mining in the Badulla District has eroded riverbanks and affected the stability of bridges. In coastal areas the deepening of the riverbed below mean sea level creates conditions for the influx of salt water. In the case of the Kelani

River, this salt water wedge may even reach the intake of the Colombo City water supply at Ambatale.

Coral mining

The loss of coastal habitats due to coral mining, among other factors, is of serious environmental concern in Sri Lanka. The National Environmental Action Plan considers the following as some of the causes for intensive coral mining.

1. Products of coral mining are valuable and saleable;
2. Income derived from coral lime are better than those from available alternatives;
3. Regulations cannot be effective when poor coral miners are put out of work with no alternative sources of income;
4. National policy has not supported actions and investment to develop alternative sources of lime;
5. Integrated coastal resource management plans which address the economic sector in its entirety – which affect and control the market and distribution for coral limestone – have not been developed;

Coral mining is considered as a major cause for sea erosion along some parts of the coast line of Sri Lanka which is quite severe during the period of the southwest monsoon, mid-May to mid-August, each year. It has been shown that between 15 000 and 20 000 people are engaged in coral mining, the majority in inland coral mining. The coral so mined is the raw material for the lime burning industry, commonly seen along the coast. In some cases, the coral is transported 40 to 50 km inland where lime kilns have been established.

EDUCATION AND RESEARCH

Teaching and research on mineral resources and their applications is at present carried out only by a few organizations. Among these, The Department of Geology of the University of Peradeniya is the foremost. It still remains the only University Geology Department which offers honours degree courses in Geology. Other organizations which contribute, on a somewhat lesser scale, are the Department of Mining and Mineral Processing of the University of Moratuwa, the Department of Natural Resources of the University of Sabaragamuwa, the Institute of Fundamental Studies and the Geological Survey and Mines Bureau. The Peradeniya Geology Department, in particular, has carried out significant research on the geology and nature of mineral resources of Sri Lanka. The University of Moratuwa has done some useful work on the more applied aspects of mineral sciences such as *geuda* heat treatment and gold exploration. The GSMB remains the only organization with capabilities for deep drilling and similar geological investigations. On the whole, however, the applied aspects of the mineral resources of Sri Lanka have been grossly neglected and this is clearly shown by the fact that our mineral industry is still dependent only on the export of raw materials.

The major constraints on teaching and research on mineral resources are, as expected, lack of resources. The universities in particular, are at a serious disadvantage owing to the lack of essential analytical equipment, as well as field instruments such as geophysical equipment necessary for mineral resource investigations. On the other hand, teaching of geology has been quite satisfactory, with good quality graduates passing out regularly. Most of these geology graduates have, until recent times, obtained employment befitting their qualifications, though the situation has changed due to the fewer jobs available and due to the larger numbers of graduates passing out.

RECOMMENDATIONS AND INSTITUTIONAL RESPONSIBILITIES

Value addition to mineral products

The lack of value addition to mineral products has, for several decades, been the bane of the mineral industry of Sri Lanka. Except for the *geuda* industry, where some efforts are being made to enhance the value through heat treatment techniques, the efforts to upgrade the value of other mineral products are woefully inadequate. One of the major priorities in the mineral industry of Sri Lanka is, therefore, to initiate research and development in the area of value addition to mineral products.

Establishment of small and medium scale mineral-based industries

One of the established facts on mineral resources of Sri Lanka is that they are of medium to small scale in size. However, compared to the area of the land, the distribution, variety and occurrences, these deposits are substantial and hence, small and medium scale mineral industries appear to be the best option for the mineral sector. Among some of the advantages of such small industries are the significant potential for expansion, low consumption of capital and foreign exchange, and the high level of employment of youth from the vicinity.

New Exploration Strategies

In his Presidential Address to section D of the Sri Lanka Association for the Advancement of Science, 1995, Dr. N.P.Wijayananada, Director GSMB, stated *"so far the mineral deposits we have discovered, except for the Panirandawa iron-ore deposit, are exposed to the surface. If the Eppawala apatite deposit had been a few meters below the ground we would not have found it."*

This statement clearly points to the fact that our mineral exploration programmes are far from adequate. This fact has now been recognized by the GSMB and an extensive field programme has been undertaken to produce a new series of geological maps at 1:100 000 scale, covering the whole country. Geochemical exploration techniques also need to be applied in mineral exploration in Sri Lanka and the university departments, in particular, need to be supported in such ventures.

In addition, quantification of some of our industrial minerals e.g. feldspars, clays, needs to be undertaken, possibly by the GSMB.

Coordination between institutions

In order to develop the mineral industry, the few organizations working on different aspects, such as basic research, geological surveys, mineral exploration, value addition to resources and marketing strategies, should share their expertise and resources in a coordinated plan of action. Wasteful duplication could be prevented thereby and outputs achieved more rapidly and efficiently.

REFERENCES

1. Arjuna's Atlas of Sri Lanka (1997) Arjuna Consulting Co. Ltd. Dehiwala, Sri Lanka. 220 pp.

2. Cooray P.G. (1984) *An Introduction to the geology of Sri Lanka* (Ceylon). National Museums of Sri Lanka. 333 pp.

3. Dinalankara D.M.S.K (1995) Eppawala phosphate deposit of Sri Lanka - present status. In: *Proc. Int. Workshop: Direct application of phosphate rock and appropriate technology fertilizers in Asia. What hinders acceptance and growth?* (Eds.K Dahanayake, S.J van Kauwenbergh and D.J Hellums). International Fertilizer Development Centre and Institute of Fundamental Studies.

4. Gunaratne H. S & Dissanayake C. B (1995) *Gems and gem deposits of Sri Lanka.* National Gem and Jewellery Authority of Sri Lanka. 195 pp.

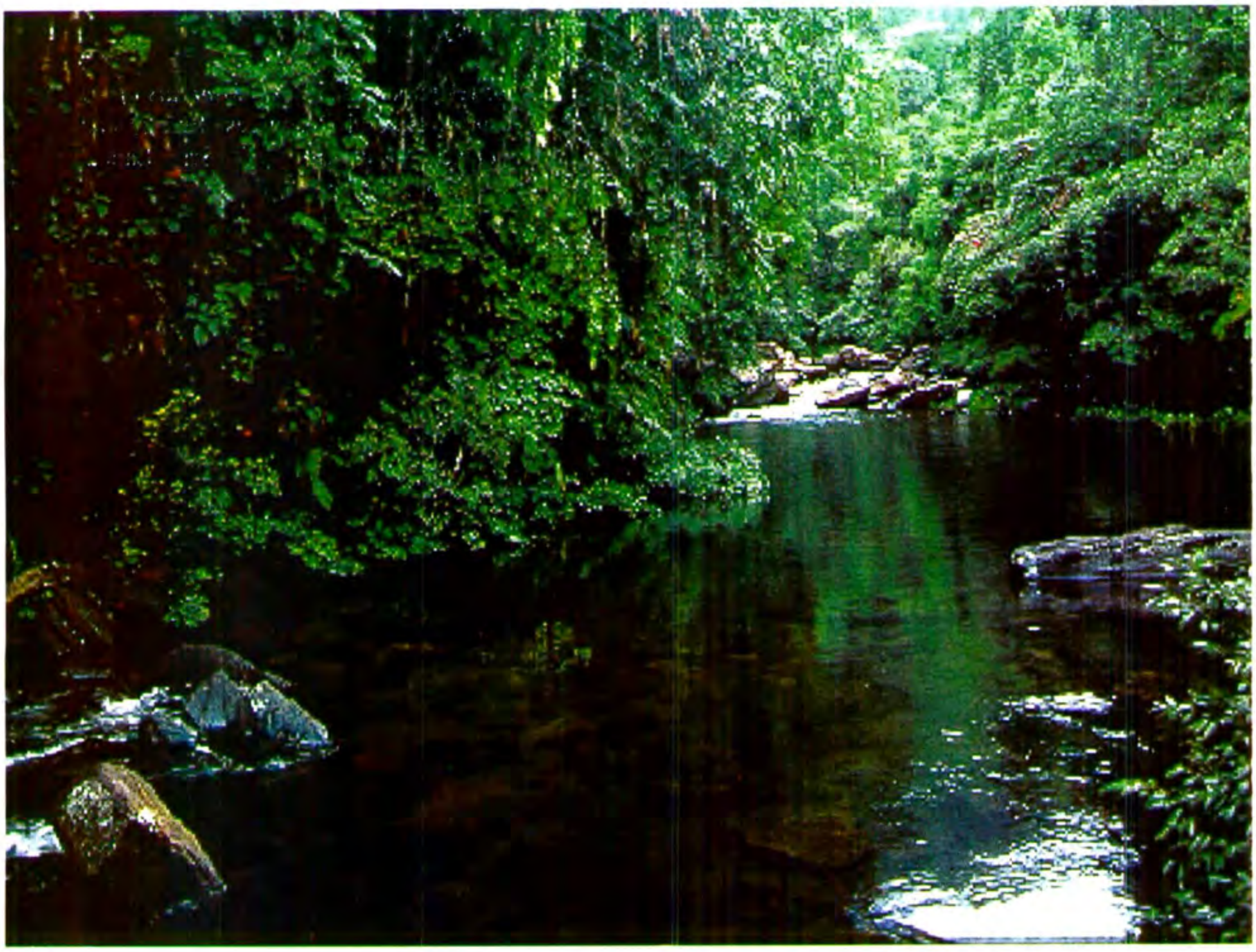
5. Herath J.W. (1995) *Economic geology of Lanka.* Ministry of Industrial Development, 216 pp.

6. Herath J.W. (1992) Lime Industry of Sri Lanka. *Int. Seminar on Lime, Colombo.* Intermediate Technology Publications, UK. 35 pp.

7. Herath J.W & Grimshaw R.W. (1971) A general evaluation of the frequency distribution of clay and associated minerals in the alluvial soils of Sri Lanka. *Geoderma.* **5**: 19 – 30.

8. Rupasinghe M.S. & Cooray P.G (1993) The effects of gem mining on the environment. In: *The Sri Lankan geuda* (Eds. M.S. Rupasinghe, C.B. Dissanayake, and D.G.A. Perera) Institute of Fundamental studies, Kandy. 166 pp.

9. Seneviratne L.K. (1997) *Minerals of Sri Lanka.* Natural Resources, Energy and Science Authority of Sri Lanka, Colombo. 106 pp.



Photograph by Chandima Kahandawala.

Inside Sinharaja - World's Heritage

FOREST RESOURCES

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Forestry Consultant; Formerly Senior Assistant Conservator of Forests

Summary

Sri Lanka's natural forests comprise mainly dry mixed evergreen forest (monsoon forest) and rainforest, the former being the more extensive. Once extensive and widespread, they have now been reduced to 23.8 per cent of the land area, and even these remaining forests have been severely degraded by excessive logging. The forests are mostly state owned, and are under the charge of either the Forest Department or the Department of Wildlife Conservation. According to the Forestry Sector Master Plan, the forests under the charge of the Forest Department will be reclassified, rehabilitated, and placed under appropriate management systems. At present the bulk of the timber supplies come from non-forest sources (e.g. home gardens, rubber plantations, coconut plantations). In the future, while non-forest sources will continue to provide the bulk of timber needs, with better management and with the active participation of the private sector, forest plantations are expected to provide a growing share of the timber demand. The Forestry Sector Master Plan of 1995 has set out an integrated strategy for the sustainable management of the nation's forestry resources.

Sri Lanka was once a land of rich tropical forests, nurtured by abundant radiation, high temperatures and rainfall, and long growth periods. In pre-colonial times, these ecosystems provided local people with many of their daily needs. Over the last century much of this heritage has been destroyed, along with many of its material benefits. Rich forest diversity was, we now know, highly vulnerable to misuse. While the extraction of non-wood products (like medicinal plants, fruits, seeds, bark and cane) has increased over the years, the adverse impacts of such extraction are insignificant compared to the drastic effects of extensive forest clearing and over exploitation for timber. Deforestation has seriously diminished timber supplies, made soils less productive, water supply more erratic, and floods more frequent and severe. Management of what is left, and re-establishment of new forests, will require concerted planning and strong political will. That there has been some recognition of the sad state to which the country's forest resources have fallen, is evident in some of the measures that were taken in the last ten years to resuscitate these resources. The most notable of these is the moratorium on logging in the natural forests of the country (which had previously been the chief source of timber) imposed in 1988 and still in place. Forests can be destroyed in a short time, but it takes many decades to rehabilitate them. It is therefore necessary to continue and build upon the forest conservation measures that have been put in place in the recent past.

FOREST COVER

Climate, the main determinant of forest distribution, does not preclude the presence of forest in any part of the country. Except in a few locations limited by soil factors, the entire island was once covered with forests. Conditions today are very different.

Along the coastal fringe, tidal mud flats had mangrove forests much more extensive than today's. Until the early part of this century the higher sandy soils also had strips of littoral woodlands, but these have now almost completely disappeared.

The wet southwest region and the central highlands have the most luxuriant plant cover. The lowland area, up to an elevation of about 900 m, has a climax vegetation of Tropical Rain Forests, where the crowns of the dominant trees form a closed canopy at 25 to 30 m, with emergents rising to about 45 m. These forests have relatively sparse undergrowth, but are rich in epiphytes and lianes. They gradually give way through Sub-montane Forests, at 900 to 1350 m, to Wet Evergreen Montane Forests at the higher elevations. The latter have a lower canopy and denser undergrowth. Their stems are often covered with lichens, bryophytes and other epiphytic plants. In the marshy areas of the wet zone there was a type of marsh forest with its own unique combination of species. These have all but disappeared as these areas have been converted into paddy lands over the years.

The transition zone between the wet zone and the dry zone – the seasonally dry northern and eastern plains – has Tropical Semi-evergreen Forests with their own characteristic species, as well as, some common to the adjacent zones.

The major part of the dry zone has Tropical Dry Mixed Evergreen Forests. In these, the dominant species now present often do not form a closed canopy and seldom exceed 20 m in height. The extreme southeastern and northwestern regions of the island, which have very long dry periods, are covered with Tropical Thorn Forests with low trees and an undergrowth mainly of thorny scrub.

In the dry zone, intensive felling and a form of shifting cultivation locally called *chena* cultivation has badly degraded the forests. During fallow periods secondary successions lead to the development of scrub or low jungle, but where successions are prevented by frequent clearing or burning, the areas are unable to support any tree growth and are covered by coarse grasses. The forests that have escaped *chena* cultivation have been heavily logged leaving them seriously depauperate in terms of the more valuable timber species.

Some edaphically determined natural grasslands are also present in the island. These are the *villus* on seasonally submerged depressions in the dry zone, and the wet patanas in certain boggy highland areas.

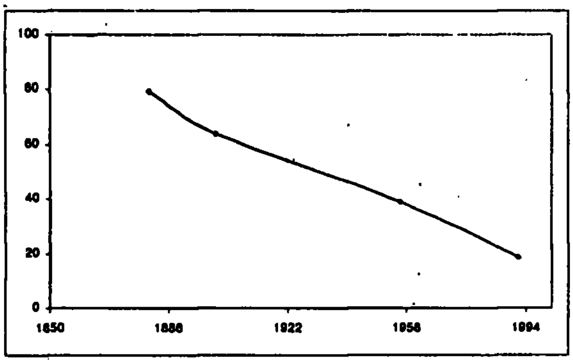
Plantation forests in Sri Lanka consist mostly of monocultures of teak, eucalyptus or pine. A few mixed plantations of broad-leaved species, such as jak and mahogany, have also been established.

NATURAL FORESTS

During Sri Lanka's hydraulic civilization beginning more than 2000 years ago, agricultural development in the dry zone required transformation of natural ecosystems to agro-ecosystems. Wetlands in the valleys and flood plains became rice fields, and clearings on high ground became multi-layered home gardens. From about AD 1200, invasions from India and the spread of malaria, among other causes, forced population shifts to the central highlands, where similar village settlements were established, in the valleys and lower slopes of the hills. Forest cover on the ridges, upper slopes and hilltops remained undisturbed.

During the time of the British colonial government shifting cultivation and forest exploitation for timber supply increased sharply. In 1881, the forest cover was estimated at 84 per cent of the land area (Nanayakkara, 1987) and in 1900, at 70 per cent (Baldwin, 1991).

The first comprehensive forest survey was conducted after Independence, in the period 1956-1961. The survey found that the total area of forest was 2.9 million ha, or 44 per cent of the land area (Andrews, 1961). Even then overexploitation had spread and as much as 42 per cent of all natural forests were classified as non-productive. Except for



Source : Baldwin (1991) and MALF (1995).

Figure 1 : Percentage of land area under natural forest : 1880-1992

a limited forest inventory carried out by the F.A.O. in 1982-1985, the next comprehensive forest inventory survey was done in the period 1992-1993. It was based on satellite imagery supported by ground sampling. It revealed that the "dense" forest cover had by then dropped to 23.88 per cent of the land area, from 44 per cent 36 years before (Ministry of Agriculture, Lands and Forests - MALF - 1995). This means that the average annual loss of forest cover during that period amounted to 37 000 ha. Most of the deforestation occurred in the dry zone and was due to opening up of forests for irrigation and land settlement and to illicit clearing (mainly for shifting cultivation). Between 1983 and 1992, around 37 per cent of the deforestation was attributed to the Mahaweli, Kirindi Oya, Inginimitiya, Sevenagala Sugar Company and Pelawatte Sugar Company projects (MALF, 1995). There were no major irrigation and land settlement schemes since then, but deforestation from illicit clearings and forest encroachment has continued. The extent of deforestation in the wet zone was much less than in the dry zone, but the area of forest cover in that part of the country is at any rate very low, and deforestation has made significant inroads into the natural forests pushing back their *de facto* boundaries.

The data on forest cover provided by the 1992 survey are presented in Table 1. In addition to the 23.88 per cent forest cover the survey shows a further 7 per cent of the land area covered by what is called "sparse forest". This refers to scrub and early secondary growth in land abandoned after shifting cultivation.

In addition to forest and scrub, *chena* cultivation occupies a large area, mainly in the once forested parts of the dry zone. As the population expanded, more high forest came under shifting cultivation with shorter rotations. In 1956, the total area exposed to shifting cultivation was one million ha, or 15 per cent of the country's land area. Since then some *chena* areas have been absorbed into permanent agriculture or otherwise developed, while more forests have been cleared for *chena*.

Table 1 : Area of natural forest cover in 1992, in '000 ha ("sparse" forest excluded)

Forest type	Area	% of land
Montane forest	3.1	0.1
Sub-montane forest	68.8	1.0
Lowland rainforest	141.5	2.1
Moist monsoon forest	243.9	3.7
Dry monsoon forest	1094.3	16.5
Dry zone riverine forest	22.4	0.3
Mangrove	8.7	0.1
Total	1582.7	23.8

Source: Forestry Sector Master Plan, 1995.

In 1986, the country's first Forestry Master Plan (FMP) was prepared. To the dismay of many conservation conscious organizations and individuals the plan was wholly focused on meeting the timber needs of the country. This objective was to be achieved by felling in the remaining natural forests. The plan identified 47 500 ha, comprising the only rainforests remaining that had sufficient timber for exploitation, and proposed that these be commercially logged. There was widespread opposition to the plan, leading, also, to protests being lodged with potential funding agencies. Many favourable developments followed.

The government decided to suspend the proposal and commissioned a biodiversity assessment of the forests. The assessment that followed (called the Accelerated Conservation Review) revealed that the targeted forests should not be logged because of their high biodiversity value and their richness in endemic species. A further development was the inclusion of an Environmental Management Component to the five-year Forest Sector Development Project that was to be implemented from 1991 to 1996. A key activity of the environmental management component was a National Conservation Review (NCR) of the natural forests of the country (including those under the control of the Department of Wildlife Conservation). Under this programme limited biodiversity and hydrological assessments were carried out in the project areas and other natural forests (IUCN, 1997). The government had also declared a moratorium on logging in natural forests throughout the island. The moratorium was to remain in place until the NCR was completed and the results analysed. As at 1998, the moratorium was still in place.

FOREST OWNERSHIP

Over 95 per cent of Sri Lanka's forests have been state owned since British times. Following the Forest Ordinance of 1885 some forests were proclaimed Reserves. Because of time consuming legal and administrative procedures for establishing reserve forests, several other areas were set apart following less cumbersome procedures. These included Proposed Reserves under the jurisdiction of the Forest Department, Village Forests under the Government Agents and Other Crown Forests. Forests in the last category were transferred at various times from the Forest Department to Government Agents and vice versa.

The Forest Department has proposed a new system of classification of the forests under its charge, based on their current condition and recognizing the importance of managing them in an ecologically sustainable and socially equitable manner. Based on these principles, it is proposed to place the forests into one of four classes. These are briefly described below.

Class I forests. Forests that would be strictly conserved to protect biodiversity; soils; water; and historical, cultural, religious and aesthetic values. Research will be allowed in this class of forest, but no extractive uses will be permitted. The Sinharaja forest which is a World Heritage Site would fall into this class.

Class II forests. Forests set apart for non-extractive uses such as research and eco-tourism, as well as for the controlled collection of non-wood forest products and perhaps dead wood for use as a domestic fuel by people living in areas peripheral to the forests.

Class III forests. Forests recognized as multiple-use forests. They will be managed primarily for the sustainable production of wood to meet national needs on the basis of plans to be developed by the Forest Department. Wherever feasible, the implementation of the plans will be carried out in collaboration with Forest User Groups to which certain responsibilities will be delegated. Any contribution which the natural forests could make to the national wood supply will have to come from the multiple-use forests. Considering that the large majority of the forests that would fall into the multiple-use category will have to be rehabilitated through promoting natural regeneration, enrichment planting, and even reforestation where the existing forest is badly degraded, their contribution to the wood supply in the short term would not be appreciable.

Class IV forests. Forests that do not fall into classes I-III will be placed in class IV. They will be managed with community participation to meet the needs of the people living in the area.

In addition to the forests falling under the purview of the Forest Department, there are extensive areas falling within the jurisdiction of the Department of Wildlife Conservation (DWLC). These areas fall within one of several categories: Strict Nature Reserves, National Parks, Nature Reserves, and Jungle Corridors. In addition there are many areas, containing both state and private land, that have been declared as Sanctuaries.

TIMBER YIELDS FROM NATURAL FORESTS

As its main function the Forest Department was expected to manage its forest resources so as to supply timber and other forest products to meet the national demand while at the same time ensuring that conservation values (biodiversity, hydrology, soil conservation, etc.) are safeguarded.

From 1968, with the setting up of the State Timber Corporation, forests from which timber was to be extracted were identified by the Forest Department and assigned to the Corporation for extracting the timber. The Corporation was expected to follow the Forest Department's felling prescriptions. A single large rainforest complex, the Kanneliya - Dediyagala - Nakiyadeniya group, was handed over to the Plywoods Corporation to serve as a source of logs for its two mills at Gintota and Kosgama.

The Forest Department carried out an indicative inventory of wood volume in 1993, in the natural forests that were identified for management for producing timber on a sustained basis. The inventory data were used in the preparation of the second master plan, called the Sri Lanka Forestry Sector Master Plan – FSMP (MALF, 1995).

A comparison of the results of the 1993 inventory with those of the previous one carried out during the period 1982-1985 showed that there was a pronounced decline in stocking during the decade. There was a sharp drop in the number of stems per hectare in all size classes and, alarmingly, this was most pronounced in the larger size classes and among the commercially important species. While this was expected because of the heavy commercial logging carried out by the State Timber Corporation, it meant that there would be a shortage of mature trees of the preferred species to provide seed for regeneration. Also, the quality of the forest even after recovery will be inferior to what was there before in terms of its timber value. The FSMP has *inter alia* made the following comments :

- Previous logging (legal and illegal) has extracted volumes of timber that have proved to be far in excess of the sustainable yield. The result is a degraded forest structure that has persisted, as regeneration has generally failed.
- Most of the areas of natural forest which have been allocated for sustainable yield production on present plans have insufficient stem numbers or volumes to support economic and commercial logging in a sustainable manner. *It is not possible to meet a significant proportion of local timber demand from sustained commercial logging in these forests.*
- In order to be able to produce commercially exploitable volumes of timber in the long term, most of the forests will have to regenerate and be permitted sufficient time to grow.
- Regeneration and rehabilitation of the forests will only come about through active silvicultural intervention. Suitable proven techniques are generally not known. Useful research in this area has been carried out but ecological understanding of the regenerating potential of the residual stands still needs to be improved, in order to develop appropriate silvicultural interventions. In many cases, a more feasible alternative would be to release seriously degraded forests for other land uses or to convert them into forest plantations.
- Deforestation and degradation of the forest are still continuing in spite of the management and protection activities carried out over the past ten years.

Based on the findings of the inventory, the FSMP concludes that *"Timber production from the indigenous forests should no longer be a principal policy objective, although there may also be blocks whose primary management objective will be wood production. The majority of these forests should be managed to conserve their biodiversity and for watershed protection. Those that are important to adjacent communities should be managed for multiple use production purposes".*

Of the four proposed categories of forests referred to earlier, timber yields are expected to come only from Class III, multiple use forests and that too many years from now, after they are rehabilitated. These forests, also referred to as 'production forests', will be managed with the primary objective of providing timber and other forest products. What is envisaged for them is a form of participatory management where user groups from within the local community will participate in decision making, and the needs of the local community will be a paramount consideration. The productivity of these forests is an expectation and not a current reality. This is borne out by the statement that, "of the estimated islandwide total of around one million ha that would qualify to be included in Class III, more than two thirds are dry monsoon forests, and of these, less than 40 per cent are genuine forests, while most of the rest is active or regenerating *chena*." (MALF, 1995). Even in the areas under a proper forest cover, over exploitation for timber in the past has left them devoid of mature trees for supplying timber.

The tasks facing the Forest Department to convert these areas into actual production forests are formidable. The forests to be placed in this category have first to be identified in the field, and this is a difficult task as they are rarely discrete entities and they often occur as scattered blocks of just a few hundred hectares each. User groups have to be identified and established and a legal basis for involving them in management and providing them benefits has to be evolved. The Department and the user groups, working together, have to assess the potential of the forests and decide on measures to be adopted for rehabilitating and increasing productivity. The FSMP envisages that within 25 years it will be possible to place 500 000 ha of multiple use forests under proper management.

FOREST PLANTATIONS - HISTORICAL PERSPECTIVE

Reforestation in Sri Lanka has a long, important history. The government of Ceylon perceived a century ago that the exploitation of natural forests could frustrate sustained production of timber. This prompted the forest officers at the time to raise forest plantations, although at first on a very limited scale. Teak (*Tectona grandis*), an exotic species to Sri Lanka, was perhaps the first species to be raised as a forest plantation. This was done at different sites, mainly in the dry zone. Another exotic species, *Swietenia macrophylla*, the broad-leaved mahogany, was also planted towards the end of the nineteenth century in the intermediate zone lowlands around Kurunegala. From then until the 1950s plantation trials were carried out with numerous species, and those that showed promise were planted on a management scale. Most trials were carried out in the montane zone to meet fuelwood demands of households, the tea industry, and the railway. *Eucalyptus* species received the greatest attention. Although originally raised to produce fuelwood, the wood of some species of eucalyptus was later found suitable for industrial use.

In the early forestation activities in the montane zone, besides the various species of eucalyptus, other exotic hardwood species like *Cedrella* spp. *Tristania conferta*, *Acacia melanoxylon*, and *Acacia mollissima* were planted. Several softwood species were also tried and, of these *Pinus patula*, *P. caribaea* and *Cupressus macrocarpa* were extended to management scale planting. In the 1960s *Pinus* trials reached the lowlands, and in the 1970s appropriate varieties of *Pinus caribaea* began to be planted extensively in the low- and mid-country wet zone and the montane intermediate zone. Meanwhile, from the late 1950s onwards, extensive planting with teak in particular was carried out under the Cooperative Reforestation Scheme, the counterpart of the Burmese Taungya system. This scheme was terminated in the early 1980s.

At present the forestation programme focuses primarily on participatory forestry involving homestead development, raising of farmers' woodlots and protective forestation.

TIMBER PRODUCTION FROM FOREST PLANTATIONS

The main species that have been used for raising forest plantations are teak (*Tectona grandis*), pines (*Pinus caribaea*, *Pinus patula)*, cypress (*Cupressus macrocarpa)*, eucalyptus (*Eucalyptus grandis*, *E. microcorys*, *E. robusta)*, and mahogany (*Swietenia macrophylla*). These plantations have a considerable potential as sources of timber, but that potential remains largely unrealized. In the 1950s the annual reforestation programme was sharply increased. The Department found it difficult to cope with the extra workload without additions to the staff. As a consequence, standard management and silvicultural operations went by default. The neglect of essential silvicultural operations, like thinning and pruning, in the established plantations meant reduced yields and poor quality timber. Adding to the problems, illicit fellings and fires caused substantial losses.

The extents of productive plantations as of 1999, by main species, are given below in Table 2.

establishment and management. The Forest Department has invited applications from the public for giving out land on a long term lease for reforestation, and the response has been good. It is expected that, by this means, several thousand hectares can be reforested annually.

While involving the private sector in establishing and managing new forest plantations on a leasehold basis should prove beneficial, giving out plantations established by the Forest Department to the private sector may prove hazardous as there would be a temptation to make quick profits by over felling. At any rate, the involvement of the private sector in such a venture should initially be on a pilot scale only and management should be on the basis of plans prepared by the Forest Department. The fees to be paid by the lessees should be in relation to the value of the expected yields.

Table 2: Extents of productive plantations as of 1999

Species	Area (ha)
Teak	31 700
Pine (mainly *Pinus caribaea*)	16 500
Eucalyptus in the montane zone (mainly *Eucalyptus microcorys* and *E. grandis*)	9 175
Jak (*Artocarpus integra*) and Mahogany (*Swietenia macrophylla*)	2 800
Eucalyptus camaldulensis, E. tereticornis, Acacia mangium – mainly fuelwood species, in the dry zone	19 100
Other species	12 225
Total	91 500
(Enrichment planting of natural forests with mahogany is not included)	

Source: Forest Inventory Branch, Forest Department.

In 1993, out of a total consumption of industrial wood (including poles) of 1.65 million m^3, the share from forest plantations was only four per cent. The rest came from home gardens (41 per cent), natural forests (22 per cent), rubber plantations (13 per cent), coconut plantations (11 per cent) and other sources (4 per cent).

The FSMP proposes to bring in private sector groups (estate sector, farmer groups, local organized communities, forest user groups, etc.) to provide support for forest plantation

In the future, the forest plantations are expected to provide a greatly increased share of the annual industrial wood requirements – 150 000m^3 by the year 2000, increasing to 500 000m^3 by the year 2020. To achieve this goal several conditions have to be met. First, the productivity of the existing plantations has to be increased substantially. Illicit felling (though these too go to supply the market), fires and damage caused by wild animals have to be curtailed. It was estimated that 28 per cent of the forest plantations (in 1992) amounting to 23 000 ha could be considered as being of very poor quality and low stocking, which cannot be rehabilitated.

Two thirds of this is of teak. They should be clear-felled to salvage any useful material, and if the failure is not due to poor site conditions the area should be replanted with the same or other suitable species.

The annual rate of reforestation as proposed in the FSMP is 4000 ha in 1995 increasing to 5000 ha from 2005 onwards. Clearly reforestation as done in the past would not achieve the desired results. Site selection, species selection, site preparation, the selection of high quality seeds, and maintenance and silvicultural practices as required are essential activities. The Forest Department should be given the resources and the opportunity for carrying out these essential activities as well as for carrying out the required research and other ancillary activities needed for managing the forest plantations in a truly professional manner.

FUELWOOD PRODUCTION

Biomass fuel is used mainly for household cooking and it comes mainly from non-forest sources - rubber wood, coconut residues, uprooted tea bushes, and home garden cuttings. The supplies from the natural forests and other wilderness areas are mainly in the dry zone, and there, for the most part, the householders themselves gather the wood that they require. The Master Plan does not propose to raise special fuelwood plantations, but various other strategies are proposed e.g. increasing biomass fuel supplies from agroforestry systems and increasing efficiency in the use of bioenergy.

In the context of the sharply growing demand for electricity and the very limited scope for expanding supplies through hydropower generation, the possibility of dendro thermal generation should be given serious consideration. Large areas of fallow land are available in the dry zone, and suitable techniques should be developed for raising and harvesting fast growing fuelwood species so that a locally produced source of energy could be made available for power generation. There are many technical and logistical problems that have to be resolved, and the feasibility of the operation has first to be determined through pilot scale activities.

ECOLOGICAL CONSIDERATIONS

Many ecologists and environmentalists object to raising monoculture plantations, especially of non-indigenous species. Ecologically, a mixture of species is preferable to monoculture. The resulting diversity has substantial long term benefits. Yet forest plantations must meet basic needs for industrial wood and fuel, while providing adequate safeguards for conserving soil and water.

Forestation requires cost effectiveness. The suitability of a species to a site, the quality of the wood it produces, the establishment costs, and the wood increment must all be considered. Plantations produce several times more timber than natural forests and are often the only way to relieve pressure to exploit natural forests. Sri Lanka has raised tens of thousands of hectares of forest plantations, and if not for these plantations the rate of exploitation of the natural forests would have been even more severe than what it was. Those who object to forest plantations of exotics must recognize how plantations can help conserve natural forests.

Pinus caribaea, a cause of much controversy, has been planted on degraded wet zone sites of grass and scrub. It has succeeded after years of failed afforestation trials with other species. *Pinus caribaea* has shown phenomenal rates of growth. With proper management and supported by silvicultural trials it should be possible to interplant with broadleaf species, when the pine is thinned.

Silvicultural trials on the use of indigenous species for reforestation and for enrichment planting in natural forests are continuing, but this programme needs to be strengthened.

TIMBER AND FUELWOOD DEMAND AND SUPPLY

Timber supplies

Conventionally, the primary product obtained from the forest is wood, and one would expect, therefore, that in any national context the main source of timber would be the forest. In Sri Lanka, however, it is seen that at the present time the major part of the industrial wood and biofuel that is consumed comes from non-forest sources. This has been so for several years. The FSMP of 1995 estimates that home gardens, rubber and coconut plantations, and trees planted along farm boundaries, roadsides etc. collectively supply 70 per cent of the construction and industrial wood consumed in the country.

According to the FSMP there was a total of 858 500 ha under home gardens in 1992, compared to 781 000 ha in 1983. A more detailed study by the Forestry and Land Use Mapping Project in 1994 in the Upper Mahaweli catchment also showed an increase in the area of home gardens since the early 1980s. It would therefore seem that this source would continue to make a substantial contribution even if there is some decrease in productivity due to land fragmentation and some households opting to replace the mixed crop with tea, to provide cash income.

Rubber wood is in demand for the furniture and plywood industries. The age-class distribution of the rubber plantations and the continuing demand for wood suggests that the current annual felling and replanting rate of 6600 ha would continue and even increase to around 8000 ha over the next 15 years. The demand for coconut wood has shown an increase because of the scarcity of other timber and the comparatively low price of the wood. Taking into account the age-class distribution of coconut plantations and the growing demand for coconut wood, the FSMP forecasts an increasing flow of timber from this source for the next several years.

Although the non-forest sources will continue to supply a sizeable share of the wood demand, the biggest challenge the wood-based industry would have to face is the predictable shortage of wood. Three main issues relating to the wood based industries have been identified by the Forestry Master Plan. These issues and the strategic proposals for addressing them are briefly set out below:

- **Inadequate supply of wood in quantity and quality.** Wood supply will be based mainly on production by the private sector. The state will have to play a catalytic role by deregulating the wood trade, removing disincentives for production, and facilitating and supporting efficient management and use of the existing resource base. The state should promote tree growing in home gardens and other private land, and in deforested and degraded lands. Private sector involvement in plantation forestry should be promoted. Industrial forest plantations should be brought under efficient profit oriented management.

- **Uncompetitive wood based industries.** The wood industry, particularly saw milling, is in a decrepit state – machinery is old and inefficient and not designed for using small sized logs, resulting in high levels of wastage and substandard products. Utilization capacity is low and there is reduced labour productivity. Management and labour skills are substandard. A series of proposals are made for addressing these issues. These include the modernization of the saw milling industry, training management and labour, and increasing wood supplies.

- **Unfavourable business climate.** Among the issues cited are the lack of stable policy directions for wood based industry development, excessive regulation of transport of wood and finished products, inadequate financial arrangements for modernizing the industry, the State Timber Corporation's monopoly access to wood from state forests, and lack of market and industry information systems. Committed, stable policy decisions are needed, providing directions and a supportive framework for the development of the industry. The role of the wood based industry in the economy and in meeting the basic needs of the people has to be emphasized in order to improve the sector's public image. It is also important to create a dialogue between the government and private industry so that the problems and viewpoints of both sides can be understood and joint action taken to resolve issues. Specific action needs to be taken to develop markets by establishing comprehensive industry statistics, developing market information systems, and disseminating market information to producers and traders.

The Master Plan gives two alternative scenarios: the FSMP scenario, based on the implementation of the proposals relating to the wood industry in the plan, and the current trends scenario which describes the likely scenario if the present state of affairs in the industry is allowed to continue. These are depicted in Table 3. It must be noted that the "current scenario" assumes that the forests will be utilized sustainably. A third scenario is that it will not be possible to control illegal logging and that the state will not be able to implement its plans for the sustainable management of the natural forests and forest plantations. In such an event, the sawmills will get their wood supplies from unsustainable sources i.e. from the remaining forests, causing their destruction and degradation.

Fuelwood supplies

Fuelwood continues to be the major source of energy for domestic cooking. Biomass fuel is also the source of thermal energy for many industries. The total consumption in 1995 was estimated at 9.3 million tonnes (with the household sector consuming 8.3 million).

Table 3 : Sawnwood and plywood consumption, production, and imports under current trends and FSMP scenarios (in '000m^3)

Product/Scenario	1995	2000	2005	2010	2015	2020
Current trends						
Sawnwood						
Consumption	567	626	688	753	820	885
Production	539	563	585	640	646	646
Imports	28	63	103	113	174	239
Plywood and other wood based panels						
Consumption	35	41	49	58	70	82
Production	5	5	5	5	5	5
Imports	30	36	44	53	65	77
FSMP						
Sawnwood						
Consumption	567	626	688	753	820	885
Production	539	595	654	730	804	876
Imports	28	31	34	23	16	9
Plywood and other wood based panels						
Consumption	35	41	49	58	70	82
Production	5	5	5	5	5	5
Imports	30	36	44	53	65	77

Source: Forestry Sector Master Plan.

Forecasts of consumption show a drop in per capita consumption but a small rise in total consumption. Forecasts of supply show that there will be a sustainable supply of biomass fuel, with the same sources contributing a share more or less similar to what they do now. However, if it proves feasible to raise fuelwood plantations and use the produce to generate power there will be a significant increase in demand compared to that forecast in the FSMP.

POLICY, LEGAL AND INSTITUTIONAL ASPECTS

There have been statements of forest policy since 1929. At first, emphasis was primarily on achieving self-sufficiency in timber, but there was also explicit mention of the preservation of indigenous fauna and flora. Since 1953, the objective of conserving fauna and flora, soil and water, and the general environment was given first place in the forest policy statement. The last statement, in 1995, sets out the following objectives for the forestry sector:

- To conserve forests for posterity, with particular regard to biodiversity, soils, water, and for their historical, cultural, religious and aesthetic values.
- To increase the tree cover and productivity of the forests to meet the needs of present and future generations for forest products and services.
- To enhance the contribution of forestry to the welfare of the rural population, and strengthen the national economy, with special attention paid to equity in economic development.

That the forestry sector has not performed up to expectations is evident from the trends over the past decades. Although policy statements were made, and they could not be faulted as to their contents, no serious attempt was made to analyse the policy objectives, identify issues and root causes and to develop strategies for implementation. The first Forestry Master Plan prepared in 1986 was typical of the failure of the planning process to match implementation strategy with the declared policy. Whereas the policy was explicit on conserving fauna, flora, soil, water, etc. the plan had focused its strategy entirely on meeting the demand for timber irrespective of what it would cost in terms of forest degradation and its environmental implications. The FSMP of 1995 was a welcome change. It has not turned a blind eye to the current state of the nation's forests. It has recognized the serious depletion of biodiversity as a result of over exploitation of the natural forests, and it has provided remedial measures to reverse the current adverse trends. The Plan has analysed the issues and focused on addressing the root causes of forest destruction.

The proposal to place a large area of forest into the multiple use category is central to the strategy of increasing the productivity of the natural forests. The involvement of forest user groups is envisaged in a kind of participatory management role. Even in the management of Class II forests there is expected to be a participatory role for the people living in the vicinity. In all these cases a prerequisite for people's participation is that they should be beneficiaries. In this context it is necessary to recognize the following factors:

(a) The vast majority of the forests that will be expected to come under participatory management are severely degraded and will have to be rehabilitated.

(b) The people living in proximity to the forests depend on the forest for a wide range of non-wood products, but these collectively make only a small contribution to the household income.

(c) The wood products that they get from the forest are poles, sticks, and fuelwood, and these products are already in short supply.

(d) The villagers depend on the forest *mainly* for obtaining land – in the dry zone it is for shifting cultivation and in the wet zone it is to expand their agricultural holdings (IUCN Sri Lanka, 1995). These illicit activities have to stop if the forests are to be rehabilitated.

Under these conditions, the participatory approach to forest management has to include a substantial component for providing benefits to the stakeholders until such time as the forests could be rehabilitated and made productive. Some benefits could come through allowing the collection of non-timber forest products on a regulated basis. Other benefits could come by involving the community in èco-tourism activities (e.g. serving as guides) and making investments in the buffer zone to enhance the resources of this area and provide opportunities for the people to improve their livelihoods. In this context, the most serious constraint the Forest Department will face is the shortage of financial resources. At present its development programme is heavily dependent on donor funding (grants and soft loans).

The Department of Wildlife Conservation (DWLC) is part of the forestry sector, and yet it functions under a separate ministry. This situation is bound to act as an impediment to good management unless a strong and effective coordinating mechanism is established. A separate wildlife policy had been declared several years ago, but progress in implementation had been slow. The wildlife policy has now being revised.

The Forest Department derives its legal authority from the Forest Ordinance. The ordinance was originally drafted so as to provide legal support for the 'command and control' mode of forest management. Even with all the amendments that have been made from time to time, the basic tenor of the law has not changed. A notable amendment was, however, introduced through the Forest Amendment Act, No. 3, of 1995. This amendment introduces, for the first time since the Forest Ordinance was originally enacted, a new category of legally defined forests, Conservation Forests. According to the relevant section of the amendment, any land 'which has unique ecosystems, genetic resources, or is the habitat of rare and endemic species of flora, fauna and micro-organisms and of threatened species, or which needs to be preserved in order to achieve an ecological balance in the area by preventing salinization or drying up of rivers, ensuring adequate rainfall, preventing landslides and fires hazardous to human life' could be declared a conservation forest.

CONCLUSION

A common conclusion of several studies that have been made on the forestry sector and its ability to implement the proposals in the FSMP is that legislative change, institutional reform, and a supporting human resources development and management programme are essential. A radical reform is necessary to provide the enabling legislation for introducing the many policy changes proposed in the FSMP and the five-year Implementation Programme (Ministry of Forestry and Environment (MOFE), 1997). The Forest Ordinance is now undergoing another revision. The re-classification of the forests, the involvement of forest user groups and other stakeholders in management, and the introduction of leasehold forest plantation and management are some of the innovations that need to be accommodated in the new Forest Act.

The Fauna and Flora Protection Ordinance which governs the activities of DWLC was amended comprehensively by the Fauna and Flora Protection (Amendment) Act, No. 49, of 1993. Among the changes brought about by the revision are the inclusion of a greatly expanded list of protected species (e.g. the list of protected species of plants has grown from nine to several hundred) and provision for imposing much stiffer penalties than before for offences under the Ordinance. This Ordinance, like the Forest Ordinance, is currently undergoing revision. Since a good part of the work of the Forest Department is also concerned with the conservation of fauna and flora, it is important to ensure that the new Forestry Act that is being drafted and the Revised Fauna and Flora Ordinance now under preparation complement each other.

With regard to institutional capacity, it is agreed that institutional reform is needed at different levels: at the inter-ministerial level (e.g. to co-ordinate functions between the two ministries under which the Forest Department and DWLC function); at the ministerial level (e.g. the creation of a profit centre in the Forest Department and the removal of monopoly rights now enjoyed by the State Timber Corporation); and at the provincial, district and project levels (e.g. coordination of implementation arrangements and extension services at field level) (MOFE, 1997).

The enforcement of the Fauna and Flora Ordinance as it now stands is deficient in many ways. For example, although the Ordinance was revised in 1993 and protection given to a large number of species of fauna and flora, it appears that collection from the wild and export of protected species is going on apace. The DWLC would have to examine its current institutional structure and capability and make the changes necessary to move into an active phase of managing the protected areas under its charge and safeguarding the country's indigenous fauna and flora.

REFERENCES

1. Andrews J.R.T. (1961) *A Forest Inventory of Ceylon*. Forest Department, Battaramulla.

2. Baldwin M.F. (Ed.) (1991) *Natural Resources of Sri Lanka – conditions and trends*. Natural Resources, Energy and Science Authority of Sri Lanka, Colombo 7.

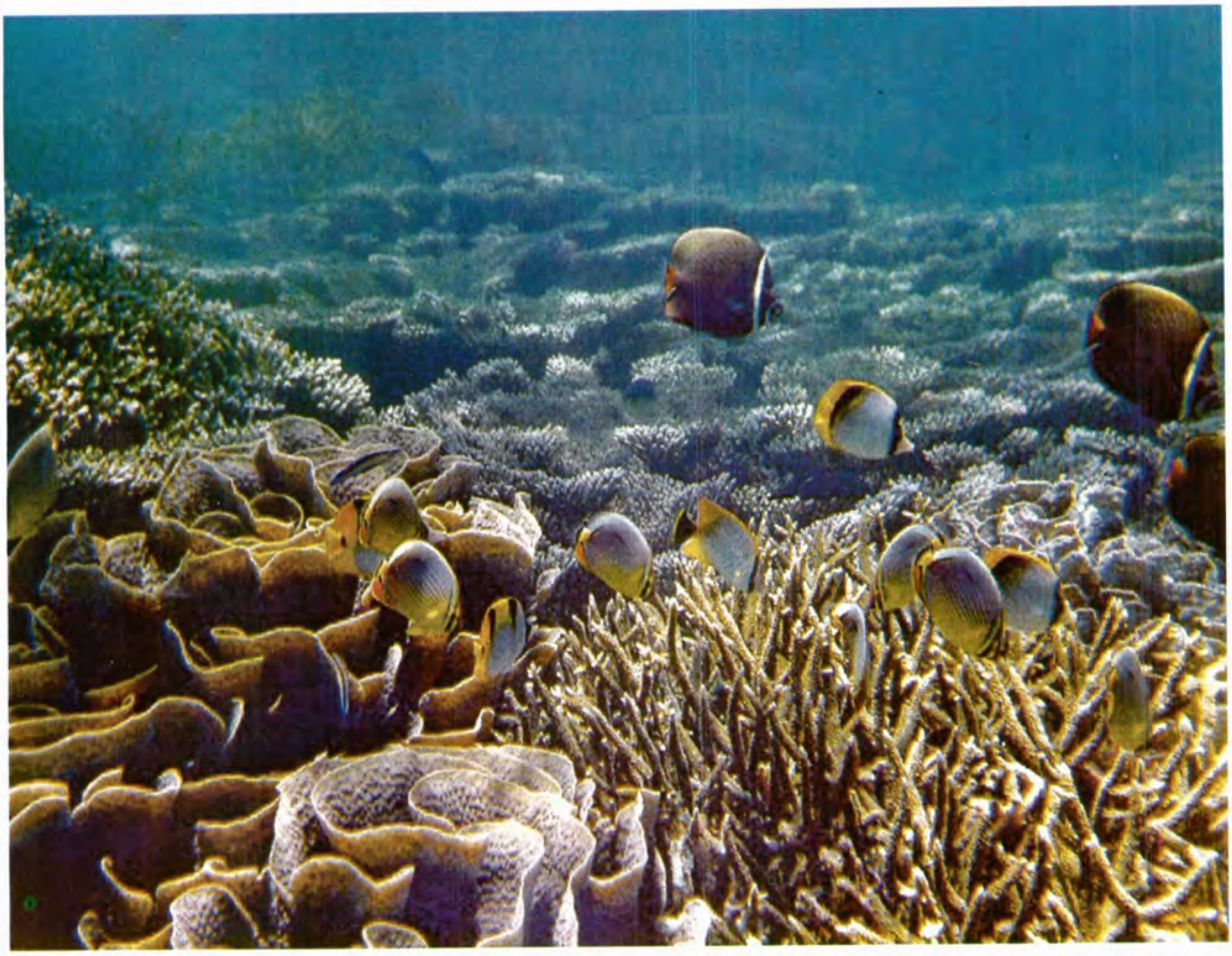
3. IUCN Sri Lanka (1995) *Traditional Uses of Forests in Sri Lanka, Volume 1*. IUCN, Colombo 5.

4. IUCN Sri Lanka (1997) *Designing an Optimum Protected Areas System for Sri Lanka's Natural Forests*. IUCN, Colombo 5.

5. MALF (Ministry of Agriculture, Land and Forestry, now Ministry of Forestry and Environment) (1995) *Sri Lanka Forestry Sector Master Plan*. Ministry of Agriculture, Land and Forestry, Battaramulla, Sri Lanka.

6. MOFE (Ministry of Forestry and Environment) (1997) *Forestry Sector Master Plan – Five-year Implementation Programme* (mimeo). Ministry of Forests and Environment, Colombo.

7. Nanayakkara V.R. (1987) *Forest History of Sri Lanka*. In: *1887-1987 – 100 years of Forest Conservation*. Forest Department, Sri Lanka.



Photograph by Arjan Rajasuriya.

Coral Seascape

Coastal and Marine Resources

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Summary

Sri Lanka is a small island in the Indian Ocean with a coastline of about 1 760 km. A wide range of coastal ecosystems are found in the coastal zone which is also characterized by a series of scenic bays and beaches which are major tourist attractions. Living resources include production from the fisheries. A major contribution comes from the coastal fisheries now being operated at more or less optimum levels. Offshore fisheries are in their infancy but have considerable potential for exploitation, though cost intensive. Apart from finfish, there are resources of lobsters and shrimps as part of the capture fisheries. However, shrimp culture has become an important and lucrative investment during the last two decades. There has been rapid expansion along the northwestern coastline leading to problems of diseases, environmental concerns and socioeconomic concerns. Among the coastal ecosystems coral reefs are important, well represented and have been subjected to intense study in recent years. Human impacts, such as coral mining, are destructive influences by which reefs are being degraded. Ornamental fish is collected from the coral reef environment and forms the basis for a lucrative export market. A number of estuaries and lagoons occur around the island and major urban centres are associated with them with the attended problems of pollution and adverse human impacts. Non-living resources include the environment itself which is the basis for a rapidly growing tourist industry, industrial mineral sands and sand pumped in from offshore for land fill and building. The coastal zone is managed by the Coast Conservation Department which has produced the management plans entitled "Coastal 2000". Problems such as erosion which is serious on the west and southwest coast and economic development within the coastal zone are addressed by the Coast Conservation Department.

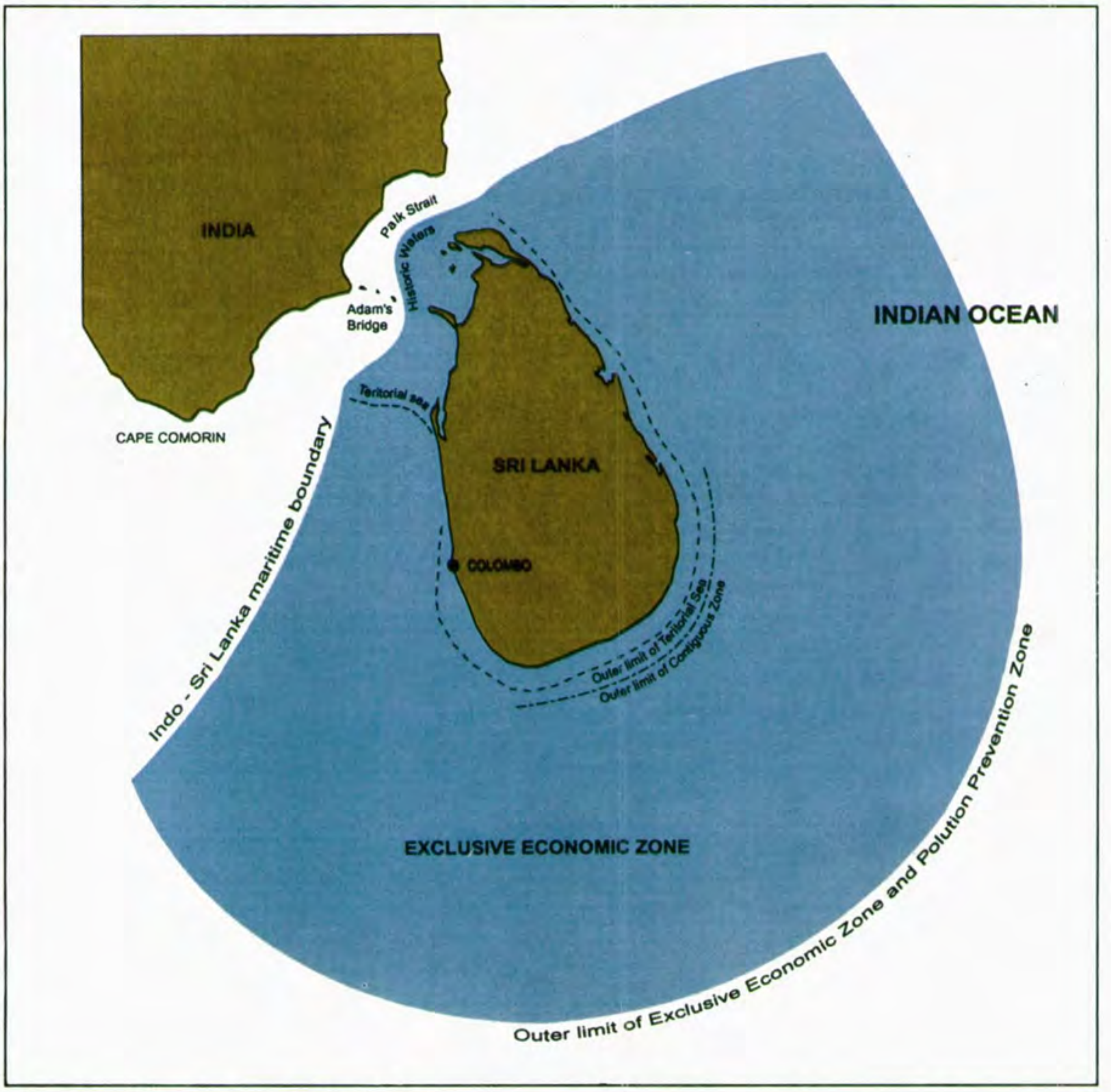
INTRODUCTION

Sri Lanka's coastline is about 1 760 km long. Along its length are a variety of ecosystems which include sandy beaches, rocky shores, lagoons and estuaries, mangrove stands, salt marshes and sand dunes. In the shallow waters off the coastline are found sea grass beds, coral growths and coral reefs.

Extending outwards from the coastline is the continental shelf, with an average width of about 40 nautical miles and a total area of about 26 000 km^2 (an area that is nearly half the total land area of the island.) It is narrow around most of the island. In the northwest and north it is broad and shallow. In the Gulf of Mannar and Palk Bay the shelf merges with the Indian continental shelf.

The shelf itself, is for the most part uneven and rough, major exceptions in this configuration being the Pedro and Wadge Banks and the bed of the Gulf of Mannar. Cutting across the shelf are a few deep canyons, the most striking of which is the one off Trincomalee. It is this feature that makes the Trincomalee Harbour one of the best natural harbours in the world. Depths of over 600 m are reached within the harbour area, itself.

The seas overlying the shelf are referred to as **coastal**. They support our coastal fisheries, which are the main source of marine fish production. Beyond the edge of the continental shelf is the **'continental slope',** which descends rather steeply to the floor of the deep ocean. The waters beyond the continental edge form our **'offshore'** ocean waters. The **'territorial limits'** of the island extend to 12 miles (19.2 km) offshore, beyond which lies the **'contiguous zone'** under the provisions of the UN Law of the Sea. Sri Lanka has jurisdiction over an **Exclusive Economic Zone (EEZ)** which extends 200 nautical miles outwards from the shoreline and covers an area of over 230 000 km^2 of the ocean (Figure 1).



Adapted from Natural Resources of Sri Lanka, 1991.

Figure 1: Coastal and maritime jurisdiction of Sri Lanka

Until the beginning of the sixteenth century, at which time the country first came under foreign domination, there was little development of the maritime regions. Over the past five centuries, the picture has changed and the major centres of economic activity have shifted to the coastal sectors of the island. This is evident from the distribution of major urban centres, at the present time. The census of 1981 (the last census conducted) recorded 5.04 million people, or 34 per cent of the total population, living in Assistant Government Agent (AGA) divisions of coastal areas of which about 45 per cent are in urban areas. Trade and commerce, tourism, industry, fisheries and agriculture are the main types of economic activity in the maritime areas.

The coastal and marine resources of Sri Lanka comprise the commonly recognized two main components of many natural resources, **Living Resources** and **Non-living Resources**. The living resources include, mainly, fish and shell-fish, squid and cuttle fish, ornamental fish, sea cucumbers, from which 'trepang' is produced, coral reefs and the rich biota associated with them, mangroves and sea grass beds, salt marshes and peat marshes.

The non-living resources include, the beaches, sand and sand dunes, the clear blue coastal seas, coastal scenic bays and the variety of interesting habitats, the direct use of which form the basis of a thriving Tourist Industry. Tourism already holds an important place in the country's economy and has the potential to become our prime foreign exchange earner, in the future. Non-living resources that generate extractive uses include mineral sands, sand and coral sands.

MARINE FISHERY RESOURCES

The marine fish resources of the island exist in our **coastal waters** - the waters that overlie the continental shelf - and in **offshore waters** - the deep waters that extend beyond the edge of the continental shelf to the edge of Sri Lanka's **Extended Economic Zone**. Coastal waters support the coastal fisheries while the offshore waters support resources that contribute to the **offshore or deep sea fisheries.**

The marine fisheries resources are grouped as **small pelagic** and **large pelagic species**, both of which groups are free swimming in open water, **semi-demersal species**, that live near the ocean bed and **demersal species** that are bottom living.

The most numerous of the small pelagic fish species in the fishery are sardines, seer and herrings. Large pelagics include the seer, tuna, barracudas. Demersal species include, silverbellies, moonfish, ribbonfish and large demersals such as breams, groupers and snappers. Shrimps, referred to as shellfish, as opposed to finfish, are also demersal.

Total marine fish production in 1996 was 206 300 t of which 72 per cent or 149 300 t was from the coastal fishery and 57 000 t from the deep sea fishery. It is of significance that the contribution from the offshore fishery has increased from 11 000 t in 1990 to 57 000 t in 1996 (Table 1).

The Beach Seine or Ma-dal Fishery, once a major contributor to the catches of small pelagic fish (over 40 per cent), in the coastal sector, in the forties, has declined steadily and now contributes only about 10 per cent to the total coastal catch.

The coastal fisheries provide nearly 97 per cent of the marine fish production, 90 per cent of the employment in fisheries and almost all of the foreign exchange earnings.

Potential Marine Fishery Resources

The most recent data available on potential fish resources of the island were produced by the 'Fridjot Nansen' Fishery survey of 1978-1980. This indicated that the highest fish concentrations are found in areas close to the edge of the continental shelf. Here, the highest fish densities have been located along the stretch extending from Negombo to Galle, on the banks of Hambantota and along the stretch from Trincomalee to Mullaitivu. The survey estimated the potential annual substantial yield of the coastal fisheries at 250 000 tonnes, about two thirds from pelagic species and the rest from demersal and semi-demersal speoies.

Table 1 : Fish production by sub – Sectors (1990 – 1996) (t)

Year	Total Fish Production	Marine Fish Production	
		Coastal	Offshore & Deep Sea
1990	177 063	134 132	11 666
1991	198 063	159 151	15 080
1992	206 168	163 168	22 000
1993	220 900	174 500	33 000
1994	224 000	157 500	37 500
1995	237 500	149 300	*60 000
1996	206 300	171 550	*57 000

Source : - Department of Fisheries & Aquatic Resources & NARA.
* Also includes fish purchases from foreign vessels permitted to land in Sri Lanka

Per capita consumption of fish in Sri Lanka, declined from 14 kg in early 1980s to about 11 kg in 1990. It increased to around 15 kg during 1991-1994 primarily because of increased imports of fish products. The Ministry of Fisheries & Aquatic Resources Development has targeted a per capita consumption of 18 kg for 1999 in its six year Fishery Development Plan - 1999-2005. The targeted local production for 1999 is 280 000 t of which around 8 900 t would be exported (shrimp, lobsters, frozen fish). The shortfall of over 71 000 t would be imported in order to achieve the targeted per capita consumption.

Current Status of Marine Resources

For over a decade Sri Lanka was not able to make assessments of its fish stocks. In the absence of basic data on stocks, fishery scientists have not been able to assess trends in the fishery, with any degree of accuracy. This has affected fishery planning and management, adversely. Research conducted by NARA research personnel has indicated that there is potential for expansion of fisheries, in the offshore (deep sea) and that there are resource constraints in respect of coastal fisheries.

The large pelagics include fish such as skipjack tuna, yellowfin tuna, bill fish, shark and seer. In coastal waters these types are being exploited, already, at optimal level. However, it is estimated that smaller tuna species (Kawakawa and frigate tunas) that inhabit, mainly, the continental shelf area can be exploited further.

While there does not seem to be much room for expanded production of large pelagics in coastal waters, the offshore/deep sea fishery can be expanded. Recent stock assessments indicate that stocks of these highly migratory (cross ocean) species appear to be healthy. The increasing catch, especially from the purse seine fishery in the southwest Indian Ocean supports this view.

Exploratory tuna fishing in offshore/deep sea areas, using multiple gear has resulted in high catch rates particularly in the south. The most profitable fishing zone appears to lie 48-160 km offshore, in this region. This is reflected in the numbers of boats of different types that are operating now as compared to the past.

During the period 1995–1997 an Asian Development Bank (ADB) funded offshore fish resources survey has shown that a doubling of the current level of effort may give yields of 80 000 t. However, there would be a 20 per cent reduction in the catch for each boat. Further, financial viability can be guaranteed only when the fleet expansion rate is less than two per cent (i.e. about 35 boats per year). The same survey has indicated that there is a potential for the introduction of a fleet of about 160 small boat tuna longliners to harvest large sized, deep swimming tuna varieties which could be exported to the lucrative 'sashimi' market in Japan, which is already being tapped.

With regard to small pelagic species, NARA studies show that sardine stocks in the south and southwest are not exploited at the optimum level. The purse seine fishery in the southwest appears to be maintained at the optimum level. The purse seines operating in this area have not diminished the sardine stock, the main species caught in this fishery. But because purse seines are far more efficient than gill nets, close monitoring is essential.

Current annual catches of small pelagics are in the region of 50 – 76 000 t, the large annual variations in the catches observed being characteristic of small pelagic resources. Recent stock assessment studies undertaken on the dominant sardine species, the trenched sardine, hurulla, using data from the main gillnet fishery have shown that there is little room for increased production without reducing individual effort and earnings. The purse seine fishery, conducted using light attraction in the night, (light fishing) expanded in southwest and south in the 1980s and is a fishery technique acceptable in terms of Fishery Science. It does not affect the magnitude of catch of fishermen using small gill nets. However, this particular fishery has been banned since 1994 due to objections from the small mesh gillnet and beach seine fishermen of those areas.

In similar fashion, having spent enormous sums of money on the development of Inland Fisheries, over many decades, using both foreign aid and domestic inputs the government of the day decided in 1990 to withdraw support for inland fish culture, almost overnight. This episode is dealt with under the appropriate chapter but is quoted, here, in order to underline the principle that major policy shifts in natural resource development and management should be based on solid data bases and sound scientific considerations. They should not pander to the selfish demands of a small section with vested interests.

THE FISHING FLEET

Even as late as 1988, the fishing fleet was still dominated by traditional craft. Of about 28 000 craft, only about 46 per cent were mechanized at that time. The once dominant 9 m, 3.5 t fishing fleet, more suited to the coastal fishery, has declined from 3 347 boats in 1982 to 1 357 boats in 1995. The offshore fishing fleet (in which boats may travel even outside the EEZ limits to engage in multi-day fishing trips lasting up to about 30 days) has increased from 302 boats in 1986 to 1 710 in 1996. Offshore fish catch has increased from a little over 5 000 t in 1985 to over 76 000 t in 1995.

As in many tropical fisheries, a variety of species are caught in a single fishery, different types of gear being used by the boats. About 80 per cent of total coastal production comes from fisheries that use gill nets. These are nets that are suspended from floats and extend down into the surface waters. A number of units are strung together and may extend for long distances. They are operated both by mechanized and non-mechanized craft.

DOLPHINS IN THE SRI LANKA FISHERY

There is no organized or established fishery for dolphins in this country nor is there any tradition of using dolphin or whale meat as a source of food. Dolphins abound in our waters (Table 2). Various species of whales can be seen in our seas and off and on, individuals move into shallows to die, as they do in other parts of the world, too. NARA started a programme of 'Whale Watching' at Trincomalee, now in abeyance due to unsettled conditions. However, there is great potential for this to become part of ecotourism development in the country, in the near future and plans should be developed in this regard.

Table 2 : Overall species composition of dolphins landed in Sri Lanka.

Species	Male	Female	M / F	Total	Percentage
Spinner Dolphin *Stenella longirostris*	824	683	114	1621	58.2
Bottlenose Dolphin *Tursiops sp.*	118	98	19	235	8.4
Striped Dolphin *S.coeruleoalba*	106	89	5	200	7.2
Spotted Dolphin *S.attentuata*	110	62	21	193	6.9
Risso's Dolphin *Grampus grisus*	67	51	5	123	4.4
Roughtoothed Dolphin *Steno bredanensis*	21	14	-	35	1.3
Fraser's Dolphin *Lagenodelphis hosei*	9	6	-	15	0.5
Common Dolphin *Delphinus delphis*	3	-	-	3	0.1
Melonheaded Whale *Peponocephala electra*	41	30	2	73	2.6
Pygmy Killer Whale *Feresa attenuata*	29	21	-	50	1.8
False Killer Whale *Pseudocra crassidens*	19	9	5	33	1.2
Dwarf Sperm Whale *Kogia simus*	9	7	-	16	0.5
Pygmy Sperm Whale *Kogia breviceps*	11	4	1	16	0.5
Southern Bottlenose Whale *Hyperoodon planifrons*	2	1	-	3	0.1
Unidentified Dolphins & Small Whales	-	-	175	175	6.3
Total	1 369	1 075	347	2 791	100

Source: Pauline Dayaratne & Leslie Joseph, A study on Dolphin catches in Sri Lanka Bay of Bengal Programme.

Sri Lankan fisheries use a very large component of drifting gill nets. Unfortunately for the dolphins, their prey are the same species as are caught in the gill nets. As a result, they become an incidental by-catch either by direct entanglement or when they attempt to feed on fish trapped in the nets.

There is, quite appropriately, world wide concern about the conservation of whales and dolphins, which are important parts of the world's biological heritage. However, well meaning conservationists have targeted Sri Lanka as one of the countries that is wantonly destroying its dolphin population. Much adverse publicity has resulted.

Estimates made ranged from 9 000 to 60 000 killed per year. This was proved false in a review made by Dayaratne and Joseph under the Bay of Bengal Project (BOBP) in 1993. They conducted a one year study which revealed that earlier estimates were based on inadequate coverage geographically, and assessments of fishing effort likely to cause dolphin mortalities by methods and standards which were not rigorous and therefore unscientific. Their study has provided solid data which shows that the total number of animals landed annually is in the region of only 5 000. The survey shows that eight species of dolphins and six species of small whales appear in the catches and that 85 per cent of the catch consisted of five dolphin species. There is some harpooning of dolphins, meat being used by longliners for shark. Among a few communities dolphin meat is eaten. It does not fetch a high price.

There are no figures of available stocks of dolphins either in Sri Lankan waters or in the Indian Ocean, but figures for the Eastern Pacific for landings and stocks give no indication of any threat to the Dolphin population. It can be assumed quite safely that the Dolphin population in Sri Lanka waters are under no threat. Any interference with the gillnet fishery will be counter-productive. However, awareness creation among the fishing community about the value of Dolphins and how they might be rejected safely from the fish catch is important.

CRUSTACEAN FISHERIES

Lobsters and shrimps are the crustaceans that are exploited by these fisheries. Lobsters have been fished at a low level over a long period of time. However, with the expansion of the tourist industry, the demand for lobsters has shot up and there is over exploitation, at the present time. Shrimps too have been fished in lagoons and coastal waters over many years, the most sought after species being the Tiger Prawn, *Penaeus monodon* and the Indian Prawn, *Penaeus indicus*.

Lobster production in 1977 was 2 599 t . It declined to 663 t in 1989 but has increased again in the 1990s, averaging 800 t per year in the early 1990s. This increase was due to a significant increase in fishing effort, in response to increased demand from the tourist trade and resulting high prices. Catch rates have declined but the number of gear used per boat had increased in order to increase capture.

In the south coast lobster fishery, the average annual catch rate (catch per boat per day) has dropped from 3.30 kg in 1986 to 1.24 kg in 1991, while there has been an increase of over 40 per cent in fishing effort during the same period. Total catch too, has dropped from 272 t in 1986 to 146 t in 1991. However, several factors make the lobsters specially vulnerable to over exploitation. The combination of high product prices, low fishing costs and low opportunity of labour encourage fishing even at very low catch rates. Stock assessment studies indicate that urgent management measures are necessary and that increase in fishing effort must be prohibited.

With regard to shrimps there has been a major development over the past decade or so with the introduction into the country of modern techniques of shrimp farming, many, on the basis of turn key operations. Shrimps command high prices on the export market and this applies mainly to the cultured tiger prawn.

Catch rates in the shrimp trawl fishery off the west coast (Negombo) have fallen from 7-8 kg/day in 1978 to 4.5 - 4.8 kg/day in 1985/1986. Stock assessment studies have shown that the maximum sustainable yield has already been achieved in the case of large shrimps which are being grossly over exploited, at present. Potential for additional yields from stocks of smaller shrimp species are assessed as marginal. In the above context shrimp culture takes on major significance.

SHRIMP CULTURE

An excellent analysis of the growth, status, production and value, problems and potential of the shrimp farm industry has been published by Siriwardena (1998). Much of the information relating to crustacean fisheries and shrimp culture used here is derived from that report which also lists the primary sources of information.

In early 1980s a number of small scale entrepreneurs and a few large multinational companies embarked on shrimp farming. The industry grew slowly and by 1990 a total of 60 farms covering an area of 405 ha had come into operation. Growth picked up in the early nineties, mainly in the northwestern and western coastal belts. A total of 970 farms had been developed over a total farm area of 2 400 ha by 1996, ranging in extent from 0.5 ha to 200 ha. Of these farms, 589 have been operating without the necessary authority or approvals. Most of the unauthorized farms are small scale and occupy an estimated area of 600 ha.

As will be shown, the rapid expansion of shrimp farming has brought along with it a number of environmental and social problems and problems of disease in the industry. However, shrimps are a source of valuable foreign exchange earnings. Therefore, it is planned to allow expansion into other areas of the country in the northeast and the south. Obviously, any future development must take account of the mistakes made in the past and the lessons learnt. Sustainability and compatibility with the environment must be assured in all future development.

Along with the shrimp farms, there has been the welcome development of shrimp hatcheries. These produce the post-larvae that are necessary for stocking the prawn ponds. At one time, post-larvae were collected in the wild. Now these hatcheries produce the fry using the latest technologies and have grown into prosperous industries, themselves. From the point of view of resource management, therefore, there is no pressure on recruitment to wild prawn population deriving from the expansion of the shrimp culture industry.

The contribution of shrimp aquaculture production to total fisheries production in Sri Lanka ranged from 0.54 per cent to 1.4 per cent between 1992 to 1996 and comprised the largest export product and the highest foreign exchange earner within the fisheries sector. In 1980s the quantity exported ranged between 1 300 t and 2 600 t, the highest quantity exported being in 1984. In 1984 the total production of cultured shrimp was about 10 tonnes. By 1990, production has increased to 3 555 t. Table 3 shows the trends in shrimp exports between the years 1992 and 1996.

The shrimp culture industry requires a number of imported inputs. Of these, the major such input is feed. Others include equipment such as pumps, generators and paddle wheel aerators. Feed is the most important and the most expensive. The industry depends to a large extent on the imported feed. This accounts for 50 per cent - 60 per cent of total cost of production. Table 4 gives the quantity and cost of feed imports between the years 1992 and 1996. Over the same period, foreign exchange earned from shrimp exports was Rs. 7 447 million, while net exchange earned was Rs. 5 591.6 million.

According to a rough estimate, the total direct employment generated by the shrimp culture industry is around 20 000. A number of support industries and services are associated with the shrimp industry. It has been estimated that an additional 20 000 indirect employment opportunities have been created through them.

According to the current estimates the profits made by the shrimp farming industry is about Rs. 75 000/crop/ha. Thus shrimp farming is a very profitable venture, with much of the produce being snapped up for export. The local consumer has to pay high prices for shrimp and has little access to the high quality product targeted to the export market.

After initial success, shrimp farming has run into major disease problems which resulted in greatly reduced production, profits and potential for viability. There were two major outbreaks, the Monodon Baculus Disease (MBV) in 1988 - 90 and the White Spot Disease in 1996. Unfortunately, the very few trained fish pathologists that we had, have

Table 3 : Shrimp exports and contribution to the total fishery exports

Year	Quantity Exported (t)	Value (Rs.)	% Contribution
1992	1246 (1121.4)	613 (551.7)	42.31
1993	1246 (1283.4)	808 (727.2)	33.90
1994	2301 (2071.0)	1650 (1485.0)	45.12
1995	2781 (2503.0)	2153(1937.70)	53.00
1996	3555 (3199.5)	2365 (2128.50)	51.60

Source : Customs Department.

Table 4 : The quantity and value of shrimp feed imports

Year	Quantity of Feed (t)	Value of imports (Rs. Million)
1992	2018.5	1231.11
1993	2310	150.11
1994	3728	261.00
1995	4505	360.50
1996	5760	460.70

Source : Customs Department.

left our shores and we do not have trained personnel to handle disease outbreaks on shrimp farms. The trouble shooting, advice and extension arm that should have developed in tandem with the industry is grossly underdeveloped.

In order to address this problem the shrimp culture industry has set up a laboratory facility to serve the farmer's needs. The Industrial Development Bureau of the northwestern Provincial Council is also in the process of setting up an Aquaculture service centre to cater to the needs of the shrimp farmers and to coordinate the activities of institutions involved in the shrimp culture industry. In addition, an Aquaculture Extension Centre has been set up by the relevant Ministry. The National Aquatic Resources Research and Development Agency (NARA) is in the process of training personnel on the handling of shrimp diseases. The diagnostic facility is to be set up with assistance from FAO.

The shrimp culture farms now in operation, have concentrated around the Dutch Canal, which extends from Mundel to the Kelani mouth using this as their focal water base. The canal provides the intake into the farms and also receives the effluents. It caters to about 150 farms covering about 1 400 ha. The question of water quality and quantity, therefore, has become an important factor for these farms. Levels of sulphides, nutrient chemicals and suspended solids have increased.

The bigger farms have introduced treatment and recirculating systems, on site. Small scale farmers, however, do not have the capacity to take similar remedial actions. Recently the government has intervened to facilitate bank loans for such purposes. Though there are several possible outlets through which the canal could connect to the sea, only two outfalls are functioning as partial openings. Therefore, water movement between the sea and the canal is restricted and the natural process of water exchange and renewal is severely constrained. Several recommendations have been made to improve the renewal rates and carrying capacity of the Dutch Canal, including dredging and opening of some of the sea outfalls and keeping them open on a permanent basis. This needs to be done if the industry is to be assured of sustainability around the Dutch canal.

The opening up of shrimp farms, which must necessarily occupy large extents of coastal lands has led, inevitably to user conflicts. These have emerged between the large scale operators and small farmer; between the traditional fishing community and shrimp farmers and also with the surrounding communities. Large extents of land which are suitable for shrimp culture have been leased out to large entrepreneurs, especially during the last decade. Community concerns are that they are losing agricultural lands, there is salt water intrusion into domestic wells and lowering of groundwater levels. These are very real concerns compounded by the knowledge that intruders and relatively small groups of investors are making huge profits on land that rightly should belong to the community.

There are environmental concerns related to shrimp farming. The Central Environmental Authority has laid down a set of guidelines with respect to environment protection, project design and construction, operations and processing. Shrimp farmers are required to follow these guidelines. An Environmental License is issued to a farmer once the construction is completed according to the guidelines. Shrimp culture projects over 4 ha in extent are subjected to an Initial Environmental Examination (IEE) or to an Environmental Impact Assessment (EIA) and the projects over 40 ha in extent are subjected to an EIA.

NARA has taken steps to train personnel in the field of shrimp pathology and health management with the assistance of donor agencies such as FAO and ADB. Awareness programmes and extension services are being developed. The monitoring of the growth of the industry is being carried out using GIS under an FAO assistance programme.

It is accepted that shrimp culture development is depleting the mangrove cover. Guidelines have been set in order to reduce this impact to a minimum and prevent further loss.

FOREIGN TRADE

Exports of fishery products are relatively insignificant. Exports consist of prawns, lobsters, crabs, ornamental fish, shark fins, all of which come from the marine sector. Imports consist of canned

Table 5 : Quantity & value of imports of fish & fish products 1990 – 1996 (Quantity in tonnes, value in Rs. Million)

Type	Maldive Fish		Dried Fish		Canned Fish		Others	
Years	Qty	Value	Qty	Value	Qty	Value	Qty	Value
1990	1614.53	92.43	24 164.94	587.20	8137.38	223.20	3 710.61	46.69
1991	3169.43	264.28	41 077.60	1420.28	7860.11	318.50	0.09	0.25
1992	3042.51	300.20	41 246.90	1497.01	10 681.80	534.31	29.46	2.48
1993	4011.35	348.05	42 465.92	1421.42	7008.26	417.40	0.39	0.32
1994	4193.35	460.28	39 404.08	1629.85	12 664.52	802.85	-	-
1995	3371.13	412.53	44 798.84	1738.68	20 169.23	1 215.20	4.14	2.59
1996	3809.50	481.25	43 864.94	1872.75	15 208.49	1 071.21	0.92	1.02

Source :- Customs Department.

and dried fish and Maldive fish. Trends in exports and Trade balance (Table 5) show an increase in the value of exports and imports but the trade balance has remained adverse.

In 1994 the contribution to GDP was Rs. 14 376 million, equivalent to 2.8 per cent of the total GDP. Earnings from export of fish and fishery products increased from Rs. 453 million in 1985 to Rs. 4 125 million in 1996.

ORANAMENTAL FISHERY RESOURCES

The international aquarium trade has boosted Sri Lanka's ornamental fishery exports. Ornamental fish exports rate third highest in terms of volume and value of fishery exports (next to prawns and lobsters). Nearly 70 per cent of the aquarium fish exported are brackish water or marine species. Of the marine species exported approximately 80 per cent are finfish while the balance are invertebrates - corals, mollusc shells bivalves, holothurians and echinoderms. A small number of large scale operators dominate the market. A list complied in 1984 indicated that of 26 exporters, three who dealt primarily with marine species controlled about 80 per cent of the export trade. Table 6 gives a list of ornamental fish species prohibited from export.

Approximately 139 species of marine fish are exported. Included are 29 species of butterfly fish, 13 species of wrasses, 11 species of trigger-fish, 10 species of angelfish and nine species of sturgeon fish.

Ornamental fish collection often occurs near coral growths, although fishing in estuaries for some species has increased during the past few years. Shallow reefs are fished by skin divers, while deeper areas are exploited by scuba divers. Collecting is seasonal and dependent on the monsoons. Many collectors and exporters report that coral reef fish collected for the aquarium trade are less abundant now than in previous years, but accurate data are not available. From collectors' reports it is understood that the population of many species are significantly depleted on a seasonal basis, while other species are being gradually depleted, year by year.

Certain species of reef fish collected for the aquarium trade have a localized distribution and/or are uncommon or rare. We do not yet know whether this is a natural feature of these species or whether over exploitation has caused low density. At least 29 species, including 13 species of butterfly fish, are recorded by collectors as rare or uncommon. Heavy exploitation could cause depletion or local extinction.

Table 6 : Ornamental fish species prohibited from export under Fisheries and Aquatic Resources Act, No.2 of 1996

Scientific Name	English Name	Sinhala Name
Marine Fish		
Chaetodon semeion	Dotted butterfly fish	Panawa, gallela
Centropyge bispinosus	Two-spined or dusty angelfish	Nona malu, manamalaya
	Coral beauty	
Pygoplites diacanthus	Regal Angel fish, Royal angelfish	Nona malu, manamalaya
Coris aygula	Clown coris	Molli girawa
Labroides bicolor	Bicolor cleaner wrasse	Girawa
Pterois radiata	Radial fire fish	Gini maha
Platax pinnatus	Pinnate spadefish, Dusky bat fish	Kotadora, kottanthalaya
Hymnocera elegans	Orchid shrimp	

Source : Sri Lanka Fisheries year book 1997.

COASTAL ECOSYSTEMS

Coral Reefs

Coral Reefs, which are among Sri Lanka's most valuable shallow water marine habitats and resource bases, are famed for their spectacular beauty. They were made world famous by Sir Arthur C. Clarke in his book, *'The Reefs of Taprobane.'*

Fringing reefs and continental shelf patch reefs are common in Sri Lankan waters. They range from shallow fringing reefs to offshore reefs lying at depths of about 50 m. Three habitat types have been identified among these reefs namely coral, sandstone and rock boulders. Coral cover varies from about 80 per cent on healthy coral reef habitats to less than one per cent on some rock boulder habitats (Rajasuriya, 1995).

Coral reef habitats are less in extent compared to sandstone and rock reef habitats. Extensive coral reef habitats occur in the Gulf of Mannar between Kalpitiya Peninsula and Mannar Island. Other areas are from Trincomalee to Kalmunai on the east coast, from Akurala to Tangalle in the southwest and southern coast and off the Jaffna peninsula. In addition there are scattered offshore patch reefs of limestone and coral at depths of 15 to 25 m.

Sri Lanka's reefs support high species diversity of both fauna and flora, of which, most are unidentified. Some taxonomic groups where considerable amount of identification has been carried out include fishes, spiny lobsters, turtles, cephalopods, stony corals, molluscs, echinoderms, seaweeds and sea grasses.

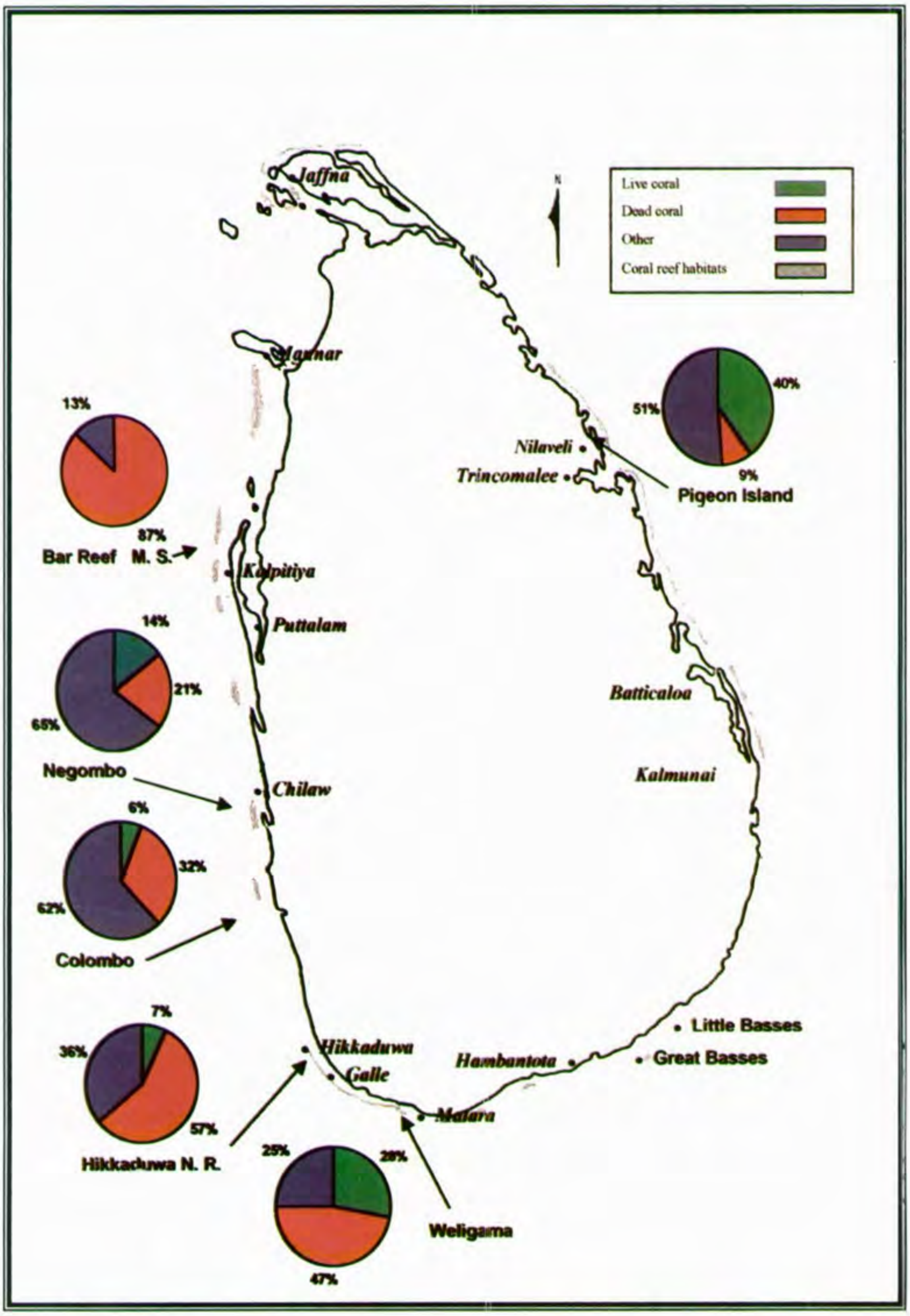
Reefs and their resources are important for the fisheries industry, tourism and coast protection. Fisheries and tourism industries also provide employment to many. Fishing is the main human activity around reefs. Spiny lobsters, chanks, ornamental fish and ornamental shells are harvested for export. A study carried out on the marine ornamental fish industry by NARA and the Marine Conservation Society of UK revealed that this industry provides employment to about 1 500 divers and many others associated with the industry.

Tourism, both local and foreign, utilizes reefs for recreational purposes such as coral viewing and scuba diving. Reef lagoons that provide calm waters are also used for swimming and bathing. The trend in the recent past to build many tourist facilities in close proximity to coral reefs has led to deterioration of water quality and damage to coral reefs.

The quality of reefs has degraded rapidly during the past two decades, both due to human activities and natural causes. Main causes of reef damage arise from coral mining in the sea, blast fishing, use of bottom set nets, destructive ornamental fish collecting techniques, boat anchoring, reef trampling, pollution and uncontrolled harvesting. In 1978, a cyclone damaged reefs in the east coast around Batticaloa. More recently (1998) an El Nino Southern Oscillation (ENSO) related coral bleaching event caused considerable damage to corals and to coral habitats in several Indian Ocean states including Sri Lanka (Rajasuriya, 1999).

Major causes of reef degradation in Sri Lanka related to human activities

- Coral mining from the sea.
- Blast fishing.
- Other destructive fishing techniques (bottom-set nets, moxy-nets) that cause damage to reef habitats.
- Pollution.
- Uncontrolled harvesting of reef resources.
- Sedimentation.
- Boat anchoring and operation of glass bottomed boats.



Source : NARA. 1999.

Figure 2 : Distribution of coral reefs and post bleaching status of selected coral habitats in Sri Lanka

Natural causes

- Coral bleaching in 1998.
- Crown of thorns starfish.
- Other invasive organisms such as tunicates, corallimorpharians and algae.
- Sedimentation due to natural erosion.

Coral bleaching event in 1998 in Sri Lanka and its impact

An El Nino related Sea Surface Temperature (SST) elevation in the months of April and May caused large scale coral bleaching and eventual destruction of corals in the Indian Ocean, including Sri Lanka. Most of the branching and tabulate corals were completely destroyed within the depth range of one to eight m. Most shallow water reefs along the western, southern and eastern coasts lost branching, tabulate and foliaceous coral. However, three species, *Montipora aequituberculata, Psammacora digitata* and *Porites rus* were hardly affected (Rajasuriya, 1999). Almost all the dead coral areas are now covered by various species of algae and invasive organisms such as tunicates and corallimorpharians. There was no evidence of coral bleaching around Trincomalee and Pigeon Islands. The status of reefs at selected sites is given in the attached map based on surveys carried out by NARA after the bleaching event in April-May 1998 (Coral Reef Research Programme, NARA, 1999).

Coral Reefs are invaluable systems, not mere objects of passing tourist interest. These are tropical shallow water marine ecosystems that rank among the world's most biologically productive and diverse natural resources. Coral reefs have levels of primary productivity far greater than those of most terrestrial ecosystems. The sea in the vicinity of coral reefs supports a large biomass of fish and large numbers of fish and invertebrates for the marine aquarium trade. Reef organisms provide medicinally important compounds and the reefs, themselves, act as natural breakwaters that reduce coastal erosion by moderating the impact of waves on adjacent coastlines. Coral reefs are a major tourist attraction and offer us unsurpassed recreational, educational and research opportunities, as well.

Coral reefs are being destroyed systematically, by a small part of our population which derives short term benefits from coral mining. As against this very limited benefit, the loss to the nation's biodiversity is enormous and the productivity base of adjacent seas is affected. Further, large scale environmental and economic losses result from erosion of coastlines exposed by the destruction of coral reefs which function as natural protective barriers.

Various environmental factors impact on the condition and healthy growth of coral reefs. Figure 2 shows the high percentages of dead coral in some locations: about 80 per cent at Polhena, nearly 50 per cent at Weligama, and about 25 per cent at Hikkaduwa and Akurala. Most of the damage has occurred over the past ten to fifteen years. Estimates of coral conditions and losses on the east coast have not been made, in recent times, due to the unsettled security situation that now prevails in that area. The major threats to coastal habitats, including coral reefs, are summarized in Table 7. Reef mining for manufacturing lime used by the building industry is the single most destructive action. Certain fishing methods also destroy coral. These include the use of explosives, the use of Trammel nets to catch reef fish and spiny lobsters and the practice of breaking coral to net ornamental fish. Damage is done, also, by the improper operation of glass bottomed boats in the tourist industry. Fuel oil too adds to the pollution. While this activity should be allowed to expand, safety standards in respect of their operation must be introduced. Clearing of coral reefs for the passage of boats, trampling of coral at low water, collection and sale of coral specimens, and extraction of coral sand for aquaria are other human impacts that contribute to the degradation of our coral reef resource. The southwest is a naturally eroding coastline facing the full impact of the southwest monsoon. Coral reef destruction makes matters worse.

Coastal Wetlands

Coastal wetlands include shallow coastal seas, coral reefs, estuaries, lagoons, seagrass beds, mangroves and salt marshes. They also include the man made systems which have been constructed

Table 7 : Impacts on coastal habitats of particular concern to the CCD (CCD 1990)

Coastal Habitat	Impacts of Particular Concern to the CCD
Coral Reefs	Physical damage to coral reefs and collection of reef organisms beyond sustainable limits.
	Increases in freshwater runoff and sediments
	Introduction of waterborne pollutants
Estuaries /	Encroachment
Lagoons	Changes in sedimentation patterns
	Changes to the salinity regime
	Destruction of submerged and fringing vegetation
	Inlet modifications
	Loss of fishery habitat
Mangroves	Changes in freshwater runoff, salinity regime and tidal flow patterns
	Excessive siltation
	Introduction of pollutants
	Conversion of mangrove habitat and overharvesting of resources
Seagrass beds	Physical alterations
	Excessive sedimentation or siltation
	Introduction of excessive nutrients or pesticides
Salt marshes	Degradation of bird habitat or seed fish collection sites
(tidal flats)	Obstruction of storm water runoff
Barrier Beaches, Sand Dunes and Spits	Sand mining
	Erosion
	Dune migration

Source : Coastal 2000. CCD, 1992.

recently for the purpose of shrimp farming. Coral reefs, which too belong to the coastal wetland system have been dealt with, in fair detail, in the preceding section.

Estuaries

According to current internationally accepted definition, an estuary is a partially enclosed body of water with free connection to the ocean and within which sea water is measurably diluted with fresh water from terrestrial runoff. In Sri Lanka estuaries are either basin estuaries, where rivers discharge into relatively shallow basins connected with the sea (Puttalam, Chilaw and Negombo 'Lagoons'), or riverine estuaries, where rivers discharge directly into the sea through relatively narrow channels (Kelani, Kalu and Nilwala Ganga estuaries) (Fig 3).

Estuaries are associated with important urban centres, industrial development and fishing activity. Therefore, they are of great economic importance.

Further, because of high density of human population and impact of human activity, estuaries are subject to appreciable levels of pollution. The city of Colombo lies at the mouth of the Kelani Ganga and has major impacts on the water quality of the river and its estuary. Fish kills occur at frequent intervals, indicative of the high levels of pollution. Another alarming feature is the extensive salt water intrusion in the estuary. In recent years, during dry periods, salt water intrusion has extended even up to the Ambatale intake from the Kelani Ganga, which forms a considerable component of the pipe-borne water supply to the city of Colombo. This major problem is caused by extensive sand mining which results in the river bed lying, below the mean sea level in certain places.

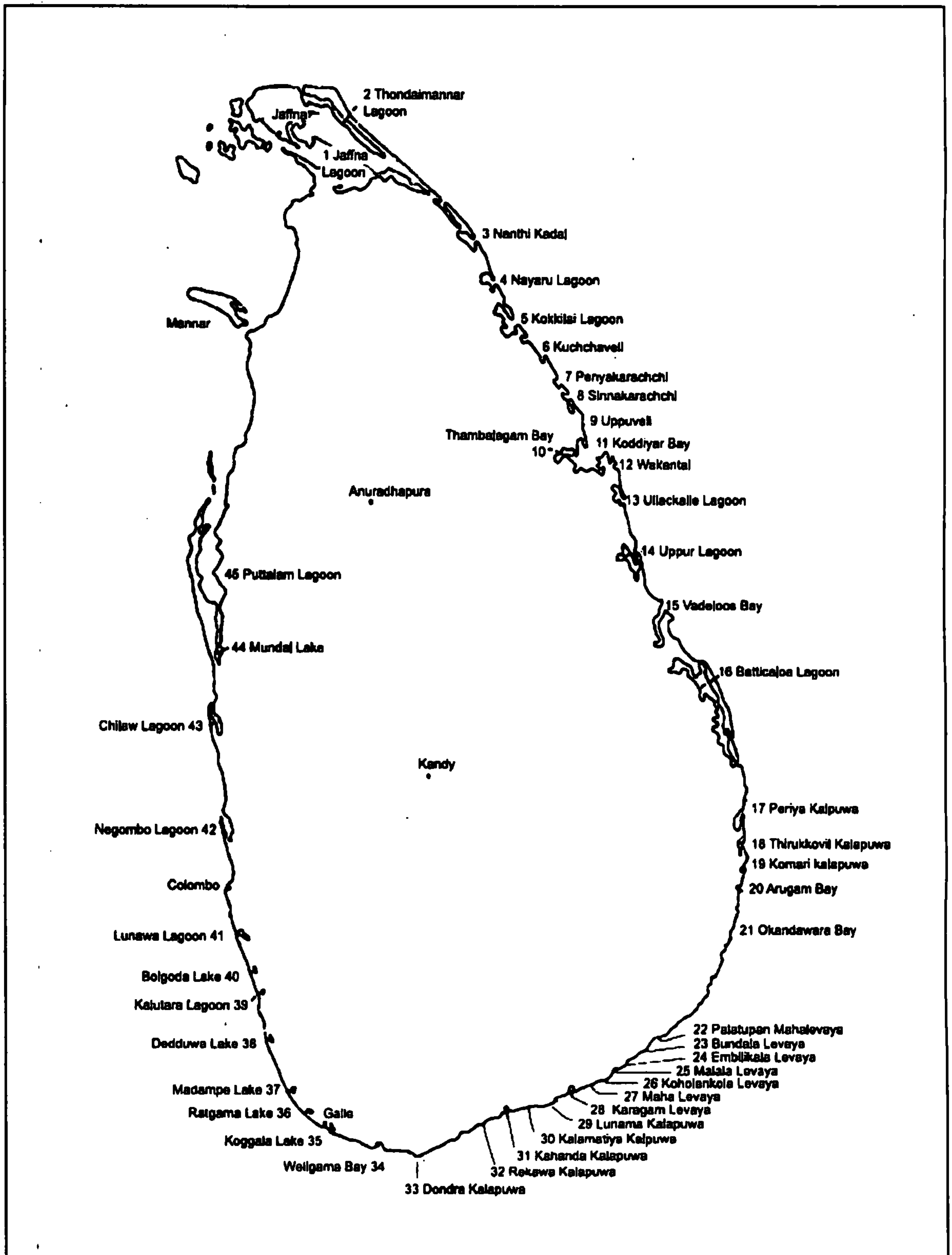
Lagoons

These are also brackish coastal water bodies, by definition, they are either permanently separate from the sea or they connect with the sea only during part of the year. In fact, many of our coastal wetlands are labelled lagoons but are in fact, estuaries. True lagoons are water bodies such as Mundel Lake, Bolgoda Lake, Koggala Lagoon, Mawella Lagoon, Kalametiya Lagoon, Rekawa Lagoon, Lunawa Lagoon and Batticoloa Lagoon.

Many of the estuaries and lagoons, shown in Figure 3, are closely linked with the major urban centres. Urban growth and concentrations of populations in and around these centres place heavy demands on these wetlands and have adverse environmental impacts on them. Sand bar formation at the mouths of estuaries is a natural process determined by the balance between volume of outflow and supply and accumulation of beach sand. The latter process is controlled by prevailing patterns of coastal currents. However, several human activities contribute to aggravate sand bar formation. Several recent river basin development/diversion schemes have restricted water flow and altered flow patterns, leading to increased sand bar formation. Sand bars obstruct navigation in the Chilaw and Negombo Lagoons and in the Panadura-Bolgoda estuary.

Several estuaries and lagoons have gradually decreased in size. In Negombo Lagoon for example, the effective water area has diminished by 791 ha, between 1956 and 1981. The delta area at the Attanagalu Oya inlet almost doubled during this period, indicating high rates of siltation. In recent times, purpose oriented, land filling, to create land for habitation has become a major factor. This is achieved through encroachment planting of mangrove seedlings, on the pretext of *in situ* mangrove conservation, which helps to stabilize temporary shoals. Deposition of garbage then helps in the stabilization process. The building of new piers, jetties, and bridges restrict water flow and promote further siltation. Similar human activities have resulted in considerable decrease in the extent of the Lunawa and Kalametiya Lagoons.

Many of our estuaries and lagoons are polluted to different degrees. These include the Negombo 'Lagoon', Kelani estuary, Lunawa Lagoon, Walawe estuary and the Batticaloa Lagoon. The Walawe estuary and the Valaichenai section of the Batticaloa Lagoon receive major chemical and other contamination from the two state owned paper factories. The other water bodies receive industrial effluents, domestic waste, municipal waste and sewage. The Negombo lagoon, which serves as an anchorage for fishing crafts is contaminated by oil from fishing crafts, boat repair yards, and fuel supply stations along the banks. Some of the lagoons in the southern sector are affected by inputs from the retting coir. These include nitrates and phosphates which result in higher levels of COD.



Source : Natural Resources of Sri Lanka, Conditions and Trends, 1991.

Figure 3: Basin estuaries and lagoons

Estuaries and lagoons, support fishing activities and provide employment for fishing communities. They are used as anchorages for fishing boats (Negombo Lagoon, Chilaw Lagoon), disposal sites for sewage (Kelani estuary, Negombo Lagoon, Lunawa Lagoon) and for release of industrial effluents (Negombo Lagoon, Kelani estuary, Valaichchenai estuary).

Above normal inputs of fresh water into some lagoons and estuaries have reduced salinity levels in them. For example the salinity of the Kalametiya Lagoon dropped considerably when the overflow from the Uda Walawe reservoir was diverted into the lagoon in 1950. This led to the decline of a thriving prawn fishery.

Seagrass Beds

These are composed of rooted, seed-bearing marine plants (halophytes) occurring in shallow, sheltered nearshore coastal waters and as underwater meadows in estuaries and lagoons. Seagrasses and the associated epiphytes together with the rich detritus which accumulates around them are centres of high productivity. They are habitats that support diverse communities of organisms and provide nursery areas for fish species of commercial importance. Notable amongst the species of animals supported by the seagrass beds is the dugong, commonly known as the sea cow. This is a large marine mammal growing to about seven to eight feet in length and to weights of many hundred kilograms. It is a bottom feeder whose main diet consists of species of seagrass. Its meat is much sought after and it brings to the fisherman who captures it a considerable sum of money. In order to protect the animal its capture is prohibited. It is listed as one of our endangered species.

Seagrasses bind sediment and stabilize the underlying seabed bottom sediments. They provide nursery grounds for many species of fish and food for a range of marine organisms. The dugong has already been mentioned. Other important species include sea turtles and fish species, such as parrot fish. The commercially important estuarine species, *Etroplus suratensis*, lives mainly among seagrasses, but moves also into estuaries and up-river.

Although their locations and extent have not been mapped out precisely, seagrasses occur as extensive beds from the Dutch Bay to the western end of the Jaffna peninsula. From Mannar, seagrass beds extend northwestwards across Palk Bay to Rameswaram Island on the Indian coast. Seagrass beds thrive in many basin estuaries and lagoons - Puttalam, Negombo, Mawella, Koggala, Kokilai, Batticaloa and Jaffna Lagoons. Twelve species of sea grasses have been recorded. (Abeywickrema, 1961).

Mangroves

These are salt tolerant, woody, seed bearing plants, occurring along sheltered intertidal coastlines, in association with estuaries and lagoons. The vegetation ranges in size from small shrubs to tall trees. Mangrove cover in Sri Lanka is not very extensive, primarily because of the very limited range of tidal variation (maximum about 0.8m). No precise data are available of the area covered by mangroves in the country. Estimates range from 6 000 ha to 13 000 ha. Recent remote sensing surveys indicate the existence of larger extents of mangrove than estimated earlier. Mangroves fringe the Puttalam Lagoon, Dutch Bay, Portugal Bay complex and this cover, alone, is estimated at 3 385 ha. There are extensive mangrove stands in the Jaffna Peninsula but no estimates have been made, in recent times due to prevailing unsettled conditions. The aerial extent of mangroves in six districts, as given in Land Use Maps of the Survey Department are as follows -

District	Area (ha)
Colombo	09
Ampara	54
Gampaha	723
Trincomalee	1 020
Batticaloa	1 520
Puttalam	2 970
Total	6 296

Twenty three species of mangroves and mangrove associates have been recorded from Sri Lanka.

The natural ecosystem functions of mangrove systems include serving as nursery grounds for post larval shrimps and for various fish species. They support populations of crab and of bivalves such as oysters. These natural functions of mangrove habitats have to be balanced, rationally, against both, the natural and the man induced tendency to reduce the extent of the waterways that they fringe by continuous accumulation and consolidation of silt. Another important economic consideration is that these locations, by their intrinsic nature, are sometimes suitable locations for the establishment and expansion of shrimp farms. Further, these locations are in high demand for the expanding tourist industry. They can be developed into very attractive beach resorts, with lagoon, estuary, mangrove stands, sea and sand.

In the early days of development of the tourist industry, much damage was done by unplanned clearing of these systems mainly out of ignorance of consequences. Now, the best conserved and protected areas of isolated mangrove stands are associated with Beach Resorts, especially around Aluthgama, Bentota and Maha Ganga. Mangrove environments also provide a resource base for ecotourism development.

An interesting observation, to make and to follow up, is that though much is said about mangroves being essential nursery grounds for coastal fish species, no correlation has ever been established, in this country, between reduction in mangrove cover and the levels of production of the coastal fishery.

Some species of mangroves, such as *Rhizophora, Bruguiera* and *Avicennia*, are commonly used as firewood. Large scale extraction of mangroves for firewood for domestic use, firing of bakeries, kilns and of illicit distilleries are a threat to sustainable use of the mangrove resource, in certain areas.

Poles of *Rhizophora, Bruguiera* and *Avicennia* are used for temporary housing, while plaited leaves of *Nepa* are used to thatch roofs. *Cerba manghas* is used in the making of masks. *Rhizophora* and *Avicennia* provide fodder for livestock. Fruits of *Sonneratia caseolaris* are eaten and at times used to make a beverage. Tender leaves of *Acrostichum* are consumed as a vegetable. Poles and posts of several species are used for construction of fish traps, while *Avicennia* and *Rhizophora* branches are heavily exploited in the Negombo Lagoon for the construction of brush piles. Tannin obtained from the bark of *Rhizophora mucronata* and *Ceris tagal* is still widely used to tan fishing nets and the sails of traditional fishing craft. Mangrove timber is sometimes used to construct the outriggers of traditional craft.

Further, in the light of the expansion of the culture industry for shrimp, with the development of modern hatcheries producing post-larvae to order, wild collection of shrimp fry from estuaries has become insignificant. Their main importance lies in their stabilizing functions in erosion prone areas and their intrinsic value as a type of coastal wetland system that must be preserved, as part of our national natural resource heritage.

Impoundment of mangrove areas for aquaculture ponds commenced in the early 1980s. NARA at that stage assessed the coastal systems of the north western coastal belt and indicated that these areas were suitable for shrimp farms. Since then the shrimp aquaculture industry has developed rapidly, with large scale operators, as well as, medium and small scale operators.

Over 2 400 ha of coastal land between Chilaw and Puttalam (around the Chilaw Lagoon, Dutch Canal, Mundel Lake and Puttalam Lagoon) have been developed for shrimp aquaculture.

Salt Marshes

These are tidal flats, periodically inundated by sea water. They support herbaceous, salt tolerant plants and associated biota. In Sri Lanka they occur mainly in the north, northwest, northeast and southeast, in which areas the dry season is prolonged. In the north, salt marshes occur mainly on exposed tidal flats and in the south mainly in the shelter of sand dunes. Salt marsh vegetation in most areas occurs as sparse, short growths interspersed with some other types of vegetation. During the rainy season, an algal mat consisting mainly of nitrogen fixing organisms occurs on the surface. This provides habitats for many young stages of aquatic organisms including milk fish.

Salt Marshes have no major economic value but are interesting habitats with their own range of biodiversity. In Mannar and Puttalam they have been sites for the collection of milkfish fry *(Chanos chanos)* for brackish water aquaculture. Certain species of migrating & wading birds are associated with salt marshes.

High saline coastal water bodies have been converted to saltpans in the northwestern and southeastern coasts. Coastal Land areas are reclaimed, also, for coconut by draining out the brackish water by the construction of special channels. Such activities are damaging, have no national economic development overtones and should not be permitted.

On the other hand the Muthurajawela project, covering the Negombo lagoon and the Muthurajawela peat marsh serves as a classic example of planned use of coastal wetland resources. Under this scheme, provision has been made for biodiversity conservation, eco-tourism, fisheries, traditional uses and the needs of resident communities, as well as provision for housing and industrial development. A notable feature of this project is the use of offshore sand resources for landfill purposes, demonstrating clearly a wetland resource that has much potential for future exploitation. Considering the major problems caused by sand, mining and the continuing need for sand for construction and landfill, this is a resource that needs to be carefully evaluated.

Beaches and Dunes

Over three fourths of the Sri Lanka coastline is beach fringed covering an estimated 11 800 ha. Most beaches are sandy but they vary greatly in width and slope. Some barrier beaches lie across lagoons or marshes and isolate them from the sea. Elsewhere, incipient barrier beaches form spits that are free at one end, such as the shoals that build up at the mouths of the Maha Oya, Negombo and Kaluganga estuaries. Barrier beaches predominate along the southwestern and southern coasts, while spits are common in the west and east.

Spits shift position from time to time and change the form and precise location of the inlets of estuaries. The inlet of Batticaloa Lagoon has shifted northward, while the Kaluganga spit exhibits exceptional instability. The extensive spit at Kalpitiya has been stabilized by the settlement and agricultural development efforts of a relatively large population.

Dunes are windblown accumulations of sand that remain unstable unless covered by vegetation. The 'beach or littoral wood zone' was once dominant but now greatly reduced. "The littoral woodland zone is a thick growth of shrubs and low tree species which cover the sand dunes and the sandy ridge-and-runnel zone, except where cleared for cultivation. One of the commonest plants here is *Pandanus tectorius* (screw pine), which has very characteristic prop roots. Other species are *Callophyllum inophyllum*, *Pongamia pinnata*, *Barringtonia asiatica*, *Terminalia catappa*, *Thespesia populnea* and *Phoenix zeylanica*. Ground creepers extend as far as the dunes"(Cooray 1995).

Prominent sand dunes lie along the northeastern, northwestern and southeastern coasts. Extensive dune systems have developed between Mullativu and Point Pedro, between Elephant Pass and Chavakachcheri, across Mannar Island between Ambakandawila and Kalpitiya, and between Kirinde and Sangamukande Point.

Distinctive communities of plants characterize the beach/dune system. This vegetation promotes accretion, binds the sediment, provides moderate protection which serve as wind barriers against coastal erosion, and help bar the transport of sand by wind. Dunes and areas adjacent to them are important areas for the extensive plantations of *Casuarina*.

The Forest Department has a programme of development of *Casuarina* plantations in the sand dune systems, which is described in greater detail in the appropriate chapter in this publication. These plantations are multipurpose investments. They can be harvested at relatively short intervals for poles. Their needles settle on the sand surface of the dune and prevent the sand from being blown away. The cover of needles allows for maximum water retention, add nutrients to an otherwise barren sandy base.

Our extensive beach systems and the bays along the southwest and southern coastline have immense aesthetic value and form the major feature of the island's range of scenic attractions that act as magnets drawing tourists to our beautiful island. The Negombo area, Beruwela, Bentota, Hikkaduwa, Unawatuna, Tangalle, Pasikudah, Kuchchaveli and Nilaveli are prime examples.

Some of our beaches are the traditional nesting grounds of five turtle species that range over the world ocean. Over a period of ages these animals return, every year to specific beach locations on this island to lay their eggs above the waterline and bury them securely. But how can they know of the immense selfishness of the human species? The eggs are often dug out for sale soon after they are laid. The adults themselves are valued for their meat and slaughtered even though they are protected species.

The turtle species that breed in our waters are the Olive Ridely, the Hawksbill, the Loggerhead, the Green, and the Leatherback. Nesting beaches have been identified at Kosgoda, Mirissa, Kottegoda, Tangalle, Kalametiya, Bundala, Kirinde and Palatupana.

Turtle eggs are a delicacy and so is turtle meat. However, a total ban is in operation on the collection and sale of turtle eggs and the capture of turtles. There are programmes which have established turtle hatcheries under which hatchlings are released to the sea. However, while these are laudable initiatives, there has been a tendency to emphasize the tourist attraction aspect to the detriment of the conservation and release aspect. This needs to be balanced and adequately monitored.

A significant economic use of certain beaches, as for example, Lunawa and Panadura is sand mining. The beaches at Pulmoddai are rich in mineral sands. These are exploited for their mineral content. Details of this industry are dealt with in the chapter on Mineral Resources of this book.

FISHERY HARBOURS

A string of fishery harbours along the coastline serve large fishing vessels, while most traditional vessels and smaller fiberglass boats use beach landings close to fishing villages. Fishermen build semi-permanent dwellings on the beaches and also use beaches to mend fishing nets and to repair boats.

Tourism

Tourism in Sri Lanka has focused primarily on its scenic sandy beaches and coastal estuaries and lagoons. About 85 per cent of tourism revenue comes from facilities in coastal areas, supplemented by the diversity of attractions in the interior. Today over 75 per cent of graded hotels and over 80 per cent of the hotel rooms are located along the coast.

Once among the fastest growing sectors, tourism declined steeply during civil unrest in 1983-1989. It peaked in 1982, with an estimated 407 230 arrivals and revenues of Rs. 3 050 million, but then came a sharp decline in arrivals and revenue until a sharp upward trend developed in 1990. Both high and low projections to tourism to the year 2000 anticipate over one million annual arrivals.

Wildlife resources along the coastal belt add to coastal tourist potential. The Wilpattu National Park extends over about 30 km along the northwest coast, while the Ruhunu (the Yala) borders the southern coast for over 50 km. Several lagoons and other coastal wetlands serve as important bird habitats and are the breeding grounds for a large number of migratory species of water fowl. Though a marine sanctuary was declared in Hikkaduwa in 1979, there was no proper enforcement of regulations for control of development. The situation has now been rectified.

COASTAL EROSION

Coastal Erosion is a major problem in Sri Lanka which in economic terms of public and private costs are enormous. Millions of rupees are spent annually on measures to reduce erosion and in paying compensation for losses incurred by coastal erosion (See chapter on Land Resources). Since 1981 the Government has carried out major coastal erosion protection programmes with foreign donor support.

Two major factors make the western and southwestern coasts of the island particularly vulnerable: the impact of the southwest monsoon and the geology of the coastline. While the latter has produced the bay and headland topography so attractive to the tourist, this feature of the coastline is indicative of the degree of erosion risk. Estimates of losses over the coastal segment of 685 km extending from Kalpitiya to Yala National Park Bay ranges from 175 000-285 000 m of coastal land, annually. The most vulnerable section of this sector is the 137 km extending north from Kelani estuary to Thalawila. (Anon, CCD 1996).

A greater proportion of coastline consists of sloping beaches which if undisturbed are a first line of defence, dissipating the energy of breaking waves. Where coral and beachrock reefs exist, these reefs form effective protective barriers. However, large sections of Sri Lanka's coastline are retreating coastlines, subject to natural erosive forces which are compounded by unacceptable human activities. Table 8 indicates coastal erosion and accretion rates along the Sri Lanka Coastline.

While parts of the coastline are naturally retreating and others accreting, human activity has tended to aggravate the problems of erosion. Such activities are summarized in Table 9.

Sand Mining

Mining of sand from beaches and especially river mouths is causing increasingly serious coastal erosion and salt water intrusion, despite permit controls exercised by the Coast Conservation

Table 8 :Coastal erosion and accretion rates in Sri Lanka

Sector	District	Coastline km	Erosion per cent of Coast	Erosion Rate m/yr	Accretion per cent of Coast	Accretion rate m/yr	Net Erosion m/yr	Net Loss 100 m^3/yr
West	Puttalam	300	30-40	0.3-0.4	30-60	0-0.1	0.2-0.4	60-120
	Gampaha	40	45-50	N.A-1.0	10-20	0-0.1	0.9-1.0	35-40
South west	Colombo	40	20-25	0-0.1	N.A.	N.A.	0-0.1	0-5
	Kalutara	40	70-80	0.1-0.5	20-30	0-0.1	0-0.4	10-20
	Galle	75	60-65	N.A-0.3	0-10	0-0.1	0.2-0.3	10-20
South	Matara	55	N.A-88	0.9-1.0	N.A	N.A	0.9-1.0	40-50
	Hambantota	135	40-50	N.A.-0.2	10-20	0-0.1	0.1-0.2	20-30
East	Ampara	110	40-50	N.A-0.2	10-20	0-0.1	0.1-0.2	20-25
	Batticaloa	100	N.A-60	0.1-0.2	N.A-20	0-0.1	0-0.2	10-20
North east	Trincomalee	210	N.A-40	N.A-0.2	10-20	0.2-0.3	N.A-0	10-0
	Mullaitivu	50	20-30	N.A-0.2	0-20	0.2-0.3	0-0.1	0-10
North	Jaffna	275	60-70	N.A-0.3	0-20	0.1	0.2-0.3	30-90
	Mannar	155	60-70	N.A-0.5	0-20	0.2	0.3-0.5	70-80
All Sectors		1585	45-55	0.30-0.35	10-25	0-.15	0.2-0.35	300-500

Source : CCD 1986; updated by CCD in 1995.
N.A. = Information not available.

Table 9 : Activities Contributing to coastal erosion (CCD, 1990)

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

Source : Coastal 2000. CCD, 1992.

Department. A CCD study found that some 500 000 cubes (1 414 000 cu.m) of sand were mined in the coastal stretch from Puttalam to Dondra Head in 1984 - nearly all (97 per cent) from rivers, and nearly two thirds of it from the Kelani Ganga and Maha Oya. Mining provides jobs, at generally high wages, for about 1 900 sand miners and support for about 6 000 individuals. It also seriously cuts sand supplies that maintain beaches and shorelines, protect property and roads along the rivers, and eause intrusion of salt water into the ever-deepening rivers. Damage to flood protection bunds in and near the Kelani Ganga has been attributed to excessive sand mining near the bunds. Table 10 shows location and estimated volume of sand mining along the stretch between Puttalam and Dondra Head.

Table 10 : Location and estimated volume of sand mining, 1984 and 1991 (CCD)

Source	Volume of Sand Removed (m^3)			
	1984	%	1991	%
Kelani Ganga	631 000	43	633 000	37
Maha Oya	316 000	21	619 000	36
Gin Oya	225 000	15	13 000	1
Kalu Ganga	132 000	9	129 000	7
Deduru Oya	65 000	4	8 000	-
Gin Ganga	61 000	4	198 000	11
Nilwala Ganga	6000	1	3 000	-
Madu Ganga	2000		12 000	1
Sub Total (Rivers)	1 436 000	97	1 615 000	93
Sea Shore	41 000	3	118 000	7
Grand Total	**1 477 000**	**100**	**1 733 000**	**100**

Source : Coastal 2000. CCD, 1992.

Table 11 : Coral collected from Sri Lanka's southwestern coastal sector 1984 and 1994

Location	Amount (t) 1984	% of Total	Amount (t) 1994	% of Total
Inland	10 400	58	15 800	80
Sea Corals	7659	42	4020	20
Total	18 059	100	19 820	100

Sources : Premeratne, 1984; Ranaweera Banda, 1994.

Coral Mining

An important contributory factor to coastal erosion is the mining of corals from adjacent reefs. Coral is the main source of lime for the construction industry. It is also used in the agricultural sector. Though in the past most of the lime was derived from inland deposits, with growth of the construction industry since the late 60s reef mining has increased. This activity includes reef breaking, back beach mining and collection of coral debris. The removal of rubble reduces the amount of material available from beach nourishment.

Various attempts have been made by the government to draw people away from the coral incentives. However, these have not proved successful. The CCD has enforced laws in relation to coral mining. There has been some reduction in mining of reefs with an increase in mining of inland deposits. Table 11 compares coral collection in 1984 and 1991.

The management of eroding shorelines is a very complex matter. Long term solutions have to be formulated on the basis of comprehensive research expertise and the accumulation of engineering information. CCD has developed the master plan for Coastal Erosion Management in 1986. Erosion prone sites along the coast where structural solutions are appropriate have been identified. Sri Lanka has made a significant financial investment in shoreline protection investing mainly in the construction of revetments and groynes.

Ongoing erosion management activities consist primarily of construction of shoreline protection structures, use of setback lines, directing development away from erosion prone areas and the implementation of a regulatory system. Regulation of sand and coral mining and enhancement of community awareness through education are also essential.

POLLUTION

Pollution of the main wetland systems of the coastal sector have been described under the relevant sections above. A general source of pollution comes from oil entering the water from ships and fishing crafts. Discharge of industrial effluents, sewage and domestic waste are also major contributors. The major international shipping routes lie a few miles off the southern and southwestern coasts. They carry an estimated annual traffic of over 5 000 tankers, posing risks of accidental oil spills. Cleaning of fuel tanks and bilges, in and around ports cause discharges that may account for frequent appearance of tar balls on the beaches of the south coast.

NON - LIVING RESOURCES

The non-living resources of the coastal zone include mineral sands, mainly at Pulmoddai (see chapter on Mineral Resources), beach sands, sands at and around the mouths of estuaries, coral for lime and sea sand from coastal waters. In the Muthurajawela Development project referred to above, landfill operations used sand from the bed of adjacent coastal waters. With sand from other quarters becoming problematical to extract, in environmental terms, these sand beds provide a resource for future use.

Sri Lanka has a partially formed peat deposit found in the 34 km^2 of coastal swamp called Muthurajawela, located north of Colombo. However, this is not considered a potential source of energy. There are isolated peat deposits elsewhere as well. The Muthurajawela marshes and the adjoining lagoon system have been subject to a planned development programme. This stands out as a prime example of how a balance can be struck between, economic gain, conservation and the development of the ecotourism approach for the protection of our important ecosystems.

Industrial Mineral Sands

Industrial Mineral Sands are scattered around the coastline near river mouths, in isolated bays, and on raised beaches. Large placer deposits of heavy minerals containing a high proportion of the ilmenite, rutile, zircon, monazite and garnet are known (see Chapter on Mineral Resources). The deposit at Pulmoddai is worked by the Sri Lanka Mineral Sands Corporation. A smaller deposit of about 250 t beach sand containing 50-60 per cent ilmenite is found at Tirukkovil, about 70 km south of Batticaloa. Three promising deposits have recently been discovered along the beaches from Mullaitivu to Nilaveli on the east coast, estimated to contain about three million tonnes of ilmenite, six million tonnes of rutile, and four million tonnes of zircon.

Seashells

Seashells are another source of limestone an extensive deposit of seashells lies between Hungama and Bundala on the south coast - a bed 2.5 to 3 m thick spread over an area of five km. Estimated at one million tonnes, it has a high calcium carbonate content of approximately 98 per cent. Shell beds, commonly found in association with coastal lakes and lagoons, consist mainly of bivalve shells with a few gastropod varieties occurring in isolated places.

Coral deposits

Inland coral deposits occur as patches and lenses at various places along the southern and southwestern coasts, especially between Ambalangoda and Matara. Deposits largely consist of loosely packed finger coral, *Acropora* sp. mixed with other coral types and molluscan shells.

INSTITUTIONAL RESPONSES AND NEEDS

Overall responsibility for coastal resource management rests with the Coast Conservation Department (CCD) under the Coast Conservation Act No. 57 of 1981. Within the narrow coastal zone defined by the Act, activity is regulated by the CCD, through a system of permits. CCD evaluates development projects and their impact through Environmental Impact Assessments, prepares and implements a Coastal Zone Management Plan, and conducts research in cooperation with other agencies.

CCD's is mandated to coordinate inter sectoral management of the activities of other agencies which have responsibilities in the coastal zone. It meets its mandate through frequent and informal inter-agency discussion and coordination. This cross sectoral authority becomes critical, because in addition to CCD's functions, other agencies exercise significant coastal jurisdiction :

- The Ministry of Fisheries and Aquatic Resources has major responsibilities for fishery resources development and management within and outside the coastal zone.

- The National Aquatic Resources Research and Development Agency (NARA), which operates as an Agency within the Ministry of Fisheries and Aquatic Resources was established in 1981, by Act of Parliament to function as the main research arm of the Ministry, in the area of all aquatic resources of the country, both living and non-living.

- The Urban Development Authority (UDA) exercises comprehensive management authority over development within and outside the coastal zone, including all areas within one km of the coastline, which it has designated as 'urban'. Detailed land use plans have been developed for some rapidly growing urban centres (Colombo, Ambalangoda, Hikkaduwa) while plans are being formulated for other towns. All building construction within coastal areas requires permits from the UDA or its authorized agent.

- Other more specialized development oriented agencies operating in the coastal zone include the Sri Lanka Ports Authority, the Sri Lanka Land Reclamation and Development Corporation, Ceylon Fisheries Harbours Corporation, and the Board of Investment, Sri Lanka. Other agencies, like the Ceylon Electricity Board, with its role in developing thermal power generation plants, can exercise jurisdiction in specific activities over coastal resources.

- The Central Environmental Authority exercises broad coastal and nationwide jurisdiction over air, water, and land pollution through environmental standards and permit regulation, as well as Natural Resources and Environmental Policy.

- Ceylon Tourist Board.

Sri Lanka, too is affected by the full range of pressures of economic development and population expansion that threaten coastal resources in all other parts of the world. The establishment of a Coast Conservation Department with adequate regulatory and coordinating functions and the formulation of a Coastal Zone Management Plan, now updated and oriented to the needs of the Year 2000 and beyond is a major factor in rational use and protection of Sri Lanka's Coastal Zone. At present, its jurisdiction is limited to the region extending from 2 km out to sea to 300 m inland from the high water mark, and in respect of rivers and estuaries, 2 km inland along their course. On the basis of experience with the current legislation and its efficiency in management of the coastal zone, it has become evident that the boundaries are too narrow and the zone needs to be redefined.

The success of the CCD does not depend only on legislative and administrative powers but is tied up very closely with its ability to work through local communities. The interest of these communities have to be taken into account, while measures are implemented to ensure the sustainable development of coastal resources. Efforts must be made to implement coastal management programmes through smaller units and at grass root levels. This will require a range of public awareness programmes and plans that will generate new employment opportunities.

Efforts are being made by the CCD to implement Coastal Management Programmes through community participation. Some have already been initiated in this manner. The National Coastal

Zone Management Plan of 1997 has identified 23 sites for implementing Integrated Coastal Zone Management Plans at local level in collaboration with all the stake holders in the area. The success of these programmes are totally dependant on the proper identification of issues, planning, implementation and monitoring of the activities in collaboration with the communities of the area.

REFERENCES

1. Abeywickrama B. A.(1961) The vegetation of the lowlands of Ceylon in relation to soil. In: *Tropical soils and vegetation, Proceedings of the Abidjan Symposium,* Paris, UNESCO pp.89.

2. Anon (1995) Proceedings of National Seminar on *Towards A New Era in Fisheries Development.* Ministry of Fisheries and Aquatic Resources Development, Colombo.

3. *Annual Reports.* Ministry of Fisheries and Aquatic Resources Development.

4. Cooray P.G. (1995) Geology of the country around. Battulu Oya and Puttalam. *Geological Survey Department. Memoir* 5, pp. 15.

5. Dayaratne P &. Joseph L. (1993) *A study on Dolphin catches in Sri Lanka.* Bay of Bengal Programme, Madras, India.

6. NARA (1999) Distribution of coral reefs and post bleaching status of selected coral reef habitats in Sri Lanka. In: *Sri Lanka Fisheries Yearbook 1999, Vol III.* National Aquatic Resources Research and Development Agency. Colombo pp.62.

7. Rajasooriya A. & White A. (1995) Coral Reefs of Sri Lanka: Review of the Extent, Conditions and Management Status. *Coastal Management,* 23 pp 73 – 90.

8. Rajasooriya A. (1999) *Coral Bleaching Report* to National Aquatic Resources Agency (unpublished).

9. Siriwardena P.P.G. S. N. (1998) *Shrimp culture in Sri Lanka.* The problems and constraints associated with the development and management and responses to address problems (unpublished personal communication).

Picture by Prasanna weerakkody and D.A.Atukorala.

Fishery Resources of Sri Lanka

INLAND AQUATIC RESOURCES

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Summary

Sri Lanka is expected to have a density of inland lentic waters amounting to about four ha/km^2 of land, in the near future, with the completion of all reservoir projects. Our aquatic habitats are diverse and play a determining role in aquatic biodiversity, agriculture, power generation, inland fisheries and in aquaculture. They support a diversity of flora and fauna, including some endemic species. The inland fishery is essentially a capture fishery, based mainly on exotic fish species. Culture of ornamental fish and plants are inland aquatic resource development activities, with considerable potential for income generation among rural communities. Population expansion and related development activities are posing threats to the quality and extent of inland aquatic resources. Land degradation, deforestation, environmental pollution, water diversion and exploitation of resources are on the increase. Clear policies for resource management and exploitation based on careful planning, improvements in legal framework and strict enforcement of existing laws are needed to promote the sustainable utilization of our inland aquatic resources.

INTRODUCTION

Sri Lanka has perhaps the highest ratio of lentic and lotic water to land for any island in the world. This ratio is expected to increase with the completion of new reservoir projects. The high water ratio is the result, mainly of a long history of extensive reservoir construction added to, in recent times, by the construction of many large multi-purpose reservoirs.

The inland aquatic systems, while providing water itself as a major resource also create a diversity of natural aquatic habitats. They play a determining role in shaping the life patterns of the people. Besides providing water for direct human use, irrigation and hydroelectricity, water plays an important role in inland fisheries and aquaculture. In recent times inland waters have been subjected to unsustainable human activities. Pollution is becoming a major problem, especially due to the input of agrochemicals. Wetlands adjoining urban centres have been brought under landfill programmes for conversion to buildable land, destroying important habitats and increasing flood hazards as natural drainage areas become blocked. Inland aquatic habitats are valuable but often vulnerable environments. Sustainable development of inland aquatic resources demands, integrated planning and development and efficient management.

INLAND AQUATIC HABITATS

According to definitions accepted by the Ramsar Convention, all our inland aquatic habitats are **wetlands:**

Wetlands are "areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary with water that is static or flowing."

Our inland fresh water wetlands include natural systems such as streams, rivers and villus. A major part of the wetlands of the island is made up of a large number of man made water bodies, called tanks. They range from small and medium to large reservoirs like the Parakrama Samudra. Reservoirs such as Gal Oya and Victoria are recent additions.

Adjoining main water bodies are low lying areas, which play important roles. They function as natural filters and as flood retention areas, which reduce the magnitude of flood damage. They contribute to ground water recharge. They support populations of fish and amphibia and are important nursery areas for these populations. They are areas of high primary and secondary production. They contribute to the food chains of communities in connected waters.

Sri Lanka has a system of 103 rivers. Over 90 per cent of the rivers radiate from the south central highlands to the western, eastern and southern coasts. There are 28 rivers with a basin area exceeding 500 km^2. Some rivers are perennial and others dry out seasonally. Details about the riverine systems are given in the chapter on Water Resources.

Associated with some of the permanent/seasonal rivers are 'villus' or 'flood plains', also described as flood lakes. Flood plains associated with rivers are best represented along the course of the Mahaweli Ganga, Kala Oya and Modargam Aru. Their total extent is estimated at 40 000 ha (de Silva, 1988a).

Seasonal fresh water marshes are found within the Wilpattu National Park. Some of the wetlands in the Wilpattu are saline even though they have no surface connection with the sea. Wet montane grasslands can be considered as marshes, as well. These are isolated from river systems and are formed in shallow depressions where local runoff collects over an impermeable layer. Montane grassland marshes are best represented at Horton Plains at an altitude of about 2000 m. The plains receive rains during both southwest and northeast monsoons and are drained by tributaries of the Mahaweli, Walawe and Kelani rivers.

Tanks and Reservoirs

Sri Lanka has no natural lakes. Neither do we have natural lentic flora or fauna characteristic of Lake Ecosystems. However, over a long period of our history our civilization has created large numbers of major, medium and minor tanks and connected systems of irrigation canals. Together, these have sustained an agricultural economy that was largely, paddy based. Details of the irrigation systems are found in other chapters of this publication. More recently, after independence, major multi-purpose reservoirs have been constructed, adding significantly to our water resource, the area of standing water and irrigation systems.

Standing waters, though lacking in indigenous fish species that could be exploited for food are easily usable for the practice of aquaculture applying extensive, semi-intensive and intensive culture methods. Aquaculture is practised in special ponds built for the purpose, in small natural ponds, in the system of man made tanks and also in large major tanks and reservoirs. Aquaculture is important for the production of cheap protein for the diet of rural communities. The main aquaculture activities in inland fresh water, at present, are the culture of food fish and ornamental fish.

Depending on size and water supply by precipitation or from streams or surface drainage, tanks may be perennial or seasonal, the latter retaining water only for part of the year. Perennial tanks retain water throughout the year. Most of these have been built by damming a river. Generally they exceed 200 ha in extent. For purposes of irrigation and fisheries these are listed as major irrigation reservoirs. 70 820 ha of land are covered by such tanks.

Seasonal Tanks

Seasonal tanks tend to dry up towards the latter part of the dry season. These tanks were created by earthen dams constructed across micro catchments and vary in extent. Their extent is usually less than 12 ha. Seasonal tanks are included in the categories of medium scale and minor irrigation tanks for fisheries and irrigation purposes. The total area of such water bodies is estimated at 56 250 ha.

Topography and rainfall patterns have provided the country with major aquatic resources for hydropower generation. There are several reservoirs built almost exclusively for the generation of hydroelectricity. These are located in the upper catchments of the major rivers at altitudes of above 1000 m. They include Castlereigh, Norton, Lakshapana, Canyon and Mousakelle. Mahaweli, the longest river in the island, has been dammed to create a series of multipurpose reservoirs - Kotmale, Victoria, Randenigala, Ulhitiya Oya and Maduru Oya. These water bodies too can be used in the future for the practice of 'extensive aquaculture'.

INLAND AQUATIC RESOURCES - FISH

Sixty two fresh water dispersant, and 20 exotic fish species have been recorded from Sri Lanka's inland waters. Three ichthyological zones of the island can be recognized - the southernwestern zone, the Mahaweli zone and the dry zone. Each zone has distinctive elements of fish fauna and is separated from the other zones by geographical and ecological barriers.

Pethiyagoda (1991) has recorded 104 species of fish belonging to 36 families from inland waters of Sri Lanka (Table 1) including brackish water species found in the inland areas.

Apparently there are 56 indigenous species completing their entire life cycle in fresh water and two catadromus eels that migrate to the sea for spawning (de Silva, 1983). Cyprinids dominate the indigenous fish population.

Sri Lanka has no natural lacustrine fish species. There is little information on the distribution of the fish fauna. The degree of endemicity of the Sri Lankan fishes is high: 26 fresh water dispersants and three diadromus gobiids are endemic to Sri Lanka. Endemic fishes of Sri Lanka are restricted to the wet zone. Some of the indigenous species are threatened due to anthropogenic activities. The IUCN Redlist (1996), which has been updated in 1999, has listed several fish species under the categories, endangered and vulnerable. These species need careful consideration in planning management strategies for conservation and sustainable exploitation.

Though the island has a high water to land area, none of these are natural lakes that support lacustrine fish fauna. Our fish fauna is impoverished especially in terms of food species. Therefore, several exotic fish species have been introduced to Sri Lanka as food fish. In addition other species have been introduced as ornamental fish. Some species were introduced for biological control of mosquitoes.

The first exotic fish was trout, introduced in 1882-1893. *Salmo trutta* and *Salmo gairneri* were introduced into streams at altitudes of over 2000 m, to promote a sport fishery. Although they were able to spawn in natural habitats, stocks were supplemented annually from hatchery reared fingerlings. Two ornamental fish species, *Poecilia reticulata* and *Xiphophorus helleri* were introduced for the purpose of controlling mosquito larvae. There are no reliable records on the introduction of fish species for the aquarium trade.

To enhance food fish production in inland waters several exotic species have been introduced (Table 2). Three African cichlids, *Oreochromis mossambicus*, *O. niloticus* and *Tilapia rendalli*, that were introduced, have successfully colonized in inland waters, breed in the wild and contribute, significantly, to inland fish production. The common carp (*Cyprinnus carpio)*, Chinese carps (*Hypothalmichthys molitrix* and *Aristichthys nobilis*) and Indian major carps, (*Catla catla*, *Labeo rohita*, *Cirrhinus mirigala*) and the grass carp (*Ctenopharyngodon idella)* grow well in our inland waters. There is evidence that the trout, common carp and *Rohu* (one of the Indian carps), are spawning in the wild. There are records on the introduction of brackish water indigenous species *Etroplus suratensis*, *Chanos chanos* and *Mugil* sp. to inland fresh water bodies. The latest introduction was in 1993 when an exotic, an *Acipencer* sp. from the Russian Federation, was brought in for experimental purposes. This trial was a failure (Atukorale & Jayasinghe, 1994).

Table 1: Fish species found in the inland waters of Sri Lanka

Species	Species	Species
Family Megalopidae *Megalops cyprinoides* **Family Anguillidae** *Anguilla bicolor* *Anguilla nebulosa* **Family Muraenidae** *Gymnothorax polyuranodon* **Family Clupeidae** *Ehirava fluviatilis* **Family Cyprinidae** *Amblypharyngodon melettinus* *Chela laubuca* *Danio aequipinnatus* *Danio malabaricus* *Danio pathirana* *Esomus thermoicos* *Garra ceylonensis* *Garra phillipsi* *Horadandia atukorali* *Labeo dussumieri* *Labeo fisheri* *Labeo porcellus* *Puntius amphibius* *Puntius asoka* *Puntius bandula* *Puntius bimaculatus* *Puntius chola* *Puntius cumingii* *Puntius dorsalis* *Puntius filamentosus* *Puntius martenstyni* *Puntius nigrofasciatus* *Puntius pleurotaenia* *Puntius sarana* *Puntius srilankensis* *Puntius ticto* *Puntius titteya* *Puntius vittatus* *Rasbora caverii* *Rasbora daniconius* *Rasbora vaterifloris* *Rosbora wilpita* *Tor khudree*	**Family Cobitidae** *Lepidocephalichthys jonklaasi* *Lepidocephalichthys thermalis* **Family Balitoridae** *Acanthocobitis urophthalmus* *Schistura notostigma* **Family Bagridae** *Mystus gulio* *Mystus keletius* *Mystus vittatus* **Family Siluridae** *Ompok bimaculatus* *Wallago attu* **Family Clariidae** *Clarias brachysoma* **Family Heteropneustidae** *Heteropneustes fossilis* *Heteropneustes microps* **Family Hemiramphidae** *Zenarchopterus dispar* **Family Belonidae** *Xenentodon cancila* **Family Oryziidae** *Oryzias melastigma* **Family Aplocheilidae** *Aplocheilus dayi* *Aplocheilus parvus* *Aplocheilus werneri* **Family Syngnathidae** *Microphis brachyurus* *Microphis ocellatus* **Family Synbranchidae** *Ophisternon bengalense* **Family Centropomidae** *Lates calcarifer* *Ambassis commersoni* **Family Kuhliidae** *Kuhlia marginata* **Family Carangidae** *Caranx sexfasciatus*	**Family Lutjanidae** *Lutjanus argentimaculatus* **Family Monodactylidae** *Monodactylus argenteus* **Family Toxotidae** *Toxotes chatareus* **Family Scatophagidae** *Scatophagus argus* **Family Cichlidae** *Etroplus maculatus* *Etroplus suratensis* **Family Eleotrididae** *Butis butis* *Eleotris fusca* **Family Gobiidae** *Awaous grammepomus* *Glossogobius giuris* *Redigobius balteatops* *Schismatogobius deraniyagalai* *Sicyopterus grisseus* *Sicyopterus halei* *Sicypus jonklaasi* **Family Anabantidae** *Anabas testudineus* **Family Belontiidae** *Belontia signata* *Malpulutta kretseri* *Pseudosphromenus cupanus* **Family Channidae** *Channa gachua* *Channa marulius* *Channa orientalis* *Channa punctata* *Channa striata* **Family Mastacembelidae** *Macrognathus aral* *Mastacembelus armatus* **Family Tetraodontidae** *Tetraodon fluviatili*

Source : Pethiyagoda, 1991.

The fresh water ornamental fish industry has grown and is now a relatively large and profitable economic activity. Approximately 65 per cent of our species of fresh water fish are exported as ornamentals. It is estimated that the industry earns around Rs.500 million in foreign exchange annually through exports. The local market for the ornamental fisheries is estimated to be around Rs. 60 million. Sri Lanka exports wild caught marine, brackish water, and fresh water fish and tank bred fresh water species to about 43 countries in Europe, USA and Asia. Presently there are about 18 major exporters. Sri Lankan exports presently contribute only about one per cent to the world demand and there is great potential for expansion. The export industry is dominated by Guppies (60 per cent) followed by Swordtails, Angels, Platys and Tetras. A local market has developed in major towns and has penetrated to village level as well.

Contract farming is the major ornamental fish production system used for servicing the export market. This system concentrates, mainly, on different varieties of Guppy. The export of wild fish collected from inland waters has increased rapidly in recent years. These exports include a considerable proportion of endemic species. Now, there is concern on the emerging threat to the survival of endemic fish due to habitat destruction, habitat degradation, population decline and over exploitation. No reliable data on population and distribution are available for most of the indigenous freshwater fish species. Therefore, it is not possible to determine the present status of these species.

Indigenous species of food fish

There are about 28 indigenous fish species which are "traditionally" accepted as food fishes (Table. 3). Of these only around 15 species are widely used as food. Today, Tilapia species dominate inland food fish production. However,

Table 2 : Food fish introduced into Sri Lanka's inland waters

Species	Country of Origin	Period of Introduction	Breeding in Natural Environment
Salmo trutta	Europe	1882-1883	+
S. gairneri	N. America	1889-1893	+
Cyprinus carpio	Europe	1915	+
Crassius carassius	Europe	1915	+
Osphronemus goramy	Indonesia	1939	+
Ctenopharyngodon idella	China	1948/1975	-
Hypophthalmichthys molitrix	China	1948/1981	-
Aristichthys nobilis	China	1938/1975	-
Catla catla	India	1942/1982	-
Cirrhinus mrigala	India	1981	-
Labeo rohita	India	1981	
Trichogaster pectoralis	Malaysia	1951	+
Oreochromis mossambicus	E.Africa	1952	+
O. niloticus	na	1956/1975	+
Tilapia rendalli	E.Africa	1969	na
T. hornorum	E. Africa	1969	na
T. zillii	E.Africa	1969	-
Helostoma temaincki	Thailand	1952	-
Puntius gonionotus	S.E. Asia	1951	na
Acipencer (hybrid of Huso huso & Acipencer ruthernus)	Russian Federation	1993	-

Source: de Silva, 1988a.

na - Information not available, + breeding in natural environment. - No evidence of breeding in natural environment.

production levels of these indigenous species are low. They cannot sustain a continuous large scale inland fishery. This led to the decision to introduce exotics to support the development of inland fisheries.

CAPTURE AND CULTURE FISHERY INDUSTRY

Before Independence there was no organized fishery in the fresh waters of the island. In 1949/1950, a policy decision was made to develop inland water fisheries, in order to provide a cheap source of protein for the people. The origin and the gradual development of the inland fishery was based primarily on the introduction of *O.mossambicus*, an African cichlid species at that time. Within a few years of introduction, *O.mossambicus* made a tremendous impact on fish production, particularly, in the larger irrigation reservoirs. By 1956, the introduction of *O.mossambicus* proved to be successful enough to support a small scale commercial fishery.

Table 3 : Indigenous fresh water species of food fish in Sri Lanka

Family	Species	Family	Species
Anguillidae	*Anguilla bicolor*	**Clariidae**	*Clarias brachysoma*
	A.nebulosa		
Clupeidae	*Ehirava fluviatilis*		
		Heteropneustidae	*Heteropneustes fossilis*
Cyprinidae	*Amblypharyngodon melettinus*		
	Danio aequipinnatus	**Mastacembelidae**	*Mastacembelus sp*
	Esomus thermoicos		
	Puntius chola	**Channidae**	*Channa marulius*
	P. filamentosus		*C. orientalis*
	P. dorsalis		*C. gachua*
	P. sarana		*C. striata*
	Labeo dussumieri		
	L. fisheri	**Cichlidae**	*Etroplus maculatus*
	L. procellus		*E. suratensis*
Bagridae	*Mystus keletius*	**Anabantidae**	*Anabas testudineus*
	M. vittatus		
	M. gulio		
Siluridae	*Wallago attu*		
	Ompok bimaculatus		

Source : de Silva (1988a).

The annual fish yield from fresh waters, before the introduction of *O. mossambicus* was around one kg/ha in Parakrama Samudra. The average annual yield increased to 227 kg/ha by the early sixties, as a result of the success of *O. mossambicus*. Indigenous fish species comprise a sizeable proportion of the catch and consist of carps, catfish, snakeheads and an indigenous cichlid *Etroplus suratensis*. Most large shallow reservoirs show the same trends in production as Parakrama Samudra. Fish yields are low in deeper reservoirs like the Senanayaka Samudra and in deep upcountry reservoirs where temperatures are low. However, Tilapias have established themselves (Nathaniel and de Silva, 1996) and are breeding in the wild in highland reservoirs, too. In these reservoirs. *O.mossambicus* has the highest relative abundance (30-58 per cent), followed by *O.nilotica* (7-21 per cent) and *T. rendalli* (0.65-3.0 per cent).

Important factors that affect the success of these species in colonizing any water body include the availability of food and suitable nesting sites. Exotic carps have been introduced to these waters and there is evidence that common carp is breeding in the wild. Rohu too may be breeding in the wild and entering the fishery.

Seasonal tanks are relatively smaller in size and they are dry for periods of 2-10 months of the year. These tanks can be used for culture based seasonal and capture fisheries.

The present estimated annual inland fisheries production is approximately 27 000 t. According to the fisheries development plan, production is expected to increase considerably in the near future. This production is mainly based on capture fisheries in major and medium sized irrigation reservoirs. The highest production (39 700 t) was recorded during the year 1989, before the withdrawal of state patronage for inland fisheries (Amarasinghe 1998). According to the estimates of de Silva (1988a) the annual fish production is around 307 kg ha^{-1} in reservoirs. Production from individual reservoirs varies from 40 to over 500 kg ha^{-1} $year^{-1}$.

Riverine fisheries are low in production. However, fish yields of 35 to 70 kg ha^{-1} $year^{-1}$ have been recorded from selected villus in the Mahaweli flood plains.

The main gear used in the reservoir fishery is the gill net. The permissible gill mesh size is over 75 mm. In addition to gill netting, cast netting and angling take place in most reservoirs, sporadically.

Utilization of seasonal reservoirs for culture based capture fishery was initiated in the latter part of the 1970s. High production levels (890 kg. ha^{-1}) can be achieved by polyculture of exotic Carps. The combinations used include different percentages of Catla/ Big Head Carp, Rohu, Grass Carp, Mrigal and Common Carp (de Silva and Sirisena, 1987). The Department of Fisheries and Aquatic Resources has planned to develop 182 500 ha for fresh water capture fisheries. With the recent establishment of the Aquaculture Development Authority, several fish breeding centres have been established. Pond culture, pen and cage culture activities, also, have been initiated. A programme has been initiated to produce fish fingerlings with community participation.

AQUATIC RESOURCES- PLANTS

Inland aquatic plants are very widely distributed in Sri Lanka. According to Abeywickrama (1955), aquatic plants of Sri Lanka consist of 11 endemics, 90 peninsular species, and seven non-peninsular species. Some species are cosmopolitan. All the endemics and most of the peninsular species are found in the wet zone. Aquatic plants are important resources as food, medicinal plants, ornamental plants, water purifiers, livestock feed and fertilizers.

Many water plants can respond to the high quantities of nutrients such as nitrogen and phosphorus in polluted water through greatly increased growth. Such plants are useful as a means of removing contaminants from polluted water bodies. Toxic industrial pollutants such as heavy metals, too, can be extracted from water bodies by these plants.

One such plant is the water hyacinth, *Eichhornia crassipes*. Generally, this plant is considered a pest due to its high growth rate and extreme hardiness (Yapa, 1992; Little, 1979). It has very high potential to purify polluted waters due to its ability to absorb, accumulate and metabolize many toxic elements. Water hyacinth has the capacity to absorb heavy metal ions including toxic metals such as lead and mercury from contaminated water. Culture of this plant reduces algae, faecal bacteria, suspended matter and removes odour causing compounds. Significant reductions in BOD and COD have been achieved by using water hyacinth in treatment ponds.

Eichhornia crassipes is not the only aquatic plant adapted to growing in wastewaters. As far as the removal of pollutants is concerned, it certainly ranks at the top. Among the other aquatic plants that seem to grow well in waste-waters are *Phragmites* sp., bulrush - *Scripus lacastris*, *Lemna* sp. and *Spirodela* sp. *Elodea canadensis*, *Ergaria densa* and *Ceratophyllum demersum* are water purifiers. *Pistia stratiotes*-water lettuce, another floating plant like water hyacinth, has been investigated extensively as a wastewater purifier.

Salvinia molesta, a plant species accidentally introduced into the country has developed into a major weed. It was brought from India in 1939, as a specimen for use at a practical examination. The specimen discarded in to the wild grew and the species spread rapidly during world war years. (Abeywickrema, 1955). The weed can be controlled successfully using a species of weevil.

Water plants are utilized as fodder for livestock. They can be used fresh, dried as hay or preserved as silage to feed livestock. Grass Carp, *Ctenopharyngodon idella* feeds on aquatic plants. This is a specialized herbivorous fish species which feed upon a wide range of aquatic plants.

Aquatic weeds find application in agriculture as fertilizer. Application of these weeds as a thick layer on the soil suppresses weed growth and conserves moisture. Moreover they contribute nutrients to the soil and add organic matter.

Azolla is an important aquatic plant because of its nitrogen fixing capacity. It can be grown in fish culture ponds to serve as feed and also in rice paddy to add nutrients to the soil.

A number of aquatic plant species have been used as food traditionally, and several others are neglected due to lack of knowledge of their nutritive and or therapeutic value. Many potential aquatic food plants remain unutilized. The commonest food species is, of course, the paddy plant of which there are many varieties.

Lasia spinosa is a marshy plant with a creeping spiny rootstock. Both young leaves and rhizomes are eaten. They have therapeutic value. *Ipomoea aquatica* grows in damp places. This plant is common in shallow water and has been identified as a good source of iron, calcium and vitamin. It is also used for treatment of diabetes mellitus. Tender leaves serve as a vegetable. Another aquatic plant used as a vegetable, *Asteracantha longifolia*, contains alkaloids and is also used in Ayurveda, as diuretic and anti-dysenteric. It is used also in the treatment of hepatic problems. The rhizomes and seeds of Nelum, *Nelumbo nucifera*, which is common in tanks and grows in stagnant water are used as vegetables. The seeds divested of their coats are roasted or ground into flour and consumed. Different parts of the plant are used for different Ayurvedic treatments. Seeds and stems of *Nymphaea lotus*- Olu, a common plant in streams, ponds and tanks are eaten too. The powdered rootstock is used in the treatment of dyspepsia, diarrohea, haemorhoids and urinary ailments.

Ornamental aquatic plants

Ornamental plants are becoming increasingly important as foreign exchange earners. There are many aquatic plant species used in aquaria, indoor and out-door ponds. The demand for these species is increasing globally. The natural habitats of these plants are pools, ponds, lakes, seasonal tanks, slow flowing streams, water holes, rivers, rice fields and marshy areas. Economically important ornamental plant species include species of: *Aponogeton*, *Bacopa*, *Cabomba*, *Cardamine*, *Ceratopteris*, *Cryptocoryne*, *Egeria* , *Eichhornia*, *Hydrilla, Hydrocotyle, Hygrophila, Limnophila, Labelia, Ludwigia, Marsilea, Myriophyllum, Naias, Nechamandra, Nelumbium Nymphaea, Nymphoides, Ottelia ,Potamogeton, Rotala* and *Vallisneria* (de Alwis, 1992) .

BIODIVERSITY IN WATERS

Inland water bodies are integrated ecosystems, which are valuable natural resources. In addition to providing basic needs such as drinking water, water for irrigation and water for fisheries and aquaculture, they are valuable resources nurturing fresh water biodiversity.

Freshwater fauna and wildlife

Sri Lanka has a rich and varied fauna in freshwater habitats. We have no natural lakes and therefore no fauna typical of that habitat has evolved. There is extensive information on faunal composition and their distribution in lentic and lotic habitats. Fernando (1993) has estimated the number of different freshwater invertebrate species that may be expected among major invertebrate groups, in freshwater habitats of Sri Lanka. The numbers of species so far described are less than the expected number.

Our fresh water habitats support economically important vertebrate fauna. Ichthyofauna and the fishery resources of the freshwater habitats are well documented (Fernando, 1974, de Silva, 1988a, de Silva, 1988b). Two orders of amphibians (Anura and Apoda) are represented in Sri Lanka. They include a total of 10 genera, one of which is Apodan. Recent investigations have indicated that the diversity of Amphibia in Sri Lanka is very high. The aquatic reptiles in Sri Lanka are represented by three species of terrapins, two species of crocodiles and three species of snakes. All freshwater habitats support bird life. Certain birds like herons, rails, jacanas and coots live in areas close to water. Others like cormorants, teal and duck, breed and feed in aquatic habitats. A large number of migrant water birds are annual visitors to Sri Lanka (Hoffman, 1993). They are a major attraction to bird lovers and can form a sustainable base for ecotourism. The only species of mammal in the aquatic habitat is the otter. The buffalo, too spends much of its time immersed in muddy water.

The country has a monsoonal climate with well marked dry and wet seasons. With the onset of the dry season, conditions in the seasonal fresh water habitats become less favorable for aquatic animals. During this period, the water area diminishes, water quality deteriorates and food becomes scarce. Different fauna show different adaptations to survive the drought. Beetles lay their eggs during the drought and the larvae survive in moist places till the arrival of rains. The other adaptations of the fresh water fauna to survive drought include production of eggs with resistant cover, formation of cysts and carrying the young in pouches. Several species of fishes are able to breathe air and some species have developed special air breathing organs connected with the gills. The fauna gets re-established in seasonal tanks with the onset of monsoonal rains. Most of the fresh water animals breed during and after monsoonal rains when enough water is available for the young to spread over a wide area. Habitat destruction, habitat degradation, urbanization, water diversion, pollution, gemming, removal from habitats, introduction of exotic species are among factors that affect fresh water fauna and their diversity (Pethiyagoda, 1994).

Phytoplankton and zooplankton are important components in the food chains of the fresh water habitat and contribute to the productivity of the ecosystem. Diversity of zooplankton in reservoirs is generally poor. Relatively more diverse zooplankton fauna can be observed in low country shallow tanks while the number of zooplankton species is low in up-country reservoirs. Rotifers dominate the zooplankton communities in most of the freshwater habitats. They are present in both stagnant and running water. Fernando (1990) has listed more than 140 species of rotifers under 15 different families. The other predominant zooplankton are crustaceans. Among crustaceans, anostraca, cladocera, conchostraca and copepoda are the most important in fresh water ecosystems in Sri Lanka.

Aquatic insects are insects that have invaded water and show various adaptations to aquatic life. These adaptations are for locomotion, respiration and reproduction in an aquatic environment. Some aquatic insects like Hemipterans spend their complete life cycle in water, while others have aquatic larval forms. The following orders of fresh water insects are represented in Sri Lankan fresh waters (Fernando, 1990): collembola, ephemeroptera, odonata, plecoptera, trichoptera, neuroptera, hemiptera, diptera, and coleoptera. Fresh water insects depend on plants, small organisms and detritus for their food. Aquatic insects are part of the fresh water food chains and food webs. Several adult insects and the larvae of odonata, plecoptera, and ephemeroptera are important food resources for fish species. Some aquatic insects and larvae thrive in polluted waters and can be used as indicators of pollution.

According to Starmühlner (1993) there are 31 species of inland aquatic gastropods, four species of fresh water mussels and three species of pea-shell cockles in the inland waters of Sri Lanka. The dominant family among the Gastropoda is the family Thiaridae and includes about 50 per cent of all species of fresh water gastropods found in Sri Lanka. It is interesting to note that about 40 per cent of the fresh water gastropoda are listed as endemic. The bivalvia are represented in the inland waters by the families Unionidae, with *Lamellidens lamellatus*, *L.testudinarius* and *Parreysia corrugata*, the Corbiculidae with *Polymesoda ceylonica* and the Sphaeriidae with *Pisidium javanum*, *P. annandalei* and *P. prasongi*.

According to Hoffman (1993) there are about 450 species and sub-species of water birds in Sri Lanka consisting of residents and migrants. Under the Ramsar convention water birds are defined as "birds ecologically dependent on wetlands". Many of the wetland avifauna are migrants belonging to the Duck family (Anatidae). The common resident water birds include Cormorants, Darters, Herons, Ibises. The wetland birds of Sri Lanka are represented by the following groups: podicipitiformes, pelicaniformes, ciconiiformes, phoenicopteriformes, anseriformes, gruiformes, charadriiformes.

Migrant water birds are of particular importance because of their impressive movements and the world wide attention that they receive in connection with man's increasing concern for the environment (Hoffman, 1993). Migrant water birds have been identified as good indicators for the early diagnosis of adverse changes in wetlands. They assemble in large numbers during the migrant season in our important wetlands. Tourists are attracted to these locations which can develop into centres for ecotourism.

Wildlife habitats

The floodplains associated with the Mahaweli Ganga including the associated riverine marshes and swamp forests, support animal communities due to abundant food and water resources. Of particular importance is their value as elephant habitats. Floodplains serve as corridors between wet season feeding and dry season watering grounds for these animals. In addition the flood plains of the Mahaweli support an estimated 50 000 buffalo and cattle population (NARESA, 1991). Other aquatic habitats also support major elephant populations. The environs of Senanayake Samudra/ small tanks (Lahugala, Kitulana and Sengamuwa) within the 1 500 ha Lahugala-Kitulana National Park and the reservoirs within the Maduru Oya National Park also support wild elephant population.

Urban wetlands provide recreational open space and attractive habitats for birds and wildlife. The Bellanwila - Attidiya marsh in Colombo is an important urban open space and wildlife habitat, of this kind.

INSTITUTIONAL AND LEGISLATIVE FRAMEWORK

Institutions responsible for development, management and conservation of inland aquatic resources:

The following ministries, departments institutions are the main government and semi-government bodies directly or indirectly involved in inland aquatic resources assessment, development, management, conservation and sustainable use :-

Ministry of Fisheries and Aquatic Resources.
National Aquatic Resources Research and Development Agency.
National Aquaculture Development Authority.
Department of Wildlife Conservation.
National Science Foundation.
Mahaweli Authority of Sri Lanka.
Department of Irrigation .
Department of Forests.
Universities.
Institute of Fundamental Studies.
Water Resources Board.

In fact, more than 25 agencies have responsibility for one aspect or another of water resource management. Some of these, even come within the purview of a single ministry. As a result there is much inefficiency and lack of effectiveness in resource management.

Institutions responsible for enforcement of legislative procedures relevant to aquatic resources:

Central Environmental Authority.
Ministry of Fisheries and Aquatic Resources.
Provincial Environmental Authorities.
Department of Wildlife Conservation .
Department of Animal Production and Health.
Department of Customs.
National Aquaculture Development Authority.

The Ministry of Fisheries and Aquatic Resources has established, recently, by Act of Parliament, the National Aquaculture Development Authority of Sri Lanka, with wide powers and functions to conserve, develop and manage our aquatic resources. The functions of the Authority, among others, include: development of aquatic resources for the aquaculture industry, the promotion and creation of employment opportunities in the aquatic resources sector and the conservation of aquatic biodiversity.

Laws and regulations governing aquatic resources:

A fairly comprehensive set of legislative enactments and regulations exists, to regulate aquatic resources. These are listed below :-

Fauna and Flora Protection Ordinance Act No. 1 of 1970.
Fauna and Flora Amendment Act No 49 of 1993.
Fisheries and Aquatic Resources Act No. 2 of 1996.
National Aquatic Resources Research and Development Agency Act No. 54 of 1981 and amending Act No. 32 of 1996.
Water Resources Board Act No. 29 of 1963.
National Environmental Act No. 47 of 1981 and Amending Act No. 56 of 1988.
Customs Ordinance Act No. 17 of 1965.
The Animal Disease Act No. 59 of 1992.
National Aquaculture Development Authority of Sri Lanka Act No. 53 of 1998.

The above listing is not comprehensive. Individually the scope of many of these enactments is not wide, but collectively they include provision for development, sustainable use, and conservation of our aquatic resources.

In view of the rapid expansion of fish exports and the threat posed to sustainable use, regulations have been framed to restrict or prohibit the export of live fish species.

There are several exotic species that pose threats to indigenous species and live import of these species is prohibited . These are given in Table 4 along with a list of fresh water fish species prohibited and restricted from exports.

Table 4: List of freshwater species of fish prohibited and restricted from export and prohibited from import in live form

Prohibited species from export	Restricted species from export	Prohibited species from import
Family: Cypriniidae *Labeo fisheri* *Labeo porcellus* *Puntius asoka* *Puntius martenstyni* *Puntius srilankensis* *Puntius bandula* *Rasbora wilpita* *Malpulutta kretseri* **Family: Gobiidae** *Schismatogobius deraniyagalai* *Sicyopterus halei* *Sicyopus jonklaasi* **Family : Cobitidae** *Lepidocephalichthys jonklaasi*	**Family : Channidae** *Channa orientalis* **Family: Claridae** *Clarias brachysoma* **Family : Belontiidae** *Belontia signata* **Family: Mastacembelidae** *Macrognathus aral* **Family: Cyprinidae** *Danio pathirana* *Puntius cumingii* *Puntius nigrofaciatus* *Puntius titteya* *Rasbora vaterifloris*	**Family : Ictaluridae** *Ictalurus punctatus* *Ictalurus forcatus* *Ictalurus catus* *Icltalurus nebulosus* *Pylodictis olivaris* **Family:Characidae** *Serrasalmus nattereri* *Serrasalmus hollandi* *Serrasalmus eigenmani* *Serrasalmus notatus* *Serrassalmus striolatus* *Serrasalmus gibbus* *Serrasalmus sanchezi* *Serrasalmus spilopleura* *Serrasalmus antoni* *Serrasalmus rhombeus* *Serrasalmus serrulatus* *Catoprion mento*

Source: Government gazette 1036/13 of 1998 July.

HUMAN ENVIRONMENT

The chapter on Water Pollution deals with the major aspects of pollution of freshwaters. Other important impacts are discussed here.

New diseases have entered our fresh water systems through fish introductions and the import of fry for the aquaculture trade. The Epizootic Ulcerative Syndrome (EUS) is one such disease. The aquarium trade has been blamed for the spread of this disease. Many fresh and brackish water fish species are susceptible to this disease and outbreaks continue to be reported from various fresh and brackish water bodies. The Monodon Baculo Virus (MBV) and Systemic Ectodermal Mesodermal Baculo Virus (SEMBV) have come in with imported post-larvae for the shrimp industry. These viruses have been reported from our wild shrimp populations, as well. This constitutes a threat to the future of the shrimp industry.

Some twenty species of exotic fish species now live in our fresh waters. However, no critical assessment has been made of the impact of these introduced species on the indigenous species. The uncontrolled invasive explosion of Tilapia populations has been well documented. Populations of Tilapia in standing waters outnumber and outweigh those of all the other species combined. In India which has a thriving fresh water fish farming industry, Tilapia is considered a pest. It was never introduced as a part of fish farming policy initiatives into that country. While Tilapias, have certainly contributed in large measures to the creation and expansion of the inland fishery, here no information is available on their impact on indigeneous species and ecosystems functioning. No information is available for other introduced species either.

Sri Lanka's reservoir fishery is almost exclusively a gill net fishery. In most reservoirs, fishermen use wooden poles or weighted ropes to drive fish towards gillnets. The permissible mesh size is 7.5 cm and over. Cast nets and pole and line are also used in some inland water bodies. Although seine nets are not permitted, illegal seine net operations have been recorded in some reservoirs. Several incidents of use of explosives and poison to capture fish have been recorded. In the lower reaches of the rivers more diverse fishing methods are practised. These include stake nets, barrier nets, drag nets and moxi nets.

Inland waters and wetlands with diverse plant and animal communities have an enormous potential for recreational activities related to tourism. There have to be provisions to preserve areas of outstanding natural beauty, and to safeguard these from disfiguring development activity.

There are special problems related to the rapidly expanding shrimp industry. The problem of new pathogens has been discussed above. High levels of nitrites, sulfides, ammonia, suspended solids are recorded in effluents from farms together with antibiotics and chemicals. Sources of water intake are limited and effluents are returned to the intake water source, e.g. The Dutch Canal in the northwestern province. The situation is compounded by socio-economic and land use conflicts (Jayasinghe and de Silva, 1993). Such problems do not arise with fin fish culture, which is extensive.

SUSTAINABLE USE AND MANAGEMENT OF FRESH WATER FISH RESOURCES

Sri Lankan reservoir fishery is very productive and is well documented (de Silva 1983, Fernando, 1990). Several efforts have been made to determine the criteria for the sustainable use and management of the reservoir fisheries (Amarasinghe, 1994). The Ministry of Fisheries and Aquatic Resources has specified the minimum permissible mesh size for the gillnet fishery as 7.5 cm. Mechanization of craft and use of seine nets are prohibited. Empirical models have been designed for setting limits to the size of the fishery (Wijeyaratna and Amarasinghe, 1987). Based on an analysis of catch and effort data, the maximum sustainable yield (MSY) is estimated at 256 kg ha^{-1} yr^{-1}. The optimal fishing effort is 3.2 boats $/km^2$. However the estimated MSY is lower than the average annual yield which fluctuates between 283 and 307 kg ha^{-1} indicating that most of the reservoirs are exploited at sub-optimal levels (de Silva, 1991, Amarasinghe, 1996).

Stocking of perennial reservoirs to enhance natural recruitment is another management option suggested to increase productivity (Chandrasoma, 1996). Indian carps and Chinese carps can increase the fish production if regular programmes of stocking are planned and implemented.

Minor cyprinids resources remain unexploited as they are not caught in the gillnets of the existing fishery. The minor cyprinid resource includes species such as *Amblypharyngodon melettinus, Barbus dorsalis. B. chola* and *B. filementosus* and the potential annual yield is estimated at 632 kg ha^{-1} in one of the largest perennial reservoirs and could be more in some other reservoirs (Amarasinghe, 1994: de Silva and Sirisena, 1987). Introduction of suitable fishing gear will promote the exploitation of the minor cyprinid resource (Amarasinghe, 1990).

Enforcement of fishery regulations through participatory approach will promote the efficient management of the resource.

Collection of indigenous fresh water fish species without proper assessment of the resource can create the problem of over exploitation. Development of captive breeding techniques will reduce the pressure on species which are commercially important. Translocation of threatened fish, particularly those with localized distribution, into less stressed habitats is also a measure that must be practised.

Present conservation strategies are confined to the enactment of legislation and regulation of the exploitation of species.

Regular monitoring of resources, strict enforcement of existing rules and regulations, translocation of endangered species to better habitats, development of captive breeding technologies for indigenous species and introduction of captive bred stock to the natural environment are vital steps identified for the management and conservation of the aquatic resources.

Institutions and Human Resource development for aquatic resources management / conservation

The National Aquatic Resources Research and Development Agency (NARA) and the universities are the main institutions engaged in education, research and human resource development related to aquatic resources conservation, management and sustainable utilization.

NARA has the broadest national responsibilities for scientific research and development of aquatic resources.

National research needs

A considerable amount of research has been conducted on various aspects of aquatic resources of Sri Lanka. Most of the information available on inland aquatic resources relate to : basic biology, fisheries, hydrobiology, resource assessment, faunal and floral diversity, wetland ecosystems, wetland characteristics, environmental impacts and water quality.

There is a need to identify national research needs and priorities to address constraints to inland aquatic resources management and sustainable use. In recent times, government policy, market trend and social forces had a strong influence on resource conservation and the management of resources. While keeping a balance, research must focus on the technical needs to promote sustainable utilization of resources in accordance with the government policy and advise the government on appropriate policy changes.

Research areas that need to be addressed include rational utilization of reservoir resources, development of better empirical models for predicting fish yields in reservoirs, socioeconomic aspects of reservoir fisheries and ecosystem modeling for fisheries management. Other important areas are the assessment of indigenous fish populations and processes affecting these populations, impact of pollution on biodiversity and aquatic resources, impact of introduction of exotic species on indigenous fish populations, environmental impacts of aquaculture and industrial development, wetland functions, induced breeding of indigenous ornamental fish species, development of tissue culture, and techniques for ornamental plant culture and assessment of edible and ornamental inland aquatic plant resources. Improvement of Environmental Impact Assessment procedures and methodologies related to inland aquatic resources management are priority areas(Jayasinghe and Jaysekara, 1999).

CONCLUSION

Sustainable development and rational use of inland aquatic resources will promote long term utilization of these resources in agriculture, fisheries, power generation, recreation and aquaculture. Over 25 government and semi-government institutions have interests in management, utilization and conservation of aquatic habitats, watersheds and aquatic resources. They share jurisdiction over various aspects leading to overlapping functions, divided interests and duplication of work. The Ministry of Fisheries and Aquatic Resources is the key ministry responsible for looking after the living aquatic resources of Sri Lanka. Most environment related issues come under the purview of the CEA or Provincial Environmental Authority. The Department of Wildlife Conservation has the authority to protect and conserve wildlife. Mangrove and certain wetlands habitats associated with aquatic environment come under the purview of the Forest Department. Protection and safeguarding of national resources are the responsibilities of the Customs Department. However divided interests and overlapping functions among the agencies with limited capabilities and resources seriously constrain the effective management of inland aquatic resources. Therefore concerted efforts by all the ministries involved is needed for sustainable utilization and management of these resources. There has to be a clear national policy on research to avoid duplication of work. Improvements in legal framework and law enforcement, encouragement of participatory management are some of the measures to improve the efficient management of these resources.

The following recommendations are made for consideration in inland aquatic resources conservation and management:

Conservation of critical habitats and restoration of degraded critical habitats associated with inland aquatic environment.

Management of river basins, river catchments, dams and irrigation systems.

Preparation of zonal plans and integrated management plans for different activities in the aquatic environment and in associated habitats.

Formulation of permissible standards for industrial effluents discharged into the aquatic environment and prevention of the discharge of untreated effluents.

Enforcement of strict quarantine regulations and environmental impact assessments for introduction of new species to the aquatic environment.

Development of a clear policy on land use in wetlands adjoining water bodies proximate to conservation areas.

Management of upper and lower catchment areas and watersheds.

Conduct of public education programmes to enhance understanding of the values and the functions of the aquatic environment and the associated habitats.

Promotion of participatory approach for the management of wetlands, flood plains, and fisheries.

Promotion of coordinated research and development of a database on biodiversity and processes affecting biodiversity.

Capacity building of government and semi-government organizations in resource management, research and law enforcement.

Continuous monitoring of the aquatic environment for pollution.

Development of codes of practice for different activities in aquatic habitats and associated wetlands.

Dissemination of the available information on resource management to planners, policy makers, researchers, extension officers and to other end users.

Careful planning; improvements in legal framework, enforcement of rules and regulations are measures to minimize the adverse impacts on the resource. Lack of careful planning, clear policy, strong legal framework for responsible resource use and difficulty in enforcing legislation are major drawbacks faced by the inland aquatic resource sector.

REFERENCES

1. Abeywickrama B.A. (1955) *The origin and affinities of the flora of Ceylon*. Proc. Ceylon Ass. Advmt. Sc. part 2. 1-23.

2. Amarasinghe U.S. (1990) Minor cyprinind resources in a man made lake in Sri Lanka : a potential supplementary source of income for fisherman. *Fisheries Research* 9:81 -90.

3. Amarasinghe U.S. (1994) A synthesis on the management of capture fisheries in Sri Lanka. *Vidyodaya Journal of Science*. 5 (1) 23 - 40.

4. Amarasinghe U.S. (1996) Stock assessment in Sri Lankan reservoir fisheries: a review In: *Stock Assessment in inland fisheries* (Ed. I.G.Cowx) pp 345-356. Fishing News Books, Blackwell Sciences Ltd., Oxford.

5. Amarasinghe U.S. (1998) How effective are the stocking strategies for the management of reservoir fisheries in Sri Lanka. In: *Stock Assessment in inland fisheries* (Ed. I.G. Cowx) pp 345-356. Fishing News Books, Sciences Ltd. Oxford.

6. Atukorale D.A. & Jayasinghe J.M.P.K. (1994) Feasibility studies on the culture of hybrid sturgeon fish, *Huso huso and Acipencer ruthenus* in Sri Lanka. National Aquatic Resources Research & Development Agency 6 pp.

7. Chandrasoma. J. (1996) Impact of stocking exotic carp species on the fish production of man made lakes in Sri Lanka. *Sri Lanka Journal of Aquatic Sciences* (1) : 71-81.

8. de Alwis A. (1992) Aquatic ornamental plants of Sri Lanka. *Vidurava* 14 (2) :4-18.

9. de Silva S.S. (1983) The reservoir fishery : present status and future strategies. *Inland Fish Sri Lanka* 2: 3-13.

10. de Silva S.S. & Sirisena H.G.K. (1987) New fish resources of reservoirs in Sri Lanka: feasibility of introduction of a subsidiary gillnet fishery for minor cyprinids. *Fish. Res.*6:17-34.

11. de Silva S.S., Moreau J., Amarasinghe U.S., Chukajorn T. & Gurrero R.D. (1991) A comparative assessment of the fisheries in Lacustrine inland water in three Asian countries based on catch and effort data. *Fisheries Research* 11: 177- 189.

12. de Silva S.S. (1988a) Reservoirs of Sri Lanka and their fisheries *FAO Fish. Tech. Paper pp* 298:128.

13. de Silva S.S. (1988b) The reservoir fishery in Asia. In: *Reservoir Fishery Management and Development in Asia* (Ed. S.S. de Silva) pp 19-28. International Development Research Center, Canada.

14. Fernando C.H. (1974) Guide to the fresh water fauna of Ceylon. *Bull. Fish. Res. Stn. Sri Lanka* : 25 (1&2) :27-81.

15. Fernando C.H. (1990) *Fresh water fauna and fisheries of Sri Lanka.* Natural Resources Energy and Science Authority of Sri Lanka. 444 pp.

16. Fernando C.H. (1993) Impact of Sri Lankan reservoirs, their fisheries and conservation. *Proceedings of the International and Interdisciplinary Symposium on Ecology* and Landscape Management in Sri Lanka. (Ed W. Erdelen) pp 351 –374, Colombo.

17. Hoffman T.W. (1993) Wetland birds in Sri Lanka. *Conference on ecology of fresh waters in Sri Lanka.* pp 29 –36, Jaffna, Sri Lanka.

18. IUCN (1999) The 1999 list of threatened fauna and flora of Sri Lanka IUCN. Colombo, Sri Lanka.

19. Jayasinghe J. M. P. K. and de Silva J.A. (1993) Prawn Culture development and present land use patterns in coastal areas of Sri Lanka. *Proceedings of the International and Interdisciplinary Symposium on Ecology and Landscape Management in Sri Lanka.* (Ed. W. Erdelen.) pp 341-350, Colombo.

20. Jayasinghe J.M.P.K. and Jayasekara A.M. (1999) Aquaculture research needs priorities and capacities in Sri Lanka . *Sri Lanka Journal of Aquatic. Science* 4: 1 –11.

21. Little E.C.S. (1979) Hand book of utilization of aquatic plants . *FAO Fisheries Technical Paper* No 18. 176 pp.

22. Nathanael N and de Silva E. I. L (1996) Food and nest site availability : an indicator of the colonization of a highland reservoir in Sri Lanka by three species of ciclids. *Sri Lanka Journal of Aquatic Sciences* (1): 81 -90.

23. Natural Resources Energy and Science Authority of Sri Lanka (1991) *Natural resources of Sri Lanka, conditions and trends.* NARESA, Colombo.

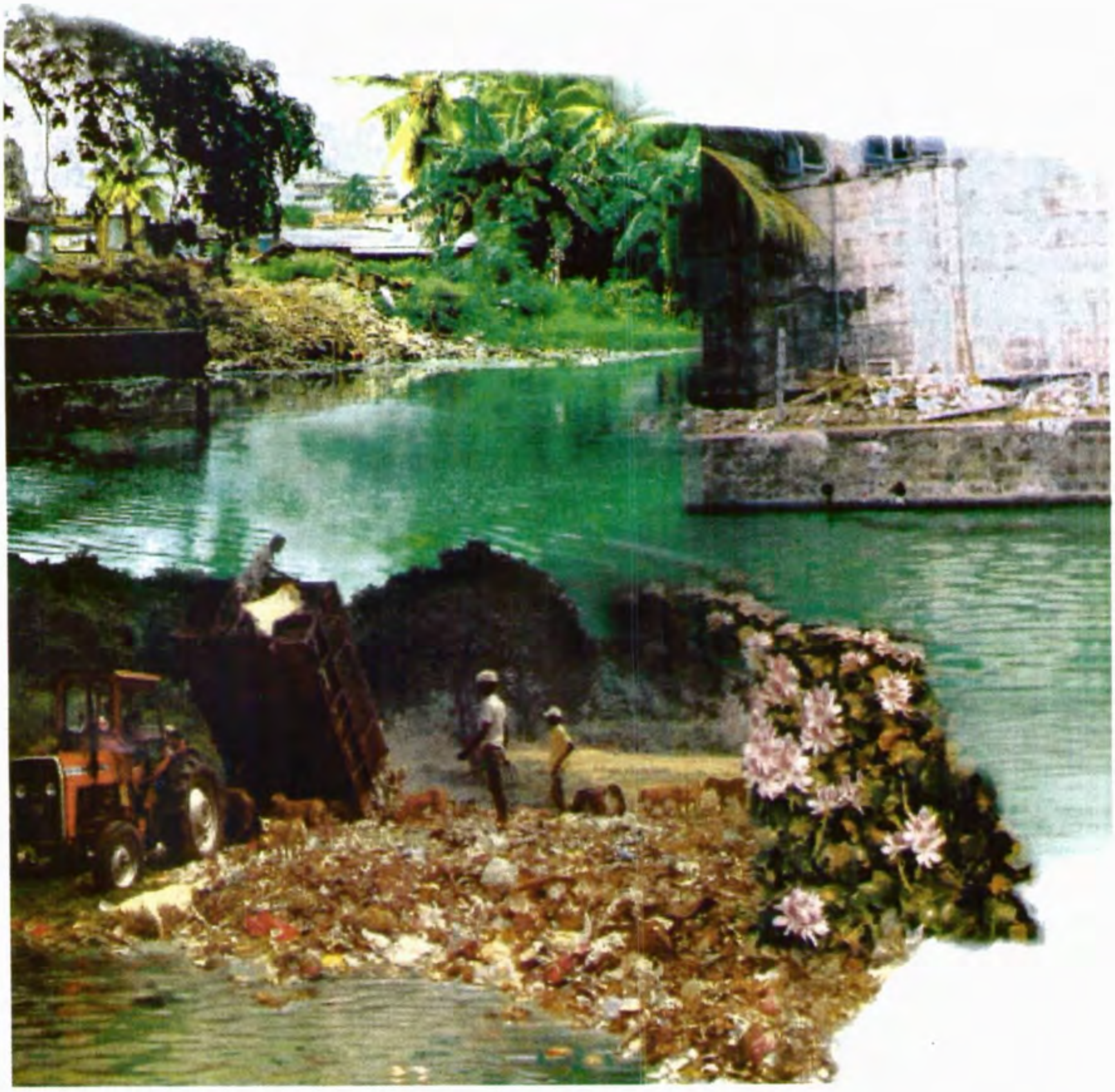
24. Pethiyagoda R. (1991) *Fresh water fishes of Sri Lanka.* Wildlife Heritage Trust of Sri Lanka. 362 pp.

25. Pethiyagoda R. (1994) Threats to the indigenous freshwater fishes of Sri Lanka and remarks on their conservation. *Hydrobiologia.* **285**: 189 - 201.

26. Starmühlner. F. (1993) *The freshwater molluscs of Sri Lanka. Proceedings of the conference on ecology of fresh waters in Sri Lanka.* pp 26 –28, Jaffna, Sri Lanka.

27. Wijeyaratne M.J.S. and Amarasinghe U.S.(1987) Estimation of maximum sustainable fish yield and stocking densities of fish fingerlings in freshwater lakes and reservoirs. *Archiv fur Hydrobiologie, Beiheft Ergebnisse der Limnologie*, **28**: 305 -308.

28. Yapa P.A.J. (1992) Water hyacinth: the silent purifier of nature's water bodies. *Vidurava* **14**(2) : 1 – 3.



Picture by Chandima Kahandawala.

Polluted Waters

WATER POLLUTION

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Summary

Water pollution problems in Sri Lanka will increase as urban communities grow, industry expands, rural areas develop, and farmers intensify agriculture. The major source of water pollution in the Greater Colombo area is domestic waste water. The existing sewerage system is grossly inadequate to counter water pollution. Frequent floods experienced in the city further aggravate the situation. Extremely poor sanitation facilities in rural areas is the major source of contamination of surface and groundwater. More than one fifth of the housing units in many of the districts do not have toilet facilities. As a result, about 50 per cent of the rural population do not have access to a safe source of drinking water. Many of the older industries discharge their effluent to water ways with little or no treatment. In addition, at least 40 000 tonnes of hazardous wastes are dumped haphazardly causing pollution of surface and ground water. Excessive extraction of well water has led to salt water intrusion and high levels of agrochemical inputs have led to high nitrate levels in groundwater in northern coastal areas and the northwest coastal belt. Economic costs of water pollution which include health impacts, loss of wages and treatment costs, have been estimated at Rs. 2 700 million. Other impacts include loss of fisheries, loss of aesthetic value, reduction in biodiversity, decline in agricultural exports and impacts on tourism. The state of the environment, including water quality, is now used as an economic indicator to attract foreign investment, tourism and to expand export markets. Sri Lanka has the potential to become a hub in the region, if a clean environment is assured.

INTRODUCTION

Three quarters of the earth is covered by water. However, 98 per cent of this water is the oceans and is saline. It is unfit for drinking and not suitable for most industrial purposes, either. Of the remaining two per cent, a large proportion is frozen in the polar ice caps. Therefore, less than one per cent is available as fresh water, a small part of which is available for direct human use. Each year an average of over 7000 m^3 per capita enters rivers and aquifers. However, human demand for water is increasing rapidly.

Moreover, water may not be found in adequate quantities in the areas where people live. There are 22 countries that already have renewable water resources of less than 1000 m^3 per capita (a level used as an indicator of water scarcity). Additionally there are 18 countries that have water supplies of less than 2000 m^3 per capita on average. This is a dangerously low level, leading to crisis situations in years in which rainfall is less than expected. (World Bank, 1992).

In many countries increased economic activity is leading to heavy pollution of many water bodies and the water becomes unfit for human consumption and even for industrial use.

The commonest contaminants of water are human wastes that may carry organisms causing diseases. Other major pollutants are agrochemicals and industrial effluents. The decomposition of these pollutants removes oxygen from the water. Oxygen depletion reduces the capacity of water bodies to support life. Prawn farming and inland fisheries can also be affected by disease out-break if water quality is not maintained.

Agrochemicals, effluents from industry and wastes from mining, contaminate water bodies with toxic chemicals and with heavy metals such as, lead and mercury. Some of these toxic chemicals and metals can accumulate in aquatic food chains, and pose threats to human health.

Groundwater is a potential source of a safe water supply. However, in many urban areas groundwater, too, is becoming polluted. Unlike rivers, aquifers do not have any self cleansing capacity. Hence once polluted they remain polluted. Some important sources of groundwater pollution are seepage from garbage dumps, disposal of heavy metals, synthetic chemicals and other hazardous wastes. In coastal areas excess extraction of ground water may cause salt water intrusion. Further, when groundwater is drawn out at a rate higher than the rate of natural recharge, aquifers can be permanently compacted reducing their storage and recharge capacity.

Pollution problems in Sri Lanka are likely to assume more serious proportions as urban communities grow, industry expands, rural areas develop, farmers intensify agriculture and mining and other developmental programmes unfold. This chapter discusses current status and emerging trends in water pollution in Sri Lanka and highlights some related major issues.

SOURCES OF POLLUTION

Fresh water is polluted by nutrients -nitrogen and phosphorous from seweage/fertilizers, pesticides from croplands, oxygen demanding organic matter and detergents from industry and sewage, sediments from cleared lands, toxic compounds both inorganic and organic, and waste oils from industry. They enter the water from either specific point discharges or diffuse, non-point sources. Point sources, relatively easier to control, include industrial effluent and discharges from urban sewers or sewage treatment plants. Non-point source pollution, more difficult to identify and manage, include urban, agricultural, and other runoff from land. Urban runoff into lakes, streams and canals includes nearly all major pollutant types. Agricultural runoff into streams and rivers usually comprises pesticides, suspended solids, nutrients and organic material. Runoff from road construction or other land clearing operations introduces high levels of suspended solids. Runoff from mines can add sediments, acids, and heavy metals.

Urban wastes

Urbanization results in increased release of wastewater and faecal matter, into water bodies, which if not managed properly will become major sources of pollution. Rising per capita income and changing life styles generate more and more solid waste intensifying further the problems of water pollution in the metropolitan regions.

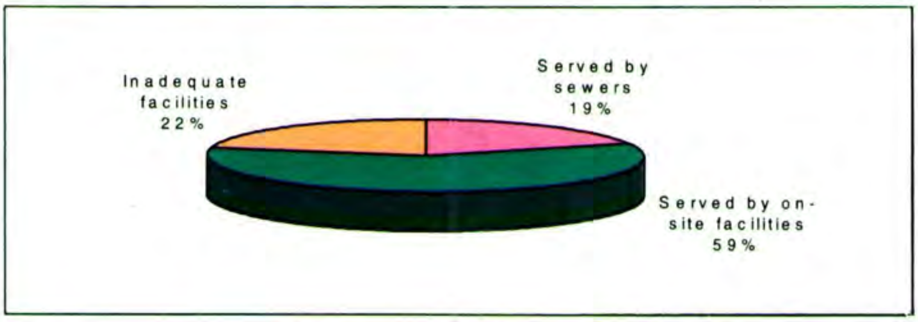
Sewerage

The major source of water pollution within the Colombo Metropolitan Region (CMR) is domestic wastewater. It has been estimated that 7150 m^3 of domestic wastewater is discharged per day within the Greater Colombo area, accounting for nearly 66 per cent of total wastewater that is generated in this region (Associated Engineering, 1994). The main reason for the high level of water pollution from domestic waste, is the inadequacy of the existing sewerage systems in the Greater Colombo area to cope with the volume of wastewater and faecal matter generated by an estimated population of 2.9 million. In 1992 only 19 per cent of the Greater Colombo population was served by sewers, 59 per cent had 'on site' facilities, while 22 per cent either had no services or had services that were grossly inadequate (Fig. 1) (NWSDB, 1993). The only large conventional sewerage system in the Greater Colombo area (Fig. 2) has 254 km of gravity sewers varying in diameter from 225 mm to 1500 mm; 13 pumping stations in Colombo Municipal Council area (CMC), three in Kolonnawa Urban Council area and two in the Dehiwala / Mt. Lavinia Municipal Council area. Wastewater is discharged without any treatment, to the open ocean at two locations, Wellawatte and Modera.

Inland water bodies are polluted due to the dilapidated state of the existing sewerage system with 15-25 per cent of sewer area blocked due to the accumulation of plastic bags, sand, silt and debris. Maintenance and cleaning is grossly inadequate.

Solid waste

The disposal of garbage by dumping in open spaces, is common practice among most of the local authorities. Indiscriminate dumping and non-engineered burial of solid wastes lead to contamination of surface water bodies and to the leaching of pollutants into ground water. Obviously the effect will be more serious in densely populated urban areas. Blocked drains and waterways which result from indiscriminate dumping of solid wastes, create breeding grounds for mosquitoes. This is one of the major contributors to the mosquito problem in the urban centres.



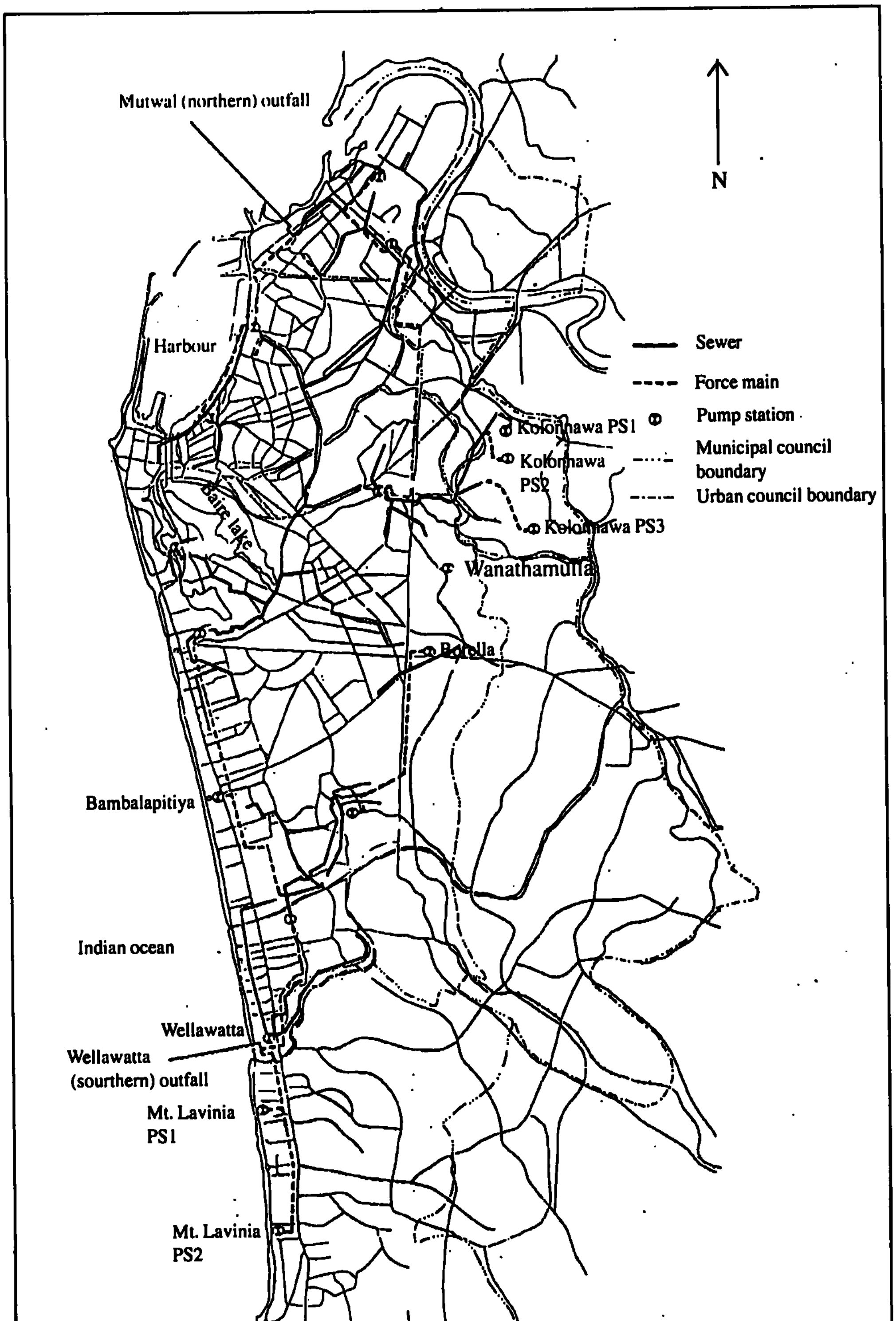
Source: NWSDB, 1993

Figure 1 : Wastewater & excreta management facilities in the Greater Colombo area - 1992

Many of the private facilities serving the 1.7 million 'on-site' users in the Greater Colombo area do not operate properly due to a multiplicity of causes including poor design and/or construction, unsuitable soil conditions, high water table, overloading and inadequate maintenance. As a result, a significant proportion of partially treated effluents directly discharges into adjacent water bodies or drains bypassing the soakage systems.

Within the Greater Colombo area, there are about 300 000 persons living in slums, shanties, and other semi-permanent dwellings, who do not have adequate sanitation and a further 340 000, who have no facilities of any kind. They defecate mostly in spaces adjacent to the sea, canal or other body of water. This segment of the population contributes significantly to the water pollution problem in the Greater Colombo area.

Solid waste in urban areas originates from a wide variety of sources including households, industry and business and commercial enterprises. The total estimated quantity of solid waste collected daily in the CMR is 1160 tonnes. Of this waste nearly 64 per cent is from Colombo Municipal Council area and 13 per cent from the Dehiwala/Mt. Lavinia MC areas. It is estimated that about half the municipal solid wastes generated within 20 local authorities in the CMR remains uncollected (Dept. of Census & Statistics, 1998a). The composition of domestic and commercial waste (including market waste) collected in the CMR is shown in Table 1. More than 80 per cent of both household and commercial waste is organic and biodegradable, thus amenable for aerobic or anaerobic conversion to useful products such as compost and methane. In the past year or so, responsibility for



Source : NWSDB, 1993.

Figure 2 : Existing Colombo Sewerage System

garbage clearance in some of the CMC areas has been handed over to a private sector concern. Marked improvement in services is evident.

Table 1 : Composition of solid waste collected in the Greater Colombo area

Composition	Household waste (per cent by weight)	Commercial waste (per cent by weight)
Paper	7	6.7
Plastic	5.6	5.2
Metals	2	0.6
Glass	0.7	0
Organic Waste	83.6	86.4
Other	1.1	1
Total	100	100

Source : Department of Census & Statistics, 1998a.

Rural Sanitation

In the rural areas sanitation facilities are poor. Faecal contamination of surface water and groundwater is common. In Puttalam 28.6 per cent of the houses do not have toilet facilites. A similar situation prevails in Nuwara Eliya (28.5 per cent), Anuradhapura (26.4 per cent), Moneragala (23.4 per cent) and Kurunegala (22.6 per cent) Districts (Department of Census & Statistics, 1996).

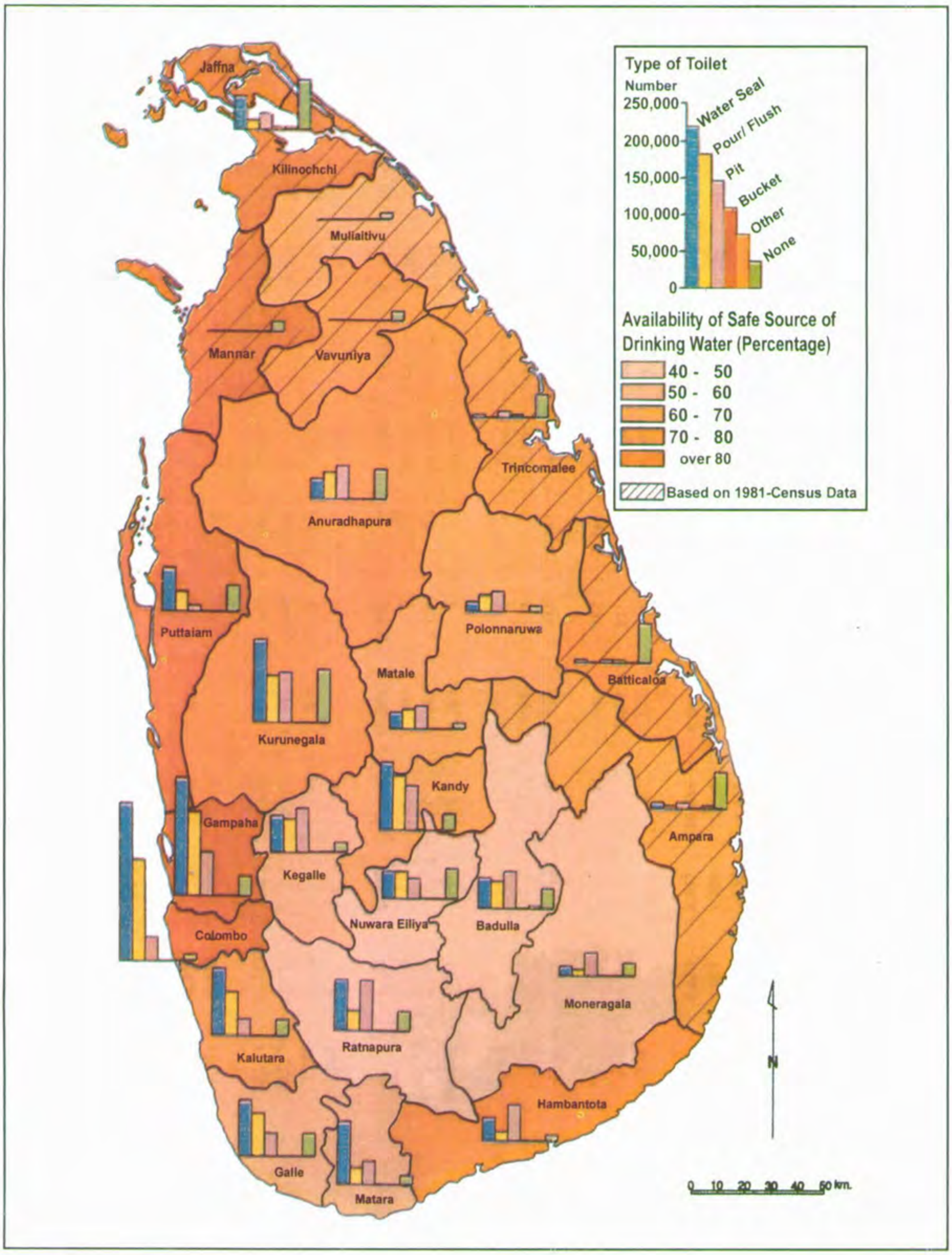
Conditions are worse in Mannar, Trincomalee, Batticaloa, Ampara and Vavuniya Districts. As a result, a significant proportion of the population in the rural areas does not have access to safe sources of drinking water. For example, more than 50 per cent of the housing units in the Ratnapura, Badulla, Moneragala and Nuwara Eliya Districts do not have access to safe drinking water, while in Galle, Matara and Kegalle Districts this figure is 40-50 per cent (Fig. 3).

Industrial waste

Industrial development mainly on small and medium scale has taken place, dominating the urban sector. Industries in the rural areas are mostly cottage scale units using traditional technology and local materials. These include foundries, handloom, handicraft, brick and tile, and agrobased industries like rubber processing, rice milling, coir and coconut processing and extraction of essential oils. Large manufacturing industries like cement, paper, steel, petroleum refining, sugar, ceramic, and textiles are few in number and for the most part established outside the main urban areas.

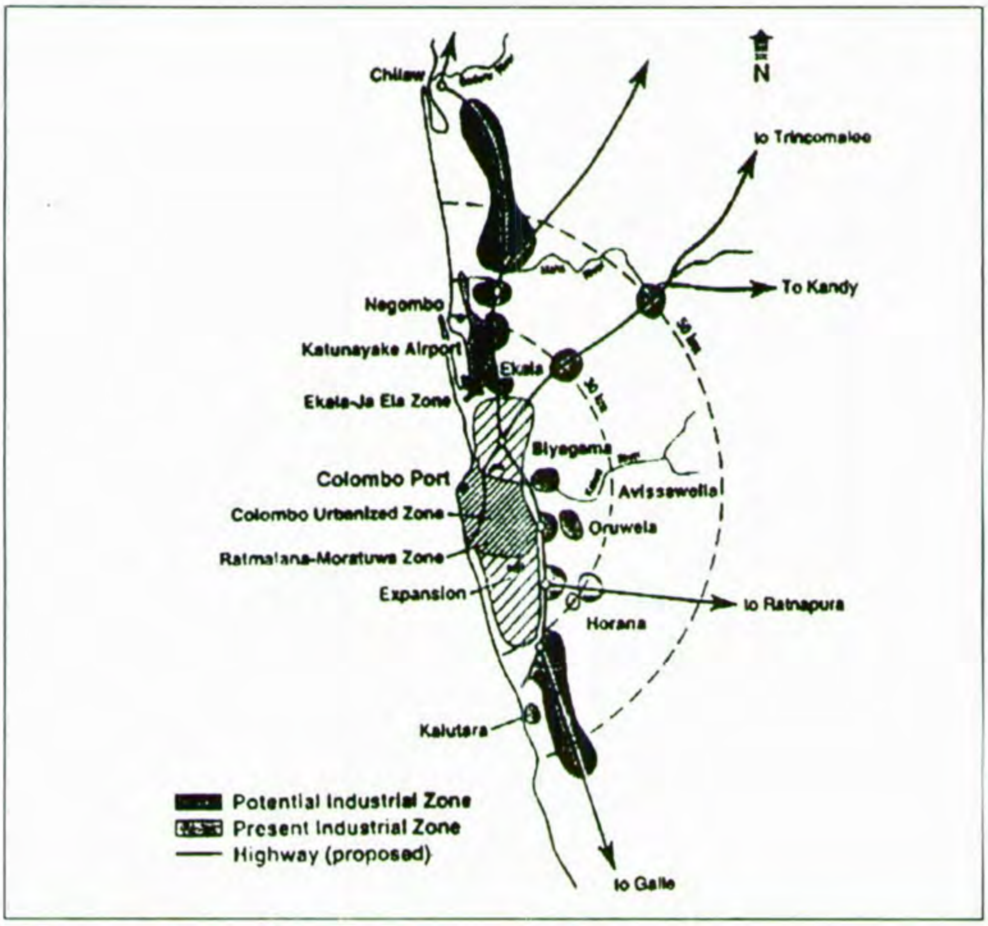
The most industrially developed regions in the country are the Colombo and Gampaha Districts. Nearly 80 per cent of the industries are located in these districts. Two major industrial areas are the Ratmalana-Moratuwa area, located south of Colombo, and the Ekala-Jaela area located in the Gampaha District. Other industrial areas such as Biyagama, Homagama, Oruwila, and Kalutara are relatively small. These industrial areas and areas proposed for future development are depicted in Figure 4. (JICA,1993).

It is estimated that there are more than 225 industries located within the Ratmalana-Moratuwa area (Associated Engineering, 1994). Textile and garment, pharmaceuticals-formulation and packaging - and the manufacture of asbestos roofing sheet constitute the major proportion of the industries in this area. In addition there are a few metal finishing industries, timber processing facilities and lead storage battery manufacturing units. Two major transportation related maintenance facilities, bus & railway, are also located in this area. These service



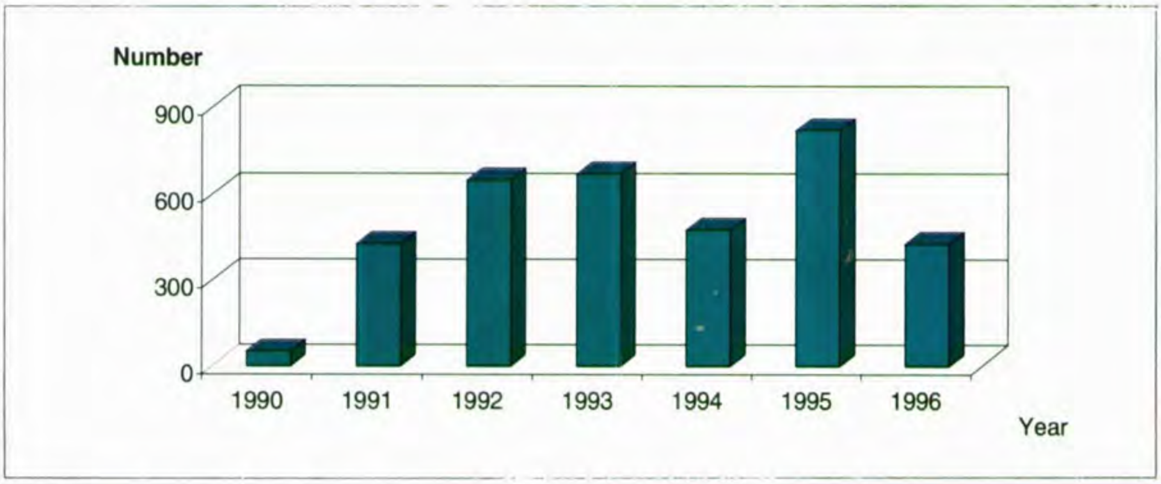
Source : Department of Census and Statistics, 1996.

Figure 3 : Availability of safe source of drinking water and type of toilet by district, 1994



Source: JICA, 1993.

Figure 4: Present and potential industrial zones in Sri Lanka



Source : Department of Census and Statistics, 1998b.

Figure 5 : Number of applications for polluting industries received by the CEA 1990-1996

facilities cover large areas which are contaminated with fuel and lubricating oils, brake oils, hydraulic oils transmission fluids and battery acid. The greater part of the industrial effluents produced in this area is discharged untreated to the surface drainage system, which itself is blocked.

The Ekala-Jaela industrial area, the major industrial estate in the Gampaha District, has been studied, as well (Soil & Water, 1993). A total of about 140 industries are located within this area, of which about 50 per cent are of high polluting nature. The major effluent generating industries have been identified as textile dyeing and bleaching, food processing, manufacturing of asbestos, manufacturing of aluminum extrusion products, leather tanning, metal-finishing, the manufacture of agro products and mineral products. The majority of these industries discharge untreated effluent to drains, and the waste eventually enters nearby water ways. Some of the potential toxic metal wastes generated in this area are chromium from tanneries and heavy metal wastes from an alkaline battery manufacturing facility.

With the expansion of the manufacturing sector, degradation of the aquatic environment, particularly in urban areas, has increased, significantly. Figure 5 shows the trend in the number of applications received by the Central Environmental Authority (CEA) annually from 1990 for environmental clearance to set up polluting industries in the country (Dept. of Census & Statistics, 1998b). The number of applications peaked at 834 in 1995 before dropping to 397 in 1996. By the end of 1997 CEA has granted Environmental Protection Licenses (EPL) to 931 medium polluting and 590 high polluting industries. However, the industries, set up under the Board of Investment (BOI) are not covered by this licensing procedure. Pollution generated by the various industrial sectors in Sri Lanka are shown in Table 2 (ERM, 61994).

A significant proportion of the industries set up before the 1990s do not have any effluent treatment plants. Desiccated coconut mills, scattered around various parts of the country, discharge their high BOD effluent into adjacent waterways without any treatment. Even where treatment plants exist, many of them do not function effectively due to inappropriate design, inadequate maintenance and inefficient operation. There are a few exceptions however, notably a few medium and large plants which could afford treatment and plants situated in industrial zones such as Katunayake, Biyagama and LINDEL where wastewater is centrally treated.

Hazardous waste

At least 40 000 tonnes of hazardous wastes (both liquid and solid), are generated in the country. These comprise about 10 000 tonnes of inorganic wastes, 15 000 tonnes of organic wastes and 14 000 tonnes of oil wastes from motor vehicles (Table 3). This amount could rise to 90 000 tonnes with a moderate rate of industrial growth of 7.5 per cent per year or to 240 000 tonnes per annum at 15 per cent growth rate, by the year 2010. Of the inorganic wastes, acids and alkalis constitute about 7000 tonnes, while heavy metal wastes account for 27 tonnes per annum. Oil wastes (3600 tonnes), solvent wastes (3030 tonnes) and agrochemical wastes (2657 tonnes) are the major categories in the organic class. At present, there is no system in the country to dispose of the hazardous wastes in an environmentally acceptable manner. Hence they are either dumped within the site or transported outside for recycling or dumped in marshy areas by contractors, a practice which leads to the contamination of surface and underground waters.

Pollution from agrochemicals

Uncontrolled and excessive use of agro-chemicals leads to pollution of inland and coastal waters due to surface runoff. In addition, underground aquifers can also be polluted. Pollution from agrochemicals, depends on, among other factors, the types and quantity of fertilizers and pesticides used. An analysis of the consumption pattern of fertilizers and pesticides in major crop production in the country will help in the analysis of water pollution from agrochemicals.

Table 2 : Profile of Industrial sectors generating pollution in Sri Lanka

	Textile	Desiccated coconut	Rubber processing	Food & Beverage	Tanning	Metal Finishing	Paints & Chemicals
No. of medium & high polluting establishments	41	53	229	47	15	76	33
Total wastewater volume m^3/day	7100	1200	4840	4111	1614	6692	928
BOD kg/day	4970	4200	9670	6166	3229		
COD kg/day	11360	7200	29040	12333	8070		
Total toxic metals* kg/day	na	na	na	na	161	669	92.8
Location	Colombo & Gampaha Districts	In rural areas within the 'coconut triangle'	South-western parts of the country	Greater Colombo & Kalutara	Colombo & Gampaha Districts	Widely distributed amongst 4 sub-areas of Colombo	50 % in Ratmalana. the rest mainly in Ekala and North Colombo

Source: ERM. 1994.

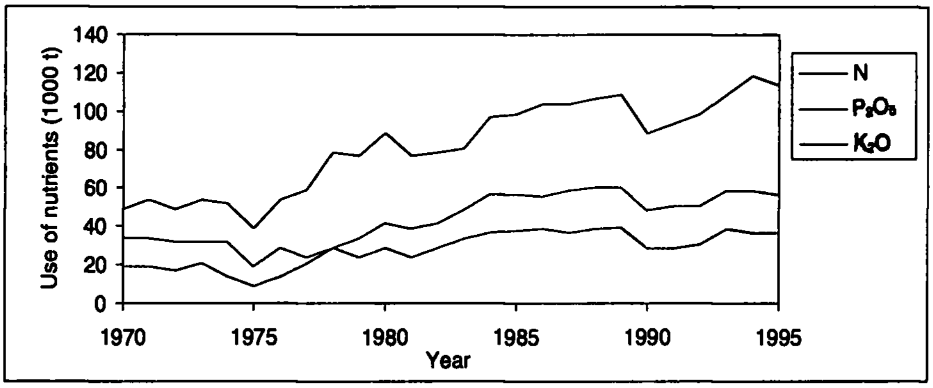
* Based on assumed average concentration of 100 mg/l.

Table 3 : Adjusted hazardous waste inventory

Waste Type	Tonnes per annum
Inorganic wastes	
Inorganic acids	2744
Inorganic alkalis	4396
Zinc bearing wastes	8.75
Heavy metal wastes	18.75
Waste treatment sludges	271.75
Containers contaminated with inorganic materials	1.25
Solid waste contaminated with inorgainc materials	2837.5
Total	**10278**
Organic wastes	
Oil wastes (liquid)	2371.25
Oil wastes (semi-solid)	1237.5
Solvent wastes (non-halogenated)	1533.75
Solvent wastes (halogenated)	1497.5
Waste paints, lacquers, varnish etc.	255
Waste agrochemcials	2857.5
Waste pharmaceuticals	210
Wood preservative wastes	38.75
PCB, PBB, PCT wastes	6.25
Containers contaminated with organic materials	8.75
Solid waste contaminated with organic materials	4722.5
Total	**14739**
Other wastes	
Asbestos wastes	117.5
Plastic/resin wastes	1482.5
Total	**1600**
Oil wastes from motor vehicles	
Total vehicle oil	**14000**
Grand Total (hazardous wastes)	**40617**

Source: ERM, 1996.

Trends in the use of fertilizers during 1975-1995 are shown in Figure 6. The highest consumption of fertilizers is in tea and paddy. The total fertilizer consumption in 1994 was 548 x 10^3 t of which paddy accounted for 250 x 10^3 t, tea 147 x 10^3 t and coconut 35 x 10^3 t. Major types of fertilizers used are sulphate of ammonia, urea, rock phosphate, muriate of potash, triple super phosphate and mixed fertilizers. Among them urea is the most popular (35 per cent), followed by sulphate of ammonia (26 per cent) (NFS, 1994). Sri Lanka has the highest fertilizer consumption (101.5 kg/ha) in the SAARC region, followed by Bangladesh and India. However this figure is very much lower than that of high-income economies such as Japan, Netherlands and Germany (Table 4)(World Bank 1992). It should be noted that the high figure for Sri Lanka partly reflects excessive and inefficient consumption.



Source: Department of Census and Statistics, 1998c

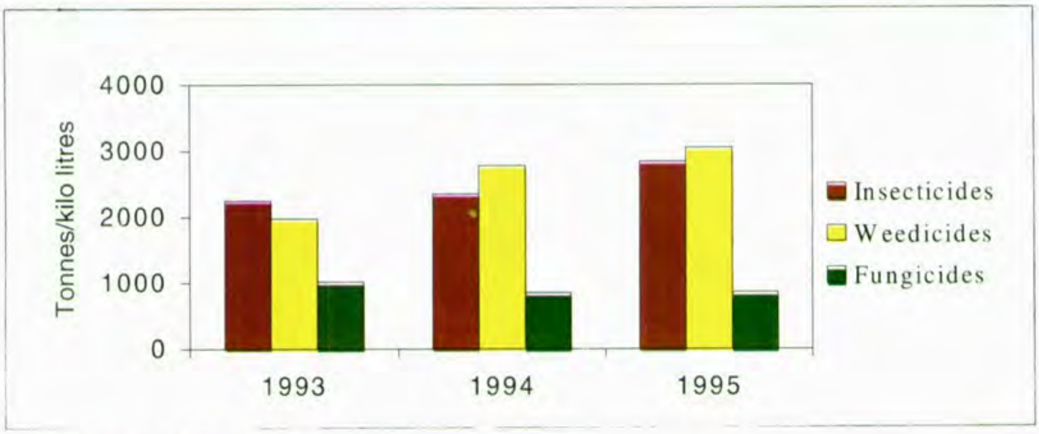
Figure 6 : Annual use of plant nutrients in Sri Lanka during 1970-95

The import statistics for insecticides, herbicides and fungicides for the years 1993 to 1995 are given in Figure 7. Total imports have increased from 5249 tonnes to 6742 tonnes during this period. About 100 active ingredients of pesticides have been registered in the country. In 1995, herbicides were the most used pesticide category with Propanil and MCPA accounting for about 85 per cent. Sulphur and copper salts and dithiocarbamate fungicides are the most popular among farmers. Carbamates are the most widely used insecticide with 1126 t in 1993. Carbofuran, (three per cent granules), a potential groundwater contaminant accounts for nearly 80 per cent of the above quantity. However, the import and use of persistent chlorinated hydrocarbons such as DDT, Lindane, Dieldrin etc., have been banned, totally. Plantation crops such as tea, coconut and rubber use relatively low quantities of pesticides. However, in paddy the use of pesticides is high and herbicides use is heavy compared to fungicides and insecticides. In contrast, insecticides and fungicides are extensively used in vegetable cultivation, particularly in cash crops such as potato, chilli and onion and in up-country vegetables. The majority of the farmers apply higher than recommended quantities. The trend of high nitrogen and phophorous fertilizer consumption is expected to increase the levels of nutrients in surface runoff from farmlands. This can lead to eutrophication of receiving water bodies. Although the use of persistant chlorinated hydrocarbons is banned, several potential groundwater contaminants such as carbofuran, alachlor, 2,4 D, MCPA are still being used and are quite popular among the farmers. Thus lands under cultivation are potential sources of water pollution due to high intensity of pesticide use. In the absence of a proper monitoring system, however, accurate assessment of water pollution from agrochemicals is difficult. Some *ad hoc* studies on water pollution from agrochemicals are discussed later in this chapter.

Table 4 : Fertilizer consumption in selected countries

Country	kg/ha
Bangladesh	99
India	69
Pakistan	89
Sri Lanka	102
Bhutan	1
Nepal	26
Netherlands	642
Japan	418
Germany	384
New Zealand	656

Source : World Bank, 1992.



Source: Registrar of Pesticides.

Figure 7 : Imports of pesticides 1993-1995

Marine pollution

Waste oil release from ships in the Colombo harbour has increased from 879 tonnes in 1997 to 1258 tonnes in 1998(MPPA,1998). Waste oils from boats operating out of various fishing villages and fishing harbours are also discharged into the coastal waters. At present there is no proper waste oil receiving facility to manage such wastes in an environmentally acceptable manner. In addition, ships anchored in near-shore waters discharge wastewater, which constitutes another source of coastal water pollution. Although there are no analytical data on environmental impact of such discharges, coastal water pollution arising from all these wastes is considered to be significant.

The main shipping lanes across the Indian Ocean lie immediately south of Sri Lanka. It is known that bilge waters are emptied into the sea in close proximity to the island. The pollution of beaches on the west coast by tar balls is well known and is related to these ship based sources.

INDICATORS OF WATER QUALITY AND POLLUTION LEVELS

Water quality indicators can be categorized broadly into five classes:- bacteriological contaminants, inorganic constituents of health significance, organic constituents of health significance, indicators of aesthetic and organoleptic quality and radioactive constituents. Comparison of WHO Guidelines and Sri Lanka Standard (SLS) for drinking water is shown in Table 5. Apart from nitrate, nitirte and fluoride, all the other basic parameters listed in the SLS are indicators of aesthetic and organoleptic quality. Hence, most of the constituents of health significance are not tested routinely, unless requested. The majority of organic contaminants including THMs listed in the WHO guidelines are not in the SLS. Further some pesticides that are heavily used in the country, carbofuran, MCPA and propanil, are also not in the SLS list.

The microbiological quality of water is of the greatest importance for drinking purpose and must never be compromised. The main indicators for bacteriological quality are faecal coliforms and coliform organisms.

The principal source of trace inorganic contaminants, with the exception of fluoride and selenium (these are mainly of natural origin) is industrial waste from manufacturing or metal finishing industries. Therefore, industries discharging wastes should reduce the concentrations of such toxic elements to acceptable levels before discharge. Industries such as tanneries, paint and pigment industries, metal finishing industries, and battery and fluorescent lamp industries are potential generators of these toxic elements.

Table 5: Comparison of WHO guidelines for drinking water with SLS standards – selected parameters only

	Parameter	WHO Guideline value	SLS 614:1983	Status
Microbiological				
	Coliform organisms n/100 ml	0	10	Mandatory
	Faecal coliforms n/100 ml	0	0	Mandatory
Inorganic constituents of health significance				
	Antimony (mg/l)	0.005		
	Arsenic (mg/l)	0.01	0.05	If required
	Barium (mg/l)	0.7	ns	
	Boron (mg/l)	0.5	ns	
	Cadmium (mg/l)	0.003	0.005	If required
	Chromium (mg/l)	0.05	0.05	If required
	Copper (mg/l)	2	ns	
	Cyanide (mg/l)	0.07	0.05	If required
	Fluoride (mg/l)	1.5	1.5	Basic
	Lead (mg/l)	0.01	0.05	If required
	Mercury (mg/l)	0.001	0.001	If required
	Molybdenum (mg/l)	0.07	ns	
	Nickel (mg/l)	0.02	ns	
	Nitrate (mg/l)	50 (acute)	10	Basic
	Nitrite (mg/l)	3 (acute) 0.2 (chronic)	0.01	Basic
	Selenium (mg/l)	0.01	0.01	If required
Organic constituents of health significance				
	Carbon tetrachloride (μg/l)	2	ns	
	Dichloromethane (μg/l)	20	ns	
	1,1,1-trichloroethane (μg/l)	2000	ns	
	Trichloroethene (μg/l)	70	ns	
	Tetrachlorethene (μg/l)	40	ns	
	Benzene (μg/l)	10	ns	
	Toluene (μg/l)	700	ns	
	Ethylbenzene (μg/l)	300	ns	
	Xylenes (μg/l)	500	ns	
	1,4 dichlorobenzene (μg/l)	300	ns	
	2,4 D (μg/l)	30	100	If required
	Alachlor (μg/l)	20	ns	
	Aldrin & Dieldrin (μg/l)	0.03	0.03	If required
	Atrazine (μg/l)	2	ns	
	Carbofuran (μg/l)	7	ns	
	Chlordane (μg/l)	0.2	0.3	If required
	DDT (μg/l)	2	1	If required
	Lindane (μg/l)	2	3	If required
	MCPA (μg/l)	2	ns	
	Methoxychlor (μg/l)	20	30	If required
	Pentachlorophenol	9	10	If required
	Permethrin (μg/l)	20	ns	
	Propanil (μg/l)	20	ns	
	Chlorine (μg/l)	5		
	Trihalomethanes (μg/l)	Sums of ratio of concentration of each of its respective guideline values should not exceed 1		
	Bromoform (μg/l)	100		
	Dibromochloromethane (μg/l)	100		
	Chloroform (μg/l)	200		

Ns = No guideline values set.

Table 5 contd.

Table 5 contd.

	Parameter	WHO Guideline value	SLS 614:1983	Status
Aesthetic quality				
	Alkalinity as CaCO3 (mg/l)	ns	400	Basic
	Aluminium (mg/l)	0.2	0.2	If required
	Ammonia, albuminoid (mg/l)	ns	0.15	Basic
	Ammonia, free (mg/l)	ns	0.06	Basic
	Calcium (mg/l)	ns	240	If required
	Chloride (mg/l)	250	1200	Basic
	COD (mg/l)	ns	10	If required
	Colour (Hz)	15	30	Basic
	Copper (mg/l)	1.0	1.5	Basic
	Detergents, anionic (mg/l)	0.2	1	If required
	Electrical conductivity at 25 µs/cm	ns	3500	Basic
	Hardness as CaCO3 (mg/l)	500	600	Basic
	Iron (mg/l)	0.3	1	Basic
	Manganese (mg/l)	0.1	0.5	If required
	Oil & grease (mg/l)	ns	1	If required
	pH	6.5-8.5	6.5-9.0	Basic
	Phenolics (mg/l)	0.001	0.002	If required
	Phosphates (mg/l)	ns	2	Basic
	Solids-total (mg/l)	1000	2000	Basic
	Sulphate (mg/l)	400	400	Basic
	Taste & Odour	inoffensive	inoffensive	Basic
	Turbidity (NTU)	5	8	Basic
	Zinc (mg/l)	5	15	If required

Sources: Extracted from Guidelines for drinking water quality, 2nd edition, Vol 2, 1996 and addendum to Vol 2, 1998, Geneva, WHO and Sri Lanka Standards SLS 614:1983.

The major concern related to trace organics in water supplies arises from the wide variety of anthropogenic compounds, mostly chlorinated, that enter our surface waters and ground waters, through the discharge of wastewater from industries and sewers. The largest category represents halogenated pesticides and herbicides (e.g. propanil, alachlor, 2,4D and MCPA). Chlorinated organic solvents also make up a large portion of trace organic contaminants that persist and are health hazards. SLS does not make any reference to these classes of compounds.

Polychlorinated biphenyls (PCB) and Dioxins are two notorious trace contaminants of global concern. The former is an industrial chemical used extensively in the past- coolant in transformers and capacitors, plasticizers, hydraulic fluids-while the latter is a by- product in the manufacture of some chlorinated chemicals, such as, phenoxy herbicides and is also produced during the combustion of a variety of organochlorine compounds. Halogenated compounds tend to be singled out because of their general toxicity, relatively high hydrophobicity (which tends to cause them to concentrate in fatty materials), large usage, and relative resistance to biodegradation. Disinfection byproducts such as trihalomethanes, which are suspected carcinogens and are generally formed during chlorination of water/wastewater are a category of pollutants of growing concern. These are formed from reactions between chlorine and naturally occurring organic matter. The BTEX group (benzene, toluene, ethyl benzene and xylene) is another set of trace organics frequently detected in groundwater, with major sources being leaking underground gasoline storage tanks, accidental spills and uncontrolled disposal of petroleum products. The benzene compounds have implications for health effects, most notably cancer. Benzene is known to cause leukaemia. However one should note that compounds that are readily degraded in the environment, even though they may be highly toxic, might not be subject to a drinking water standard. Most of the organo-phosphate and carbamate insecticides belong to this category.

Table 6 : Current industrial effluent discharge quality standards

Parameter	Units	General Effluent Standards for Discharge to Inland Surface Waters*	Tolerance Limits for Effluents Discharged to Marine Coastal Areas*	Tolerance Limits for Effluents Discharged on Land for Irrigation
pH Range (at ambient temperature)	-	6.0 to 8.5	6.0 to 8.5	5.5 to 9.0
Temperature of Discharge	°C	40	45	-
Total Suspended solids (TSS) Particle size of :	mg/l	**50	***150	-
(a) Total Suspended Solids	μm	850	-	-
(b) Floatable Solids	μm	-	3	-
(c) Settleable Solids	μm	-	850	-
Total Dissolved Solids (TDS)	mg/l	-	-	2100
Chloride (as Cl)	mg/l	-	-	600
Sulfate (as SO_4)	mg/l	-	-	1000
Sodium Adsorption Ratio (SAR)	-	-	-	10 to 15
Residual Sodium Carbonate	mol/l	-	-	2.5
Per cent Sodium	-	-	-	-
Biochemical Oxygen Demand (5 day, 20°C)	mg/l	**30	100	250
Chemical Oxygen Demand	mg/l	**250	250	-
Oil and Grease	mg/l	10.0	20	10.0
Ammoniacal Nitrogen	mg/l	**50.0	50.0	-
Phenolic Compounds (as Phenol)	mg/l	1.0	5.0	-
Colour	varies	****	****	-
Surfactants	mg/l	-	-	-
Cyanides (as CN)	mg/l	0.2	0.2	-
Sulfides (as S)	mg/l	2.0	5.0	-
Fluorides (as F)	mg/l	2.0	15	-
Total Residual Chlorine	mg/l	1.0	1.0	-
Arsenic	mg/l	0.2	0.2	0.2
Boron	mg/l	-	-	2.0
Cadmium, Total	mg/l	0.1	2.0	2.0
Chromium, Hexavalent	mg/l	-	-	-
Chromium, Total	mg/l	0.1	1.0	1.0
Copper, Total	mg/l	3.0	3.0	-
Lead, Total	mg/l	0.1	1.0	1.0
Mercury, Total	mg/l	0.0005	0.01	0.01
Nickel, Total	mg/l	3.0	5.0	-
Selenium, Total	mg/l	0.05	0.05	-
Zinc, Total	mg/l	5.0	5.0	-
Pesticides	-	Not detectable	-	-
Organo-Phosphorous Compunds (as P)	Mg/l	-	1.0	-
Chlorinated Hydrocarbons (as Cl)	mg/l	-	0.02	-
Radioactive Materials				
(a) Alpha emitters	μC/ml	10^{-7}	10^{-8}	10^{-9}
(b) Beta emitters	μC/ml	10^{-8}	10^{-7}	10^{-8}

Unless otherwise noted, all values shown are maximum tolerance limits for effluent discharges.

* Values shown are based on a minimum of 8 to 1 dilution of effluents by clean receiving waters. If dilution is less than 8 times, permissible limits are determined by multiplying the values shown by 1/8 times the actual dilution.

** Higher values are allowed for these parameters under industry-specific limits established for rubber, textile, and training industries.

*** Applies only to process wastewaters; for cooling water discharges, maximum 10% increase over the influent TSS level is allowed.

**** All efforts should be made to remove colour and unpleasant odour as far as possible.

Source: National Environmental (Protection & Quality) Regulations, No. 1 of 1990.

Under aesthetic quality, organoleptic indicators like taste and colour are included. In addition constituents like Fe and Mn and properties such as pH, hardness are also included due to their inherent potential to cause stains or discoloration, corrosion and scaling/deposits.

When assessing the pollution levels of wastewater, in addition to some of the toxic indicators mentioned above, a different set of indicators are used. Table 6 shows the National wastewater discharge standards that should be complied with before discharging wastewater into various receiving bodies. Biological Oxygen Demand (BOD) is used to measure the pollution strength while Chemical Oxygen Demand (COD) gives an indication of the organic strength of industrial and domestic wastes. Dissolved Oxygen (DO) measurement, which should be around 8 mg/l for unpolluted fresh waters, indicates the aerobic conditions in natural waters that receive pollutants. Suspended solid determination is extremely valuable, as it is one of the major parameters used to evaluate the strength of domestic and industrial wastes. Oil and grease are singled out for special attention because of their tendency to separate from the aqueous phase. As a result, these substances complicate the transportation of wastes through pipelines, destroy biological treatment units, and complicate disposal into receiving waters. Ammoniacal nitrogen is important as it is toxic to fish while phenolics are included as they are detrimental to microbes involved in the biodegradation of organic matter, both in treatment units and in the receiving water bodies.

WATER QUALITY OF MAJOR WATER BODIES

Water quality in the inland, coastal and marine environment is important as these waters are a source for a variety of purposes-potable, irrigation, industrial, wildlife, recreation and aesthetic value. In addition, it is important for the general health of ecosystems. Comprehensive water quality data on surface water, groundwater, estuaries and coastal waters are not available, in part because of diffused resources management responsibilities. Institutions such as the Irrigation Department, Water Resources Board, National Water Supply & Drainage Board, National Aquatic Resources Agency, Mahaweli Authority, and Coast Conservation Department, all manage water resources and collect data independently of each other involving duplication of effort and wastage of time and finances. Many independent water quality studies have also been carried out by Industrial Technology Institute (ITI) (successor to CISIR), National Building Research Organization (NBRO), Institute of Fundamental Studies (IFS) and Universities. NARA has carried out monitoring studies on major river systems-Kelani, Kalu and Mahaweli and some important surface water bodies. Much of the data are scattered, unpublished, sometimes unprocessed and not collated. Therefore, the analysis of water quality trends becomes difficult.

However, an attempt is made here to present information on current status and trends based on available information on a number of important water bodies in the country.

Urban waterways and water bodies

Flood and flood related problems have a significant impact on water pollution in the Greater Colombo area (LIFE, 1996). The CMR receives an average of 2400 mm rainfall each year. Despite a network of 45 km Canal systems (the Main Drain, Mahawatta Ela, Dehiwela Canal, Bolgoda Canal, Wellawatte Canal, Dematagoda Ela, Torrington Canal, Beira Lake, St. Sebastian Canal in Colombo and Hamilton and the Old Dutch Canals in the Muthurajewela area), there is frequent flooding in the city leading to pollution of groundwater and surface water sources. A number of reasons, including improper location, spread of urban/industrial development, increased runoff from impervious surfaces, excessive and often uncontrolled, unplanned filling of low lying lands, siltation and blocking of water ways, encroachment of canal banks by squatter settlements, inadequate and badly maintained drainage systems, formation of sand bars at sea outlets and poorly developed solid waste management systems have contributed to frequent flooding. In addition, where there are storm water drainage systems in place, industries often use these as a drainage system for oils, effluents and the like. Restaurants, large and small and similar commercial establishments in the CMC area discharge their wastewater, without treatment, into surface water bodies and ground water.

The most obvious adverse impacts of current wastewater management practices in the Greater Colombo area are:- black, putrid waters of many waterways scattered across the inland and northern parts of the city; the intense green, and at times stinking, water of Beira lake and the harbour; scattered faecal and other waste debris on many beaches and banks of waterways. Basically the entire canal system within the city has degenerated into a virtual open sewer, though some sections have been restored to reasonable aesthetic standards, during the past year. Other effects, not generally apparent to the public is groundwater pollution due to dumping in uncontrolled landfills, and subsequent burial without leachate controls.

Comparison of quality of water bodies, Beira lake and Kandy lake, with different types of catchments such as Parliament lake and Labugama reservoir demonstrates that urbanization without adequate planning and control of pollution leads to degradation of water quality (UDA, 1993).

Beira Lake

The presence of a dense dark green bloom of *Spirulina* sp. and *Microcystis aeruginosa* in the Beira Lake since the early eighties has made the lake a nuisance water body with no aesthetic value. A feasibility study carried out by the UDA (UDA, 1993) conclusively demonstrated that the major pollution source of the lake was the input of sewage and sullage into the extensive storm water network through unauthorized connections from households. Current land use patterns in the Beira catchment (Fig. 8) highlight the types of activities in the area.

Table 7: Beira lake - physical and biological environment

Long-term degradation of water quality	**1985**	**1992**
BOD, mg/l	37	70
Orthophosphate, mg/l	0.02	2.39
Turbidity, NTU	8.2	9.1

Average water quality ranges in major outfalls	
BOD, mg/l	129-179
Suspended solids, mg/l	61-163
Faecal coliforms, no/100 ml (106)	0.2-180
Total phosphorous, mg/l	1.6-2.4

Mean nutrient values for lake	
Total phosphorous, mg/l	1.5
Total nitrogen, mg/l	13.7

Reduction in species richness
Genera of algae in 1970 (14 green algae, 6 cyanobacteria)
Genera of algae in 1990 (5 green algae, 7 cyanobacteria)
Genera of algae in 1993 (0 green algae, 2 cyanobacteria)

Source: Dissanayke L and Pereira R, 1998.

Source: Beira Lake restoraion Study, Vol 12, UDA.

Figure 8 : Existing land uses in the Beira Lake catchment

The water quality of Beira Lake has deteriorated to such an extent, over time, that bathing or recreational activities involving prolonged water contact would be a health hazard. As shown in Table 7, the BOD_5 has nearly doubled from 1986 to 1992, while the orthophosphate level increased by 150 times, during this period. Extremely high concentrations of nutrients (P and N) observed in Beira Lake are clear indications that this body of water is at an advanced stage of eutrophication. The resulting microbial activity leads to depletion of O_2 levels in the lake bottom waters. The dense microbial cover blocks off light from sub surface waters. Organisms, including fish are killed and decaying matter produces bad odours. Such conditions are aggravated during dry spells when there is little input of fresh water into the lake.

The presence of high levels of metals in the surface sediment of Beira Lake (Table 8) particularly lead, zinc and copper has had adverse effects on the fauna in the lake over the past decades. In 1954, 12 species of fish were reported while the 1993 survey revealed only seven species. The ratio of green algae to cyanobacteria over time has decreased considerably from 14:6 to 0:2 between 1970 and 1993 (Dissanayake L. and Pereira R. 1998).

Kelani and Kalu Ganga

The Kelani and Kalu Ganga are important as they are major sources of drinking water supplies to the highly populated western coastal region. The Kelani Ganga, the second largest river in Sri Lanka (144.3 km), drains an area of 2278 km^2 in the west zone that includes some of the country's most densely populated districts. Colombo receives most of its potable water from Kelani ganga. The intake point is at Ambatale, 14 km from the river mouth. In turn Kelani receives a substantial portion of Colombo's sewage and drainage. At and near the points of discharge into the sea, the Kelani passes through population densities in the range of 5000-10 000 persons/km^2 and the Kalu through densities of 1000-5000 persons/km^2. The coastal plains of both rivers are being built up intensively and urbanized. Agriculture and tea plantations are being replaced by industries. Forests, tea plantations and home gardens have been the major land use in the catchment. The coastal flood plain includes rubber, paddy fields and home gardens, as well as, in recent years by a growing number of industries and urban housing schemes.

NARA carried out a comprehensive water quality monitoring programme of Kelani and Kalu Ganga in 1994 (NARA, 1996). The waters of the central massifs at elevations of 1000-2000 m above mean sea level, the peniplanes at 500-700 m MSL and 100-150 m MSL and the coastal flood plain have been sampled monthly and analysed for various parameters. Hatton/Maskeliya, Nallathanni/ Dalhousie, Eratna, Palabaddala/Araney, Hapugastenna off Malwala are the points of the lower slopes of the Adams peak mountain range, which represents catchment areas of both river systems. These waters were once of extremely high quality with very low dissolved salts with electrical conductivity of 20-60 μs/cm, low turbidity and high DO and low BOD levels, even during the pilgrimage season. pH was neutral to slightly acidic. However, studies show significantly higher levels of nutrients-nitrite, nitrate and phosphate indicating agrochemical leaching from tea plantations. There were also indications that the forests absorb some of the nutrients leaching from plantations.

The middle courses of both rivers which are flanked by some forests, large tea and rubber plantations and paddy fields with home gardens had high nutrient contents. Conductivity and dissolved salts were not very high except for the location just downstream of Ratnapura town, which also showed relatively high nutrient content probably due to waste disposal from the town.

The waters of the coastal flood plain showed high nutrients, increased conductivity and BOD, low pH (averaging 5.3), particularly in the Kelani Ganga probably due to industrial sources and high inputs of humic acids.

Table 8 : Metal concentration in surface sediments of Beira Lake and St. Sebastian Canal

Parameters	Units	Beira Lake (n=9)	East Lake (n=4)	Galle Face Lake (n=1)	West Lake (n=2)	Southwest Lake (n=2)	St. Sebastian Canal (n=1)
Redox Potential	MV	-428	-436	-368	-422	-447	-458
Chromium	mg/kg of dry soil	40	30	20	30	50	50
Copper	mg/kg of dry soil	100	90	60	80	130	130
Lead	mg/kg of dry soil	60	70	50	60	70	100
Manganese	mg/kg of dry soil	1530	1900	1000	800	1770	1060
Nickel	mg/kg of dry soil	185	208	190	130	188	159
Total Iron	mg/kg of dry soil	30 000	33 000	19 000	18 000	40 000	39 000
Zinc	mg/kg of dry soil	640	670	350	480	900	1 660

Source : UDA, 1993.

The waters close to and within the estuaries showed increased pollution levels with very high BOD and organic matter and high dissolved salts/conductivity due to salt water intrusion. BOD levels ranged from 1.2 to 17 mg/l, with highest levels in the coastal flood plain of Kalu ganga. Depletion of DO indicated the increased organic loading of the receiving bodies.

Microbiological results showed the presence of coliform bacteria throughout both river systems from the catchment to the coast indicating inputs of anthropogenic waste. Total coliform counts ranged from 0-1500 cells/100 ml. However these levels are within freshwater norms for bathing and recreational use but not for potable water.

Heavy metals and pesticides have not been studied extensively in the Kelani and Kalu Ganga. Trace metals contamination can occur mainly from tanning effluents from the lower reaches and to a lesser extent from discharges from metal finishing and processing industries. However without any analytical data a realistic assessment of such pollution is not possible.

Impacts of sand mining in the Kelani Ganga have been extensive in the lower reaches. As a result, the Kelani's lowered river bed which is below sea level allows the intrusion of salt water. The salt wedge which is extending steadily further inland has reached the Ambatale intake, at certain times. Appropriate remedial measures are required immediately, to prevent recurrence.

Mahaweli Ganga

The Mahaweli, Sri Lanka's longest river (325 km), with an annual discharge of 7650 million m^3 also has by far the largest catchment area (10 327 km^2) covering one sixth of the island. For approximately half its length the Mahweli traverses the wet zone, passing through densely populated towns, including Kandy and Matale. From Kandy, alone, it receives substantial untreated urban wastewater through the two main waterways draining the city- the Meda Ela and the Hali Ela, which together receive a load of 712-1507 kg BOD/d from dense city centre developments (NARESA, 1991).

Low levels of industrialization have kept industrial pollution of the Mahaweli ganga below that of the Kelani ganga, but expansion of the agricultural and agrobased industrial sector, and hospitality industry in this region will pose a serious threat to the water quality, in the future, if not properly controlled.

NARA studied the water quality in the irrigation network of the Mahaweli System 'H' during 1992/93 (NARA, 1993). The reservoirs connected to the system 'H' are mostly located in the Anuradhapura District and the extent of new land in this system is 28 000 ha. The Mahaweli river diversion at Polgolla feeds water to the Bowatenna reservoir through Suduganga, and the waters are then released to the various reservoirs connected to the system. Though the major crop is paddy, a considerable area is cultivated with vegetables such as chillie and onion which generally receive liberal dosages of agrochemicals. Main reservoirs investigated by NARA were Kandalama, Kalawewa, Rajanganaya, Nachchaduwa, Nuwarawewa, Huruluwewa and Mahakandarawa. BOD data indicated some level of organic pollution in some of the reservoirs. High concentrations of nutrients present in the waters between Kalawewa and Rajangana were attributed to leaching of agricultural inputs while nutrient enrichment seen between Nachchaduwa and Nuwaraweva was linked to population increase and proliferation of tourist hotels. Toxic metals were not analysed during this study. A screening programme carried out in 1998 by ITI did not detect any significant pesticide residues in the Mahaweli river in the Kandy District.

The occurrence of cyanobacteria in 21 surface water bodies in the Mahaweli river basins were examined during 1994 (CREN, 1998). Of the five major genera of cyanobacteria, *Microcystis* had the highest distribution and dominance index. A preliminary survey carried out on 12 reservoirs used as resources for water supply schemes by the NWSDB indicated that toxin producing algae are present at moderate levels, but during dry periods with increased pollution the levels of toxic materials increase. The presence of *Cylindrospermopsis*, one such algae in Tissa wewa and Bass in Anuradhapura is thought to be the cause of the musty odour and bad taste in the water supplied from these reservoirs.

Kotmale reservoir

Kotmale reservoir was constructed under the Mahaweli Development project for the generation of electricity. This reservoir has 87 m high and 600 m long rock filled dam across the Kotmale Oya, a right bank tributary of the Mahaweli river at a point 6.5 km upstream of its confluence with the Mahaweli. The catchment area at dam site is 544 km^2 while the Kotmale Oya, which is about 70 km long, has a catchment area of 585 km^2. The major part of its catchment is covered by agricultural land including several tea estates and thus prone to agrochemical pollution.

During the long dry spell of 1991 the entire Kotmale reservoir was covered with a thick bloom of *Microcystis aeruginosa*. Seasonal appearance of algal bloom in Kotmale reservoir has been attributed to relatively high levels of nitrates and phosphates fed in from streams passing through cultivated catchments. (NARA 1995a). Apart from large scale fish mortality due to oxygen depletion the algal bloom had serious impacts on operational activities but disappeared gradually with the onset of the monsoonal rain.

Nuwara Eliya Lake

Lake Gregory lies at an elevation of 1874 m above sea level in the valley of Nuwara Eliya. This man made lake is one of the most distinctive water bodies in the central hill country. It covers an area of about 90 ha. Part of the lake catchment contains vegetable cultivation and tea plantations. Silting of the lake becomes a problem from time to time and disposal of town sewerage into the lake was also practised during the early nineties.

A detailed study undertaken by NARA in 1995 indicated that the quality of water in feeder streams and drains entering the lake was variable and some contained a considerable level of nitrates, nitrites, phosphates and ammoniacal nitrogen far in excess of

Table 9: Selected water quality indicators of incoming streams and main water body of Lake Gregory

Indicator	Incoming streams	Main water body
Turbidity, NTU	10-235	6.3-53.7
Conductivity, μs/cm	128-346	11-122
pH	6.4-6.9	5.9-6.7
DO, mg/l	3-6.8	6-7.4
Nitrate, mg/l	0.5-4.56	0.8-2.0
Phosphate, mg/l	0.01-0.57	0.00-0.01
Ammoniacal N, mg/l	0.32-3.4	0.12-0.73
BOD, mg/l	19.5-59.5	20-46
Organic matter, mg/l	5.8-13.7	6.2-9.0
Total coliform, no/100ml	16 229-5 32 250	47-1822
Faecal coliform, no/100ml	6207-468 700	40-1259

Source: NARA, 1995b.
Indicator values are ranges for several incoming streams and sampling stations within the lake.

norms, when compared with groundwater samples in the vicinity (Table 9). A significant quantity of nitrates seep into surface runoff from vegetable cultivation. Mean BOD levels ranged from 19.7 to 59.5 mg/l while faecal concentration ranged from 6.2 x 10^3 and 4. 6 x 10^5 cells/100 ml.

Although the lake is eutrophic and moderately polluted, physical and chemical parameters except for BOD were found to fall within the tolerance limits required to support fresh water fish other than sensitive species. Water quality of the lake was generally poor with respect to bacterial contamination. However, this too improved in water flowing towards the spillway, indicating its self purification capacity. As a result water quality of the lake still exhibits suitability for recreational activities.

Estuaries and Lagoons

Sri Lanka's 1760 km coastline (offshore islands not included) is indented by extensive lagoons, bays, brackish water lakes. These water bodies include 80 000 ha of estuaries and large deep lagoons, and about 40 000 ha of shallow lagoons, tidal flats, mangroves, and swamps. Pollution monitoring data are available only for a few water bodies. No major lagoons except lagoons Jaffna, Batticaloa and Negombo are associated with urban centres, and no coastal towns are heavily industrialized, except around the Kelani estuary.

Studies on the Kalametiya lagoon have shown that ambient water quality in the lagoon is satisfactory (Dept. of Census & Statistics, 1998d). Present water quality in the Koggala lagoon was shown to be suitable for commercial prawn fishery (NARA, 1993). Considering the ecological importance of these lagoons, all developmental activities in the area including the relocation of tanneries to Bata-atha, a village near Kalametiya lagoon, should be properly regulated and monitored to ensure that the quality of the lagoons are maintained.

Pollution of the small lagoons and bay estuaries is much more serious, however. Lunawa lagoon, the Bolgoda system and Valachchenai lagoon, have suffered greatly from uncontrolled urban and industrial waste disposal.

The area around Lunawa lagoon located south of Colombo has developed as an industrial and residential suburb. The Ratmalana–Moratuwa area developed in the 1960s, has a mix of residential, commercial and industrial establishments. The lagoon, which supported a significant fisheries industry a decade ago, is so polluted that it no longer supports a fishery. More than 100 Ja-Kotus, (no longer exist) once harvested prawns. A fish catch of 50 kg/boat/day has been lost due to pollution since 1979. Some areas of the lagoon are no longer accessible due to siltation and the dense growth of water plants. Large amounts of industrial sludge has settled on the bottom of the lagoon which is covered by 3-3.5 ft (90-105 cm) of sludge. Water quality parameters measured at various locations in the lagoon are listed in Table 10. Nitrogen and phosphorous levels were far in excess of acceptable levels leading to eutrophic conditions. The level of H_2S detected in the lagoon exceeded the maximum concentrations. The heavy metal concentrations determined in sediments and the water column were high. The presence of extremely high concentrations of oil & grease ranging from 0.7 g/l to 2.8 g/l has been recorded. In its present condition Lunawa lagoon has to be regarded as a 'dead lagoon'. Restoration of quality will require urgent and drastic measures.

Table 10: Selected water quality indicators – Lunawa lagoon

Indicator	Range
Turbidity, NTU	7.9-19.5
Conductivity, ms/cm	0.9-17.4
Salinity, ppt	0-7.5
PH	6.7-8.3
DO, mg/l	0.5-18
Nitrate N, mg/l	0.11-5.7
Phosphate, mg/l	0.11-0.78
Ammoniacal N, mg/l	0.38-26.0
BOD, mg/l	1.3-82
Organic matter, mg/l	14-62
Oil & Grease, mg/l	696-2804
Lead, mg/l	0.002-0.005
Zinc, mg/l	0.016-0.1
Manganese, mg/l	0.019-0.34
Copper, mg/l	0.01-0.06

Source: NARA, 1994.

The Bolgoda lake which also receives urban and industrial waste, showed BOD values 10-100 mg/l during high tides. Although Bolgoda lake has not been polluted to the same extent as Lunawa lagoon there is rising concern that the long term impact of the continued discharge of industrial and urban pollutants into the catchment area will compromise its economic and ecological value.

The Valachchenai Lagoon receives waste from a single industry-a state owned paper factory-whose discharges cause heavy pollution. Studies done 10 years ago revealed that waste loads of 18 000 kg of suspended solids and 9000 kg BOD reach the lagoon daily (NARESA, 1991). However, with the production capacity curtailed due to civil unrest this figure may be much lower at present. No data are available on the present status of water quality.

Groundwater

Groundwater is increasingly used for potable water supplies, especially in small towns and rural areas. Estimated groundwater potential for the country is 780 000 ha/m /annum. For this water to remain safe, water extraction must not exceed the aquifer's recharge capacity. Otherwise the well will run dry or, in coastal areas, invite brackish water intrusion. The problem of saltwater intrusion has occurred in northern peninsula and the northwest agricultural belt where groundwater is held in karstic limestone and irrigates rice and cash crops.

The most serious threat to groundwater comes from leaching of agrochemicals and sewage from pit latrines leading to nitrate, pesticide and faecal pollution.

In agricultural and non-agricultural areas in the Jaffna peninsula, nitrate concentrations over 200 mg/l have been recorded (NARESA, 1991). Widespread water contamination in the peninsula was attributed to agricultural washouts and pit latrine soakaways. The presence of crevices and channels in the karstic limestone bed has helped the easy percolation of pollutants into the limestone aquifer.

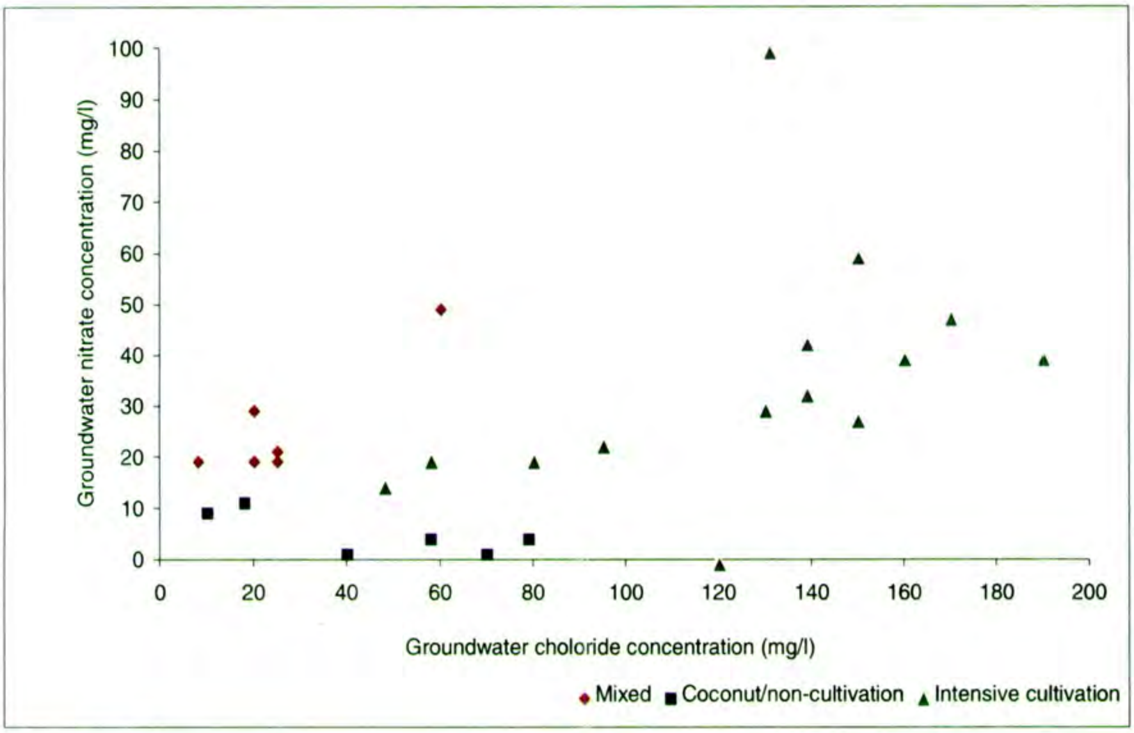
Groundwater pollution in Kalpitiya

The Kalpitiya Peninsula is a low lying sand peninsula of karstic limestone on the northwest coast of Sri Lanka. It lies within the dry zone and the climate is characterized by high temperature throughout the year and a seasonal distribution of rainfall supported by 'well irrigation'. Rainfall charges the limestone aquifer. Coconut plantations are widespread in Kalpitiya. In recent years, however there has been a significant expansion of intensive horticulture - onion, chillie gherkin and potato by well irrigation.

A comprehensive study on the impact of agriculture on groundwater quality at Kalpitiya peninsula (BGS, 1992), has revealed that irrigation wells within the extensively cultivated area had nitrate concentrations in excess of the WHO guidelines of 10 mgl^{-1}; chloride concentrations in these wells were typically in the range of 50-200 mg l^{-1} (Fig. 9). By contrast, domestic wells located outside of the intensively cultivated areas had much lower nitrates and chloride concentrations generally less than 2 and 100 mg l^{-1} respectively. This study has demonstrated clearly that the leaching of agro-chemicals from intensively cultivated soils is a serious problem that has to be addressed urgently. This study has also demonstrated that 10 per cent of the soil applied with carbofuran, a known groundwater contaminant, is leached to the water table within ten days of the application (Fig 10). In the case of alachlor, another groundwater contaminant, only three per cent leached and took more than 60 days to reach the water table. This clearly demonstrated the difference in mobility of these two pesticides in the Kalpitiya soil. When considering persistence, carbofuran was degraded completely within 60 days while alachlor remained in groundwater for about 150 days. Unlike in Jaffna where the karstic limestone aquifer facilitates lateral migration of pollutants, the sandy aquifer in Kalpitiya does not promote such dispersion thus limiting the spread of pollution to non-cultivated areas.

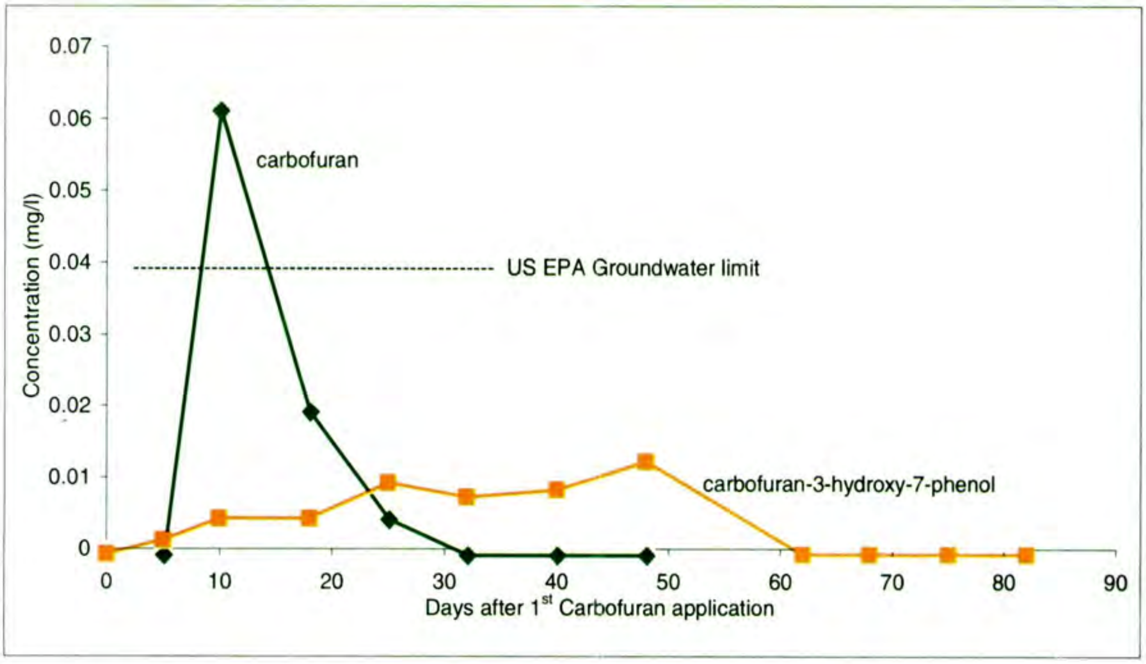
Acid Rain

Acid rain is not a major problem in Sri Lanka at the present time. Acid rain monitoring studies carried out by the University of Peradeniya (Illeperuma, 1998) indicated that acid rain (rain water having a pH <5.5) is significant in a number of locations in the hill country and the North Central Province. However the Colombo Metropolitan Region which has the highest level of vehicular and industrial pollution did not record significant acid rain probably due to the transport of acidic fumes elsewhere by wind.



Source : BGS, 1992.

Figure 9: Impact of agriculture on the groundwater quality - Kalpitiya



Source : BGS, 1992.

Figure 10: Carbofuran and metabolite in shallow piezometers, Maha 1990/91, Kalpitiya penninsula

IMPACTS OF WATER POLLUTION

Economic, social, health, and biological impacts of water pollution are inter-linked and cannot be viewed in isolation. The costs of water pollution include the damage it does to fresh water fisheries, the main sources of protein for the poor, and to the livelihoods of many rural people who are engaged in fishing.

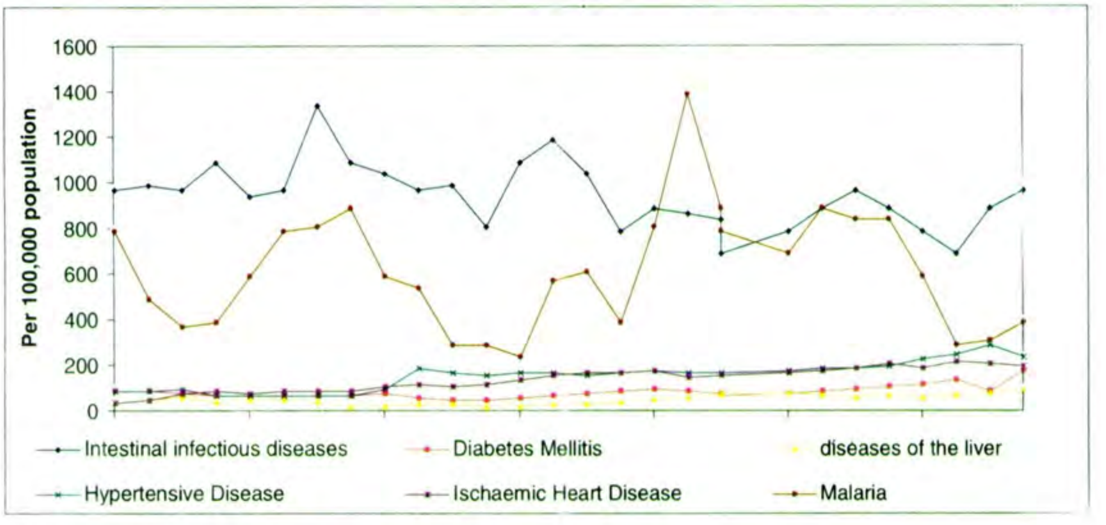
Pollution of water bodies and waterways in cities contributes to loss in aesthetic value, and may reduce diversity in plant and animal species in fresh and estuarine waters. Other impacts that water pollution can have on the economy are in the areas of agricultural exports and tourism.

Most of these impacts can be quantified, and many can be assessed in terms of costs. These include fisheries, income to fishermen, and the tourist industry. Such assessments however imperfect, offer means for anticipating and preventing, and/or treating, water pollution problems. In Jakarta, households spend more than $50 million each year for boiling water-an amount equal to one per cent of the city's GDP. During the cholera epidemic in the mid 1990s in Peru, losses from reduced agricultural exports and tourism, were estimated at dollars one billion more than three times the country's investment in water supply and sanitation services during 1980s (World Bank, 1992).

An estimate of Rs. 2700 million in 1992 was made for the economic costs of water pollution in Sri Lanka (LIFE, 1996). This includes health impacts, loss of wages and treatment costs. The National Water Supply and Drainage Board spends the substantial sum of Rs. 2700 million, annually, to purify and distribute water to the people. Yet the consumer is unsure about the quality of water coming off the tap and spends additional sums of money, for boiling water, purchasing bottled water or using water purifiers.

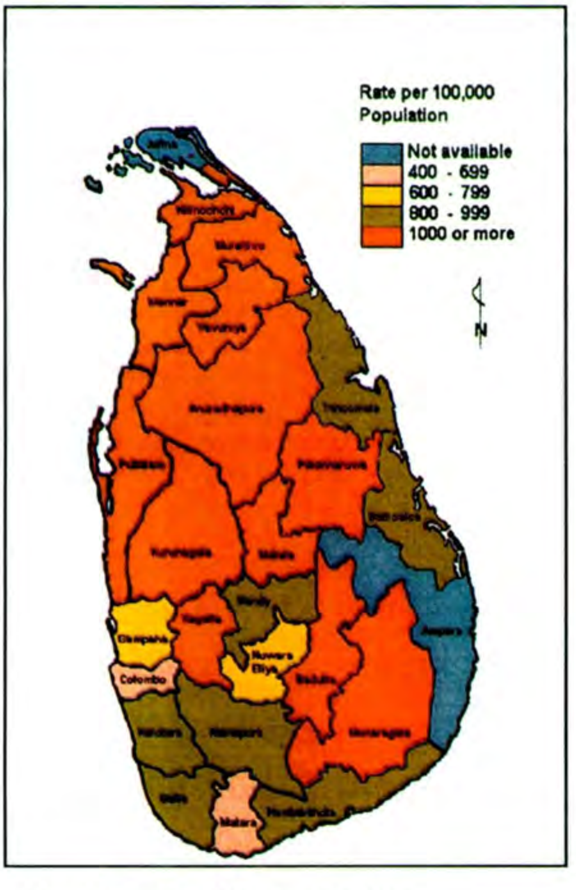
Water borne diseases, caused by polluted water, although not precisely evaluated, have increased costs of healthcare in cities, small towns, and rural areas. If one looks at the trends in hospitalization for selected diseases during 1970 to 1997, intestinal infectious diseases still remain as one of the major causes for hospitalization in the country (Fig. 11). Although deaths due to intestinal infectious diseases have declined remarkably in the past, they are ranked as the second leading cause of mortality in the districts of Kilinochchi and Mullaitivu. One should also note the resurgence of cholera during 1997 during which period a total of 430 cases of cholera and 12 deaths were reported from various districts. The largest number of cases were reported from the districts of Puttalam (268), Kurunegala (95), Gampaha (35) and Monaragala (17) areas where sanitation facilities are below accepted norms. Inadequacy of water supply and sanitation programmes in many parts of the country is the major reason for increased morbidity rate in diarrhoea diseases. As shown in Figure 12 the most affected provinces are northwestern, northcentral, uva and northern where sanitation, water quality and hygienic practices are poor.

The vector borne disease, filariasis, is also linked to polluted waters. It is carried by the mosquito *Culex quinquefasciatus* which breeds in highly polluted stagnant water, such as blocked drains, damaged septic tanks and latrine pits which abound in urban habitats. Filariasis affects teenagers and young adults. However, the disease is easily treatable. There is an increasing trend in the number of new cases reported in the recent past. The number has increased from 806 in 1992 to 4108 cases in 1997 (Ministry of Health, 1997). In Sri Lanka the highest endemecity is found in the southern and southwest coastal belts and few inland areas like Polgahawela, Kurunegala, Gampaha and Veyangoda (Fig. 13).



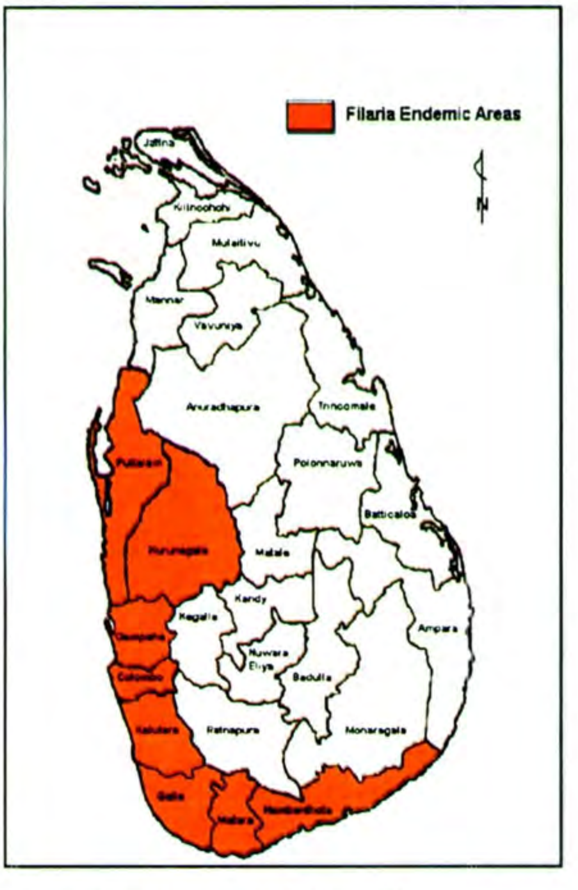
Adapted from: Annual Health Bulletin, 1997.

Figure 11: Trends in hospitalization for selected diseases



Adapted from: Annual Health Bulletin, 1997

Figure 12: Distribution of cases of Diarrhoea diseases by district



Adapted from: Annual Health Bulletin , 1997.

Figure 13: Filarial endemic areas by district

WASTE MANAGEMENT STRATEGIES

An effective waste management system is necessary to control pollution and thereby minimize contamination of surface waters and underground aquifers in the country. Such a waste management system should comprise legislation, implementation and enforcement, facilities and infrastructure and support services. Further, for this system to be effective all four elements must be in place; legislation without the facilities and support services cannot be enforced satisfactorily. On the other hand, in the absence of suitable legislation implementation of a waste management system nationally is a near impossibility.

Facilities and Infrastructure services

The waste management strategy adopted by the government includes short term actions for immediate implementation and a phased approach to implement longer term actions. One of the more important actions of the strategy is to actively promote cleaner production. Presently there is little evidence of cleaner production activities by industry. The reasons are both technical and financial and there is a lack of awareness among industrialists of the advantages of cleaner production. The potential benefits both to industry and the environment are substantial when disciplined procedures are adopted for cleaner production. It is anticipated that between 20-40 per cent of pollution can be eliminated by reduction of waste and emissions at source.

Several initiatives are already underway to promote the cleaner production concept in Sri Lanka. The UNIDO sponsored Industrial Pollution Reduction Programme (IPRP), implemented by the CEA from 1994-98, was aimed at identifying and implementing financially viable waste minimization options in textile, metal finishing, DC mills, tanneries and distillery industries and setting up site specific demonstration projects, to promote clean technologies. In addition several officers were also trained on CP audits under this programme. The Pollution Control and Abatement Fund (PCAF), operated by the National Development Bank (NDB), provides financial assistance to industry engaged in cleaner production/pollution control activities. Up to 1998 a total sum of Rs. 200 million has been disbursed as grants and soft loans to 50 projects under this programme. A World Bank funded Pollution Prevention Clearing house, named CleaNet, has been set up by the Ceylon Chamber of Commerce and Industrial Technology Institute (successor to CISIR) to offer a full package of services to industry on cleaner production activities.

To minimize the environmental degradation of water bodies in Ratmalana and Ekala industrial areas, common wastewater treatment systems are to be constructed, to treat combined industrial and domestic wastewater. Since Ratmalana is located close to the coastline, wastewater will be disposed directly via a new ocean outlet with primary treatment only. In the case of Ekala as there is no ocean outlet nearby, the combined wastewater will be sent through a secondary treatment plant prior to discharge to an inland water course.

There are technical, commercial and economic benefits of locating industries, particularly industry of high polluting category, in 'estates' or 'zones' that have been provided with common wastewater treatment facilities. The Ministry of Industrial Development has short-listed, on a regional basis, several areas suitable to be developed as industrial estates (Table 11). Construction of an industrial estate at Sithawaka is now complete while Environment Impact Assessment (EIA) is being carried out on a few more sites in other parts of the country. The government is proposing to move all tanneries to Bata-atha, in the Hambantota district with provision of a combined wastewater treatment system. A private sector managed industrial estate – LINDEL- has also been set up at Sapugaskande to accommodate low and medium polluting industries.

Industrial wastewater treatment plants (physical,chemical and biological) produce sludge that requires safe disposal, off-site, in accordance with the specific nature of sludge generated. This requirement applies to both individual industry based treatment plants and to combined industrial/domestic wastewater treatment plants. Currently viable outlets for the disposal of these sludges are limited. This

Table 11: Regional industrial estate development programme

District	Industrial Estate	Area in acres
Matara	Udukawa	17
Hambantota	DeviWimanawatte	10
	Bata-atha	105
	Middeniya	50
Puttalam	Dankotuwa	53
	St.Martin Watte	50
	Tambanakella	50
Ratnapura	Paradise Stage I&II	101
	Pelmadulla	50
Matale	Madawela	24
	Nalanda Watta	80
Gampaha	Minuwangoda	15
Galle	Karandeniya	50
	Pinnaduwa	15
Kalutara	Nagoda	50
Kurunegala	Makadura	20
	Polgahawala	100
Polonnaruwa	Kaduruwela	25
Ampara	Sammanthurai	35
Anuradhapura	Senapura	35
Badulla	Glen Alpine	50
	Gemunupura	15

Source: Ministry of Industrial Development, 1998.

forces industry to adopt a range of uncontrolled procedures for sludge disposal, including spreading on land within factory premises, with associated risk of groundwater pollution, or disposal by private contractors at unknown sites. Under the Colombo Environmental Improvement Project, a sanitary landfill with a receiving capacity of 1000 tonnes a day has been designed for construction. It is proposed to site this landfill at Alupotha in Hanwella to dispose municipal waste and non-hazardous industrial solid waste. A composting plant with a minimum capacity of 100 tonnes a day will also be set up at this location to treat market garbage.

Similarly the problem of hazardous waste generation and its safe disposal have become a major concern now. A pre-feasibility study carried out under the Metropolitan Environment Improvement Programme (MEIP) recommends a low technology central treatment facility for chemical treatment and stabilization of hazardous wastes with a landfill site for the stabilized wastes. In addition it proposes the use of a cement kiln to burn pumpable organic wastes. Two sites, Mahara quarry and an abandoned coconut estate in Pannala, have been identified for EIA studies. Currently the CEA is exploring the possibility of identifying a suitable site for the blending facility for the organic wastes prior to incineration in a cement kiln.

Several proposals are in the pipeline to improve the sanitation facility in the CMR. Two of the major activities in the next few years will be to rehabilitate the existing Colombo sewerage system and to extend the present system in a cost-effective manner to areas closer to existing collector sewers.

Policy and Legislation

A National Industrial Pollution Management Policy Statement signed jointly by the Ministers of Industry, Environment and Science & Technology (Ministry of Environment, 1998) advocates: Pollution Prevention at Source; Polluter Pays Principle; Clustering industrial units in estates or parks; Incentives and enforcement; and community, private sector and government interaction.

Heightened concern about environmental pollution has come recently, but because water is one of man's primary needs, early legislation sought to prevent water pollution. In 1861 the Thoroughfares Ordinance made it an offense to throw rubbish into rivers and canals. Since then Parliament has passed numerous acts administered by different agencies, ranging from the purely advisory and coordinating functions of the Water Resources Board Act of 1964 to the regulatory approach of the National Water Supply and Drainage Board Act of 1974, dealing with aspects of pollution control (Table 12). Only the laws enacted after 1980, in particular the National Environment Act, reflect the view that water is a resource to be protected and managed for the use of future generations.

In terms of the National Environmental Act the CEA was created in 1981 as a policy making and coordinating body. The 1988 amendments transformed the CEA into an enforcement and implementing agency. Until recently, all industries- whether they were classified as low, medium or high polluting- were required to obtain an EPL. In view of the thousands of industries scattered around the country and the regulatory burden placed on limited CEA staff, EPL issuance to all industries had become very difficult. In order to relieve this constraint, the issue of licence for low polluting industries has been delegated to the relevant local authorities from 1994.

Table 12: Environmental legislation relating to water

Name of Legislation	Pollution	Resource Management
Thoroughfares Ordinance and Act (1861)	x	
Irrigation Ordinance (1900)	x	x
Colombo Municipal Council Waterworks Ordinance (1907)	x	x
Crown Lands Ordinance (1947)	x	x
Water Resources Board Act (1964)	x	x
National Water Supply and Drainage Board Law (1974)	x	x
Sri Lanka Ports Authority Act (1977)	x	x
Agrarian Services Act (1979)	x	x
National Aquatic Resources and Development Agency Act (1981)	x	x
Coast Conservation Act (1981)	x	x
Marine Pollution Prevention Act (1981)	x	x
National Heritage and Wilderness Act (1988)	x	
National Environment Act (1980) and Amendment (1988)	x	x

Source: NARESA, 1991.

Under the EIA regulations certain prescribed projects are required by law to undergo EIAs. Large scale and hazardous industries such as iron and steel industries, chemical industries, petroleum refineries, sugar, cement, paper and tanneries (above a certain production capacity) have been listed as prescribed projects, which require an EIA study prior to commencement. In addition, all industrial estates exceeding 10 ha will also be required to undergo EIA.

The CEA and the SLSI are currently reviewing the existing discharge standards for industrial effluent into land, surface waters, and marine coastal areas. A national definition on hazardous wastes and regulations to control the collection, storage, transport, and disposal of hazardous wastes have been gazetted (Gazette, 1996). Presently the Ministry of Environment is working towards setting up a hazardous waste management system to handle these priority wastes.

It is very difficult to develop a control system for industrial pollution without strengthening institutional capacity for monitoring pollution and enforcement of the regulations. CEA is being strengthened with a new building, laboratory equipment and personnel, to implement the regulations effectively. Some of the powers of the CEA have been delegated to the BOI and other Local Authorities to help in the implementation and enforcement of the legislation.

It is also important to build up indigenous capacity to develop cost effective pollution control systems, to select and assimilate imported technology and to provide access to foreign technical information to the industry. Several state organizations such as the ITI, NBRO, Rubber Research Institute (RRI), National Engineering Research & Development Centre (NERD) and the universities offer testing and consulting services to industry to solve their pollution related problems. In addition many private sector companies and consultancy firms have mushroomed to serve the growing demands in the country to control pollution. However, to provide a more effective and reliable service to industry, expertise and facilities available in these laboratories need strengthening and accreditation to international norms.

Water quality monitoring and modeling studies are important for analyzing pollution conditions and trends in major water bodies. Legal responsibilities for these activities vest in several different agencies, such as the Mahaweli Authority and the Board of Investment, which have their own areas of jurisdiction. Nationally, the CEA has authority, over water bodies along with its regulatory responsibilities, The Coast Conservation Department (CCD) has authority to monitor water quality in the coastal zone and regulate discharge within it. NARA has the broadest national responsibilities for research on aquatic resources. Its authority includes the collection and dissemination of aquatic resource data, and the conduct of R&D, management and conservation of aquatic resources. It also has the authority to prepare an Aquatic Resources Management Development and Research Plan. ITI undertakes a wide range of analytical studies in water, soil and environment and has a full- fledged environmental laboratory accredited by ASTEL, a scheme operated by the SLSI.

Education and Research

Several environment related courses at postgraduate level have been initiated by the Universities of Colombo, Moratuwa, Peradeniya, Sri Jayawardanapura and Kelaniya to cater to the growing demand for environmental engineers and scientists in the country.

The Ministry of Science and Technology is now implementing a comprehensive ADB sponsored Science and Technology (S&T) manpower development programme to enhance, among others, the quality and R&D capability of the environmental S&T manpower in the country. Under this project the Chemical & Environmental Technology Division of the ITI is being upgraded to a Centre for environmental R&D in the country.

Environmental education at pre-school levels and a programme to train Master Teachers to strengthen teaching in schools have been initiated by the CEA and National Institute of Education (NIE). But these efforts should be expanded and sustained to have any meaningful impact among the school children.

Ad hoc training programmes/workshops on cleaner production, waste audits, EMS, ISO 14000 etc., are also being regularly organized by several organizations with the aim of promoting awareness in the country.

Under the Commonwealth Science Council Programme CREN (Chemical Research and Environmental Needs) several local scientists and engineers were given the opportunity to participate at international seminars, workshops and training programmes in a wide range of fields which are of national and global relevance.

KEY ISSUES

The increase in population coupled with continued development will demand more water and give rise to increased production of wastewater which have to be treated and disposed in an environmentally acceptable manner. The Water Supply and Sanitation Master Plan has identified the following as some of the key issues related to water pollution in the CMR. In the CMR the total population is projected to increase by almost 1.5 million by the year 2020. To cope up with the increasing load the existing sewerage system needs to be rehabilitated and reinforced to serve the larger populations.

Even though the population served by sewerage will increase substantially by 2020, the population using 'on-site' facilities too, can be expected to increase by a million or more persons during the same period. Hence provision of sanitary facilities to the 650 000 persons in Greater Colombo area now having no sanitary facilities or ones which are grossly inadequate, is also an important issue to be tackled in the coming years.

The majority of the existing on-site facilities are ineffective due to improper designs, inadequate, capacity, poor soil permeability and high water table. This has led to: a) groundwater pollution due to leakage and b) surface water pollution by users illegally, bypassing the sewage connection and household sullage drains to the storm water drains. Thus it is critical to ensure that the on-site facilities used are located, designed, constructed and operated and maintained in an optimum manner. The Water Supply and Sanitation Master Plan suggests the following to remedy the situation: a) Soil permeability tests to be mandatory, before building the facility and Certificate of Conformity to be issued only after a proper assessment and inspection and b) Periodical inspection of the facility to ensure proper functioning. The Plan also recommends that many on-site sanitation users in the CMR who can easily be connected to the existing sewer system should be encouraged to connect to the sewer system by offering attractive financial packages.

Solid waste management is another key issue in the metropolitan cities. One of the major problems is the lack of a properly engineered landfill to accommodate the garbage generated. The construction of the much needed Alupotha landfill is being delayed mainly due to lack of understanding, misinformation and unfounded fear among the residents regarding the environmental implications of the project. A conciliatory approach by all parties concerned is vital to find a rational and cost effective solution to the solid waste problem.

One of the major obstacles faced by the old industries, particularly industries which are located in urban areas, is the lack of facilities to discharge or dispose their wastewater and solid wastes. Hazardous waste disposal facility is also a major issue for industries generating such wastes. Various infrastructure programmes which are in the pipeline – combined common wastewater treatment plants for Ratmalana – Moratuwa and Ekala-Jaela areas, Municipal solid waste landfill and hazardous waste disposal facility should therefore be accelarated.

Most of the technologies used particularly by the Small and Medium Scale Industries (SMI) are outdated/inefficient and as such they consume more water and generate more pollution. Although there are financial incentives to encourage industries to replace such technologies the response from industries is poor. Possible reasons are: package is too costly to the SMI, industry being unaware of the problems and financial packages available, inability to access new technologies, and lack of commitment to improve environment. The following actions are suggested:

a) Awareness campaign on cleaner production, EMS etc.

b) To set up mechanisms to assist industries to source, access and transfer clean technologies, and

c) To educate the public on the importance of environment and through them to exert pressure on industry to act in an environmentally responsible manner.

Pollution from agrobased industries, desiccated coconut industries, rice mills, animal farms, etc., is becoming a major problem in rural areas as most of them discharge their effluent untreated into the environment. These industries should be encouraged to set up anaerobic digestors which are compact, low energy consuming and efficient for high organic wastewater. Methane generated during anaerobic treatment can also be recovered and used as fuel while the sludge generated can be made into good compost. Since imported technologies are expensive, local R & D institutions should adapt these technologies and make them cost effective.

Groundwater assumes major importance in Sri Lanka because of its potential as an abundant and clean source of water supply. Yet contamination threatens this development in urban and rural areas alike. As pointed out earlier, intensive agriculture has already affected groundwater quality in Jaffna and Kalpitiya. Comparable problems may exist in other parts of the country with similar geological conditions – limestone aquifers and permeable soils. Systematic groundwater monitoring and appropriate measures to minimize such pollution are therefore a priority. Once groundwater is polluted it is not possible to clean up. In such cases the economic and social costs will tend to be high.

Another potential source of groundwater pollution is from petrol and service stations scattered throughout the country. The problem may be severe in the urban areas due to the large volume involved. Groundwater pollution arises from seepage from leaking underground storage tanks and discharge of untreated wastewater with high oil content eventually leading to leaching of BTEX, a group of potential carcinogenic compounds. However, there is no data available to assess the situation.

Another issue that needs to be addressed is the extraction of groundwater for industrial and commercial purposes. Of the 500 industries surveyed in the Greater Colombo Wastewater and Sanitation Master Plan over 50 per cent were found to be using groundwater to supplement piped water supply. Well water usage was estimated at 58 per cent of total industrial water consumption in the Greater Colombo area. While such a cheap source of water is available, it will be difficult to induce industries to reuse, or recycle which will reduce their water consumption and wastewater generation. Introduction of an abstraction charge can have a beneficial effect in relation to water pollution control. In addition this will also help conserve groundwater, particularly in the dry zone, and minimize saline intrusion in coastal areas.

Water quality monitoring and modeling studies are important to analyse and predict pollution trends in major water bodies. A surface water quality network is long overdue and should be established without any delay. NARA, as a major player in aquatic resources monitoring, can play a lead role in the network. Currently NWSDB does not monitor the levels of THMs in pipe borne water which are formed during chlorination. Since THMs are carcinogenic regular monitoring of pipe water is urgently needed. NWSDB can initiate a joint programme with ITI, which has the instrument to do such analyses.

Legal responsibilities for these activities vest in several different agencies operating in local or regional areas while several institutions and universities are engaged in monitoring water quality. However, an apex body is necessary to coordinate the activities of all institutions concerned with water resources and water pollution.

Many countries are now using the state of the environment, including water quality, as an economic indicator to attract foreign investment, promote their countries as regional hubs for international conventions and meetings, market tourism and expand their export trade. Sri Lanka, with its unique geographical location and relatively low environmental degradation, has high competitive advantage to become a hub in the region.

REFERENCES

1. Associated Engineering (1994) *Feasibility study for establishment of a central wastewater treatment plant for industrial estates/industries at Ratmalana, Moratuwa Greater Colombo area.* Interim report, Vol. 1, Associated Engineering International Ltd.

2. BGS (British Geological Survey) (1992) Impact of Agriculture on Groundwater quality, Kalpitiya Peninsula, Sri Lanka. *British Geological Survey*, Ceylon Institute of Scientific and Industrial Research and Department of Agriculture.

3. CREN (1998) *Proceedings of CREN Symposium on Cyanaobacterial toxins in water*, 24 April, Kandy, Sri Lanka.

4. Department of Census and Statistics (1996) *Demographic Survey 1994 Sri Lanka*, Report on Housing and Basic amenities, Release 2, Department of Census and Statistics.

5. Department of Census and Statistics (1998a) Urban Environment. In: *A Statistical Compendium on Environmental Statistics of Sri Lanka*. Ministry of Finance and Planning.

6. Department of Census and Statistics (1998b) Industrial Pollution. In: *A Statistical compendium on environmental statistics of Sri Lanka*, Ministry of Finance and Planning.

7. Department of Census and Statistics (1998c) Agricultural Sector. In: *A Statistical Compendium on Environmental Statistics of Sri Lanka*, Ministry of Finance and Planning.

8. Department of Census and Statistics (1998d) Aquatic Environment. In: *A statistical compendium on environmental statistics of Sri Lanka*, Ministry of Finance and Planning.

9. Dissanayake L. and Pereira R. (1998) Restoring Beira Lake: An Integrated Urban Environment Planning Experience in Colombo, Sri Lanka.

10. ERM (1994) *MEIP/SMI-IV Strategy, guidelines and institutional strengthening for industrial pollution management*: Final Report, Environmental Resources Management.

11. ERM (1996) *Consulting services for pre-feasibility study on hazardous waste management and disposal in Sri Lanka*, Final Draft Report, Environmental Resources Management.

12. Gazette (1996) *The gazette of the Democratic Socialist Republic of Sri Lanka*, Extraordinary, No. 924/13 of 23/5/96.

13. Illeperuma O.A. and Premakeethi R.M. (1998) *Acid rain monitoring in Sri Lanka*, Proceedings of the CSC/CREN Workshop on Acid Rain Monitoring and Atmospheric Modeling, 20-23 April, Kandy.

14. JICA (1993) *The study on industrial sector development in the Democratic Socialist Republic of Sri Lanka*. Report prepared by Japan International Cooperation Agency and Ministry of Industries, Science and Technology, Sri Lanka.

15. LIFE(1996) *Linkages between Economic Policies and the Environment in Sri Lanka.* (Munasinghe M., Ekanayake A., Fernando S., Gooneratne S., Kurukulasooriya P., Ranaweera S. and Siripala N.) Lanka International Forum on Environment and Sustainable Development, Working Paper Series, Paper No. 1.

16. Ministry of Environment (1998) *National Industrial Pollution Management, Policy Statement*, Ministry of Transport, Environment & Womens Affairs, Ministry of Industrial Development and Ministry of Science & Technology and Human Resources Development.

17. Ministry of Health (1997) *Annual Health Bulletin*, Sri Lanka.

18. Ministry of Industries (1998) *Review of Status*, Ministry of Industrial Development.

19. MPPA (Marine Pollution Prevention Authority)(1998) Personal communication.

20. NARA (National Aquatic Resources Agency) (1993) *Water quality in the irrigational network of the Mahaweli "H" system*,(Azmy S.A.M., De Alwis P. and Dassnayake N.H.) Proceedings of the Annual Scientific Sessions,NARA.

21. NARA (National Aquatic Resources Agency) (1994) *Environment pollution and its impact on fishery management-Lunawa Lagoon*(De Alwis P., Ariyaratne S., Azmy S.A.M. and Dassanayake N.H.) Proceedings of the Sri Lanka/FAO National Workshop on Development of Community based Fishery Management Systems, 3-5 October, Colombo, Sri Lanka.

22. NARA (National Aquatic Resources Agency) (1995 a) *Some observations on eutrophic changes associated with natural phenomena in the Kotmale Reservoir* (De Alwis P. and Azmy S.A.M.) Proceedings of the 6th International Conference on the Conservation and Management of Lakes, October 23-27, Tsukuba, Japan.

23. NARA (National Aquatic Resources Agency) (1995b) *Enrichment of plant nutrients and pollutants in Nuwara Eliya Lake, and upcountry reservoir of Sri Lanka.* (De Alwis P. and Dasanayake N.H.) Proceedings of the 6th International Conference on the Conservation and Management of Lakes, October 23-27, Tsukuba, Japan.

24. NARA (National Aquatic Resources Agency) (1996) *Study of two important River Systems in Sri Lanka with respect to Pollutant Transport into the Coastal Region*. (Azmy S.A.M., Pinnawala P.L.S., and De Alwis P). Proceedings of the Regional Workshop on Research for the Management of Coastal Resources in the Tropics. 1991, Colombo.

25. NARESA (1991) *Natural Resources of Sri Lanka: Condition & Trends.* NARESA (Natural Resources Energy and Science Authority) Colombo.

26. NFS (1994) Annual Report. National Fertilizer Secretariat.

27. NWSDB (National Water Supply & Drainage Board) (1993). Greater Colombo Wastewater & Sanitation Master Plan.

28. Soil and Water Ltd.(1993) *Feasibility study for the establishment of a joint wastewater treatment plant for industrial estate/industries in Ekala and Ja-ela.* Interim Report, November, 1993. Soil and Water Ltd., and Enviroplan Ltd.

29. UDA (Urban Development Authority) (1993) *Beira Lake Restoration Study, Volume* 2, Restoration Strategy and Action Plan.

30. World Bank (1992) *World Development Report.* Development and the Environment, Oxford University Press, New York.

Nymphaea pubescens by Channa Bambaradeniya
Chamaeleo zeylanicus by A.K. Peiries
Talicada nyseus by Vimukthi Weerathunga
Semnopithecus entellus by Chandima Kahandawala
Threskiornis melanocephalus by Chandima Kahandawala

Sri Lanka Biodiversity

BIOLOGICAL DIVERSITY

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Summary

Sri Lanka is an island whose diversity and climate has allowed the development of a wide range of ecosystems containing rich biodiversity. The centres of biodiversity are the rain forests now remaining only as fragmented blocks in the southwest quarter of the country. There is a considerable volume of information available on the composition of the flowering plants among the flora and on the larger vertebrates including fish, amphibians, reptiles, birds and mammals. There is very little information of the species among invertebrates, on lower plants and microorganisms. The level of endemicity among the flora and fauna especially of the wet southwest quarter is high. Cultivated species include a wide range of food and spice crops. Rice stands out in respect of genetic diversity, conserved through thousands of years of selection and cultivation. The reduction of forest cover has been one of the major threats to biodiversity especially in the wet zone. Selective removal of timber species, ornamental fish and plants and medicinal plants also form threats. Recent findings indicate high levels of threat to species of fresh water fish, amphibians, reptiles, land snails, butterflies and angiosperms. Import of genetically modified organisms and the spread of invasive species are also developing threats. The government of Sri Lanka ratified the Convention on Biological Diversity in 1994. This places certain rights and responsibilities upon the government and the people. A Biodiversity Conservation Action Plan for conserving our biological resources has been prepared. Its implementation requires policy, legal and institutional interventions, financial and manpower investment and coordination of activities among many government agencies and Non-Governmental Organizations.

INTRODUCTION

Biological diversity, or biodiversity, encompasses the diversity of all life on earth. It ranges from the tiniest of microorganisms, which most people know very little about, to the largest plants and animals with which people are more familiar. Sri Lanka's biological diversity has sustained human society for countless centuries in myriad ways. Forests, grasslands, wetlands and coastal and marine habitats, and the species they support, have provided materials such as fuelwood, timber, fish, medicinal herbs, food plants and animals for domestication. They have helped regulate the climate, recycle nutrients, protect soil and water, control pests and diseases and have provided habitats and breeding grounds essential for fish and wildlife and provide an environment suitable for human survival on earth.

Biological diversity is usually viewed from three perspectives – the diversity of ecosystems, the diversity of species, and the diversity of genes. **Ecosystem diversity** lies at the broad landscape (or seascape) level – an ecosystem being easily distinguishable either by dominant assemblages of plants (e.g. a forest) or by a specific major part of the non-living environment (e.g. a lake). **Species diversity** is the second level of biodiversity. A generally accepted definition of a species is a group of organisms within which all individuals have the potential to interbreed and produce fertile offspring. The third level of biodiversity is **Genetic diversity**. It lies at the level of genes. The diversity in genetic material is immense, even within a single species. When one considers that there may be over 30 million species of organisms living, it will be realized that the variety of genes in the world is truly astronomical. Genetic diversity provides the raw material for future evolution.

A country's biological wealth is the twin product of millions of years of evolution and thousands of years of cultivation and domestication by man. Biological diversity is, therefore, of great value and it is more important than the material or cultural wealth of a country. Sri Lanka is special in respect of biodiversity. An island lying, as it does, in the tropical belt, it is rich in its heritage of species of fauna and flora, in relation to its size.

Sri Lanka, like most countries around the globe, is depleting much of its biological resources at rates that may place them under threat. We have caused species to become vulnerable to extinction, at accelerating rates. Among the most significant causes of this growing problem are: forest clearing and burning; shifting cultivation; construction of dams and filling of wetlands; timber logging; coral reef destruction; raising monocultures of crops and forest plantations; over harvesting of plants and animals; careless introduction of exotic species; indiscriminate use of pesticides; and pollution of air and water. The primary underlying cause is population growth. These and other activities tend to diminish Sri Lanka's biological resources.

Why should we care? Agriculture, plantation crops, fisheries and other economic activities, the productivity of which relates closely with healthy ecological systems, form major components of Sri Lanka's economy. Natural forests support agriculture by influencing local climate, regulating water supplies and protecting soils. They supply fuelwood and timber and many other products of special importance to rural households. Ecosystems such as wetlands and coral reefs provide habitats for fish, crustaceans and molluscs harvested by the fishery industry. Coral reefs protect coasts from erosion.

At the micro level, genetic material in domesticated crop plants, trees, livestock and aquatic animals contribute to biological diversity which too is used by us. It is the basis of breeding programmes for continued improvement in yields, nutritional quality, flavour, durability, pest and disease resistance and other tangible benefits.

Other plant and animal products gathered from the wild, cultivated or domesticated, or made from wild gathered products, support thousands of small, village-based industries and meet the daily needs of millions of Sri Lankans. These include medicinal plants, fruits and nuts, vegetables, fibre, leather, spices, rattan and bamboo. By maintaining diverse wild varieties of crop plants we ensure protection against disease and disasters and preserve the genetic material for improvement of crops and agricultural productivity.

Yet only a fraction of the country's diverse plants and animals have been utilized up to the present time, in the every day lives of our people. The majority of wild species now unused or barely used are potential sources of food, fibre, medicines and potential sources of genetic material needed in the future to sustain, diversify and improve agriculture, forestry, and fisheries.

Around the world, natural areas and special areas established by man for the preservation of biological diversity, such as zoological gardens and botanic gardens have become increasingly important for recreation and relaxation. The diversity of ecosystems with the variety of species that they include provides rich scenic and recreational experiences to people all over the world.

Table 1 gives examples of the diverse ways in which biological diversity contributes to research and education, cultural heritage, recreation and tourism, the development of new and existing plant and animal domesticates, and the supply of harvested resources to Sri Lanka.

SRI LANKA'S BIODIVERSITY

The diverse terrain and climatic variation within a small land area have resulted in an interesting array of ecosystems. The country has

Table 1 : Contributions of biological diversity

Biological Diversity	Ecological Process	Agriculture	Harvested Products	Cultural Values	Recreation and Tourism
Ecosystem Diversity	Role in watershed, soil and coastal protection, buffering environmental changes, maintenance of productivity etc.	Provides stability to agricultural system. Habitats for wild pollinators and pest enemies.	Habitats for useful species. Coastal & marine ecosystems have supported important fisheries. Forests have produced energy and timber.	Sacred mountains such as Adam's Peak, Sinharaja, Ritigala. Sacred rivers e.g. Menik Ganga.	Visitors to National Parks and Protected areas (100 000 visitors to Yala annually)
Species and Genetic Diversity	Role of individual plants and animals in maintenance of ecological processes such as nutrient recycling, forest regeneration etc. Raw materials for evolution required for survival and adaptation of species.	At species level provides diversity of food types and other useful products to man. Strains and breeds for enhancement of breeding programmes, pest and disease resistance etc.	Provides timber, fuelwood, fibre, fish, medicinal plants & other products such as rattan, weniwel etc.	Plants and animals used for cultural rituals, incense, intoxicants etc. Breeds of rice used for ceremonies. Others of cultural value are elephant (perahera), lotus etc.	Visitors to National Zoological Gardens, Museum and Plant Genetic Resource Centre

Source : Natural Resources of Sri Lanka, Conditions and Trends, NARESA.

two basic ecozones separated by a southcentral mountain massif which intercepts the monsoonal winds, thereby creating an ever wet southwestern quarter and a rain shadow in the remaining area. The far northwest and far southeast, which are not affected by monsoon rainfall, have a climate bordering on semi-arid conditions. Within this broad differentiation is a multitude of ecosystem varieties. Forests are the predominant vegetation, varying from ever wet rainforest – both lowland and montane – to dry mixed evergreen and thorn forest. Grasslands and a complex network of wetlands and freshwater ecosystems are interspersed with the forests. Added to these are the coastal and marine ecosystems. Fifteen floristic regions have been described for the island (Ashton & Gunatilleke, 1987). Within the wet lowland and the montane region at high elevation there are several local areas of high diversity and endemicity.

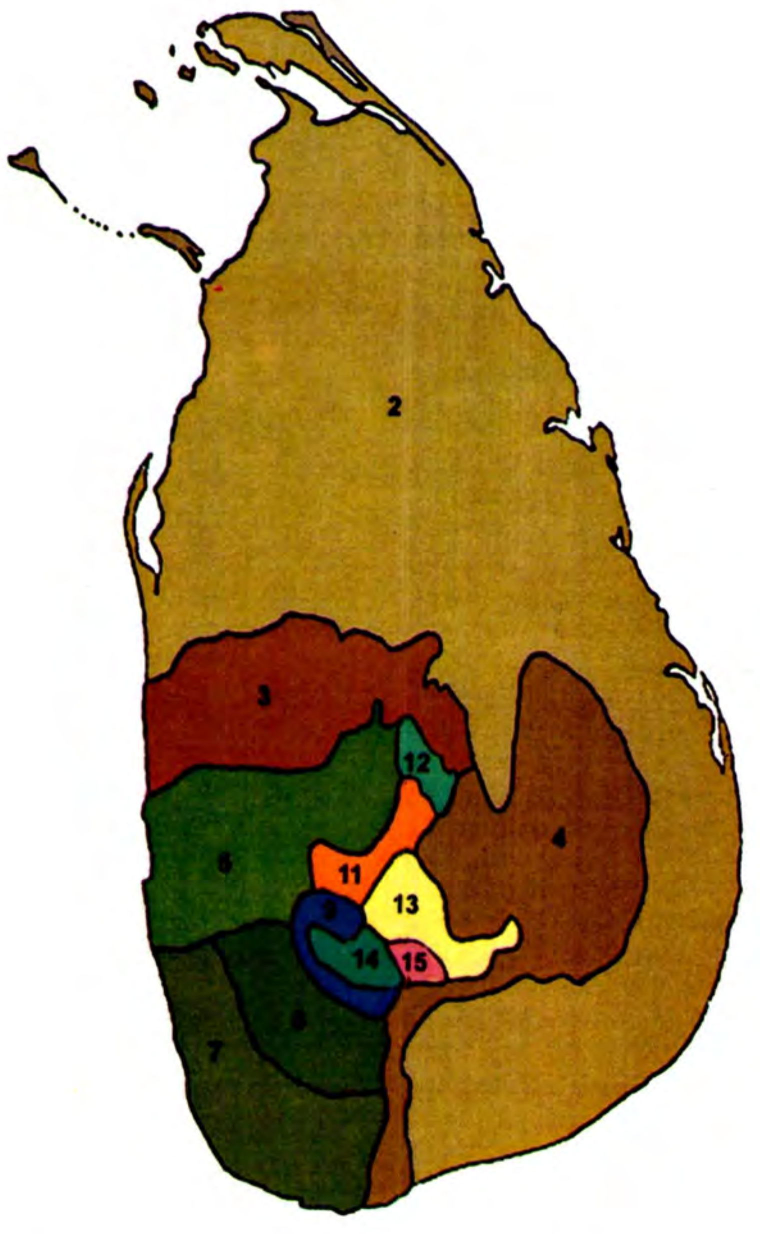
Figure 1 gives the floristic regions and Table 2 major vegetation types and dominant plant communities in each floristic region.

With regard to species diversity, the more conspicuous groups of plants as flowering plants, ferns and fungi, and animals such as vertebrate fauna are the only groups that have been relatively well studied. Collectively these account for only a very small percentage of the island's total species. The lower taxa of flora such as the algae, mosses, liverworts and lichens, and the lower taxa of fauna including the vast majority of the invertebrates are very little known. Some information is available on insect species especially those that are pests. Even less known are the microorganisms such as bacteria, and the viruses.

Table 2 : Major vegetation types and dominant plant communities in each Floristic Region

Floristic region	Characteristic natural vegetation types in each region
Coastal and marine belt	Marine, mangroves, salt marsh, sand dunes, and strand vegetation
Dry and arid lowlands	Tropical dry mixed evergreen forests *Manilkara* community Mixed community (*Chloroxylon-Vitex-Berrya-Schleichera* series) Tropical thorn forests (*Manilkara-Chloroxylon-Salvadora-Randia* series) *Damana* and *Villu* grasslands Flood-plain wetlands Riverine and gallery forests
Northern intermediate Lowlands	Tropical moist semi-evergreen forests (*Filicium-Euphoria-Artocarpus-Myristica* series)
Eastern intermediate Lowlands	Tropical moist semi-evergreen forests Savannah forests
Northern wet lowlands	Tropical wet evergreen forests
Sinharaja and Ratnapura	Tropical wet evergreen forests (lowland hill Dipterocarp forests – *Mesua-Doona* community, *Talawa* – grasslands, fernlands)
Southern lowland hills	Tropical wet evergreen forests (*Dipterocarpus* community, *Mesua-Doona* community)
Wet zone fresh water bodies	Streams, rivers and other freshwater bodies
Foothills of Adam's Peak and Ambagamuwa	Tropical wet evergreen forests
Midmountains	Submontane forests (*Shorea-Calophyllum-Syzygium* series)
Kandy and upper Mahaweli	Tropical wet evergreen forests Humid zone dry patana grasslands
Knuckles	Tropical submontane forests (*Myristica-Cullenia-Aglaia-Litsea* community) Tropical montane forests (*Calophyllum* zone)
Central mountains, Ramboda-Nuwara Eliya	Tropical montane forests (*Calophyllum- Syzygium* community, wet patana grasslands)
Adam's Peak	Tropical montane forests Tropical submontane evergreen forests
Horton Plains	Tropical montane forests Upper wet patana grasslands

Source: Gunatilleke & Gunatilleke, 1990.



Source: Ashton and Gunatilleke, 1987.

Figure 1: Floristic regions of Sri Lanka

Yet, even among the flowering plants and vertebrate fauna it appears likely that many species remain undiscovered. In the National Conservation Review (NCR) of the forests that was concluded in 1996, despite the limited scope of the biodiversity assessment that was carried out, two species of reptiles of the genus *Ceratophora*, one amphibian of the genus *Bufo* and a species of ebony, all likely to be species new to science were discovered (IUCN, 1997; Green & Jayasuriya, 1996). Biologically rich places such as the Knuckles, Peak Wilderness and Horton Plains have not been intensively studied. This deficiency will be remedied to some extent through the National Zoological Survey of Sri Lanka that has started work recently under the auspices of the National Science Foundation.

The Sri Lankan biota are an interesting mix of many different elements. Its flora represents the following floristic elements: Sri Lankan, Indo-Sri Lankan, Himalayan, Malayan, African, pantropic and cosmopoliton (Abeywickrama, 1956). The fauna has affinities with those of India, Malaysia, Indonesia, Africa and Madagascar (Crusz, 1984).

This high level of biodiversity comes primarily through the rich rain forests that now remain only as fragmented blocks in the south-west of the country. These forests are also noteworthy because of the high levels of endemism among the species. Southwest Sri Lanka has been identified as one of the World's 18 hotspots. A hotspot is an area which features 'exceptional concentrations of species with exceptional levels of endemism, and that face exceptional levels of threat' (Myers, 1988, 1990). Of the 3368 angiosperm species, 879 are endemic (Bandaranaike & Sultanbawa 1991). What is more, many of these endemics are extremely rare and highly localized. *Stemonoporus moonii*, a member of an endemic genus of Dipterocarps, and *Mesua stylosa* are restricted to the Waturana forest, a swamp forest, only a few hectares in extent (CEA, 1994). Another species of the same genus, *S. affinis*, is confined to a small area within the Knuckles forest (Green & Jayasuriya, 1996). In the NCR carried out recently as many as 119 woody species were recorded only in single forests (MALF, 1995).

The faunal distribution shows a similar pattern, particularly the vertebrates. Among the inland vertebrates, the percentages of endemic species in the different vegetation zones show a clear trend – most of the endemics being confined to the wet zone. Many species show restricted distribution even within a zone. A good example is the endemic genus of lizard *Ceratophora*. *C. aspera* is restricted to the forests of the wet zone lowlands up to about 900 m, *C. stoddarti* occurs only in the central hills above about 1200 m, and *C. tennenti* is only found in the Knuckles range (Erdelen, 1989). The Knuckles is also the habitat of some rare amphibians: *Nannophrys guentheri*, *Ramanella palmata* and *Ichthyophis glutinosus* (MFE, 1999). The Kalu Ganga and the Gin Ganga basins located in the lowland wet zone are particularly important habitats for endemic fish species (Senanayake & Moyle, 1982). Thirteen of the 17 endemic fish species are found in these river basins. Table 3 gives the numbers of known species in some taxonomic groups based on available data, and the percentage of endemic species in each group.

Southwest Sri Lanka has evolved its unique biota because of its geological history. The rainforests of southwest Sri Lanka are truly primeval and are of considerable evolutionary significance. Their ancestry dates back to the Deccan Flora of a hundred million years ago when an unbroken stretch of forest covered both peninsular India and Sri Lanka. Since then the climate underwent sweeping changes elsewhere but remained relatively stable in southwest Sri Lanka, and being climatically isolated, this area developed its own distinct biota. Some of the species of these forests are considered as relicts of the ancient continent of Gondwanaland.

Sri Lanka, being an island and relatively small in size, has an extensive coastline (1 760 km) in relation to its land area. Estuaries and lagoons, mangrove vegetation, salt marshes, sand dunes and sandy beaches dot the coast. The estuaries and lagoons covering a total area of around 160 000 ha form an extensive group of coastal ecosystems which are rich in animal and plant diversity. The plant life in the relatively calm waters of the lagoons is dominated by prolific growths of sea grasses of species of *Cymadocea*, *Enhalus*, *Thalassia*, *Halodule*, *Syringodium* and *Halophila*.

among others (Johnson & Johnstone, 1995). A study of the Moratuwa-Panadura-Bolgoda system showed the benthic fauna to include species of molluscs, crustaceans and polychaetes. Ninety species of fish were also recorded during this study (Arulpragasam, 1984).

Table 3 : Known species composition of some taxa of flora and fauna

Taxon	Described Species	% Endemism	Taxon	Described Species	% Endemism
Flora			**Fauna**		
Algae	896*	NA	Land molluscs	266	76
Fungi	1920*	NA	Spiders	400	NA
Lichens	Over 200	NA	Mosquitoes	131	13
Mosses	575	NA	Ostracods	31	36
Liverworts	190	NA	Fresh water shrimps, prawns, crabs	28	36
Ferns & Fern allies	314	18	Ground beetles	368	34
Gymnosperms	1	0	Freshwater fishes	65	45
Angiosperms	3368	26	Amphibians	48	60
			Reptiles	162	49
			Birds (residents)	237	8
			Mammals	89	13

NA= not available. *inadequate studies.

Sources: Abeywickrama & Jansen (1978 a & b); Gunatilleke & Gunatilleke (1990); Bandaranaike & Sultanbawa (1991); Ratnapala & Arudpragasam (n.d.); Costa (1984) ; Neale (1984); Erwin (1984), WCMC (1994); Baldwin (1991).

The reefs of Sri Lanka can be divided into three types: coral reefs, sandstone reefs, and boulder reefs of crystalline rock. Fringing reefs are confined to about two per cent of the coastline. They are found along the northern coastline from Kankasanturai to Point Pedro and along the western, southern and eastern coasts. Well developed offshore coral reefs occur in the Gulf of Mannar and west of the Kalpitiya Peninsula. The coral reefs are hot spots of biodiversity. They show some of the highest levels of productivity and abound in rich biodiversity. One hundred and eighty three species of stony corals belonging to 68 genera have been recorded in Sri Lanka (Rajasuriya, 1995). More than 300 species of reef and reef-associated fish species belonging to 95 genera have been recorded (Dayaratne, 1995). Many of the reef fishes are popular as aquarium fish in international markets. Sandstone reefs, dead coral and dead coral debris provide habitats for a variety of marine algae and many invertebrate species.

Thousands of years of settled agriculture have produced a storehouse of cultivated biological resources of crop plants, fruit trees, spices and livestock, and a century ago, in the plantation sector, numerous local new cultivars were developed.

Sri Lanka has a rich treasure of rice genes. Several thousand years of selection and cultivation, augmented by traditional farming practices and the country's ecoedaphic variability, have produced a wide variety of crop cultivars. These rice varieties show great adaptability to a wide range of soil conditions. Upland varieties show drought tolerance, and those grown in coastal and river floodplain areas can tolerate submergence to flash floods. Some can tolerate the low temperatures of the highlands, while others have broad-based resistance to serious pests and tolerance to iron toxicity. There are several grain types, some with medicinal properties and fragrance and others that are used for cultural rituals.

Besides rice, Sri Lankan cereals include millets, sorghum and maize. The type of millets grown from ancient times are finger millet *Eleusine coracana*, foxtail millet *Setaria italica*, common millet *Paspalum miliaceum* and koda millet *Paspalum scrobiculatum*. Unlike rice, these cereals have undergone little selection by the farmers.

Legumes constitute an important source of protein for most Sri Lankans. Some variability exists among pigeon pea *Cajanus cajan*. Wild relatives of pigeon pea such as *Atylosia*, *Rhynchosia*, *Viscosa* and *Dunbaria* have been recorded in the country. Winged bean *Psophocarpus tetragonolobus* shows much variability in seed colour, pod size, and flower colour.

Among the horticultural crops, several varieties of banana *Musa* sp. are under cultivation in the different agroecological regions of the country. *M. acuminata* and *M. balbisiana*, the wild progenies of cultivated bananas, are both present in Sri Lanka. Other fruit crops such as citrus, mango, avocado and jak exhibit much variability. Numerous types of vegetables, both temperate and tropical species, are also cultivated throughout the country, and cucurbits, tomatoes and eggplants exhibit much genetic diversity. Among the root and tuber crops, much variability exists among cassava, *Dioscorea*, aroids and innala *Solenostemon rotundifolius*.

Spices have made Sri Lanka famous. Considerable genetic diversity occurs among pepper, cardamom, betel and chilli. About 500 known selections of pepper *Piper* and about 10 wild species have been identified. Ten wild races of cardamom have been collected from the Sinharaja and adjoining forests. Sri Lanka has an estimated 170 species of plants of ornamental value, of which 74 are endemic. *Dendrobium* and *Vanda* species and foliage plants thrive in natural forest habitats.

Plantation crops have been the mainstay of the economy, particularly coconut, tea and rubber – the latter two having been introduced within the past two centuries. Tea is now grown on over 200 000 ha.

The germplasm originally introduced from Assam has undergone selection through breeding programmes and the selected genotypes are being clonally conserved in various breeding stations and tea estates in the country. Selection procedures and vegetative propagation have together produced a series of clones of high yield, with resistance to pests, disease and drought and with high rates of fermentation. The total number of clones in rubber is 132. A variety of hybrids of coconut has also been developed.

There are wild species of buffalo, livestock, fish and fowl, but with the notable exception of marine fisheries, the country relies heavily on imported strains to meet domestic demands. Apart from the Sinhala cattle that are endemic to the country, foreign breeds (Ayrshire, Herefords, Sindhi etc.) have been introduced over the last five decades. Although little hybridization has been carried out on goats and pigs, some improvement has been made with the cattle. Among poultry, some importation of selected breeds and hybridization has been accomplished. The local poultry breeds are fast disappearing due to preference for imported germplasm, despite the fact that the genes of local varieties have resistance to tropical diseases.

STATUS AND TRENDS

Loss of Ecosystem Diversity

No discussion of Sri Lanka's biological diversity can ignore the steady diminution of the country's natural forests and other ecosystems. Natural ecosystem diversity has declined and we have no evidence to suggest a change or deceleration of this trend. The dry zone floodplains are irrigated lands of the lowlands which have been subjected to extensive deforestation and settled agriculture since the third century BC. They have been modified with the construction of thousands of irrigation tanks and canals. Deforestation in the wet zone began in the thirteenth and fourteenth centuries with the establishment of the kingdoms of Gampola and Dambadeniya. Subsequently, in the colonial era, plantation crops such as coffee, then tea and rubber replaced natural forests in the wet lowlands and montane areas, while coconut expanded into the wet coastal lowlands. However, the dry lowlands – the cradle of Sri Lanka's ancient civilization – reverted to forest when the irrigation systems were gradually abandoned from about 800 years ago. In the last 50 years major new irrigation projects have been created in the dry lowlands once again.

As described in the chapter on Forestry Resources, the natural forest cover of the island is down from 70 per cent of the land area 100 years ago to less than 25 per cent today. With the exception of the dry lowlands, the forest cover in the other climatic zones is critically low. A key factor in maintaining biological diversity, and a way to measure its vulnerability is the size of the conservation area. Most forests in the high diversity zones of the wet lowlands and montane highlands are fragmented and over exploited; many of the forests are only a few hundred hectares in extent and they are surrounded by villages which continue to expand insidiously, encroaching on the forest. It must be noted that the wet zone is the most heavily populated part of the country, where over half the population lives in less than a quarter of the land area. Encroachment is primarily for the purpose of expanding agricultural holdings of the villagers as the population continues to grow. The high market price fetched by tea has tended to aggravate this trend, villagers opting to grow tea on their land holdings, to obtain income.

During the last decade serious attempts had been made to address the problem of forest encroachments in the wet zone. As a first step, the forest boundaries are being resurveyed and land-marked on the basis of the *de facto* outer limits of the forests. Management plans are then prepared with the cooperation of the people in the boundary villages. The approach now is not to adopt the 'command and control' style of management. Management plans seek to provide some benefits to the villagers while conserving biodiversity. The villagers are also encouraged to form forest conservation societies and help in protecting the forest.

Other critical habitats such as coral reefs and wetlands are also severely threatened (see respective chapters). Along with adverse effects on fisheries and coastal erosion protection, removal of coral for production of lime, which is still continuing, has diminished biological diversity. Much of the inland marsh forests has disappeared.

Loss of Species and Genetic Diversity

Biological diversity suffers from selective exploitation of species, particularly ornamental plant and fish species. Selective removal of desirable species has resulted in changes in floristic and faunistic composition of forests and other natural ecosystems and a steady depletion of populations of the exploited species.

Many species, once plentiful, are now found in small numbers, and some are considered to be threatened. Without prompt action to conserve their habitats they will become seriously endangered, their genetic variety reduced, and their long term survival will be in doubt. Others have been exploited to such an extent that they clearly verge on extinction. The comb duck, *Sarkiodiornis melanotus*, which used to breed in Giant's Tank and Senanayake Samudra has completely disappeared from Sri Lanka. Concern about elephants continues to grow. At the beginning of the nineteenth century, Sri Lanka had an estimated 12 000 elephants (McKay, 1973). They roamed the dry and wet zones and at the high elevations. Elephant killing for sport in the past and the more recent habitat destruction and killing to defend crops, have greatly reduced the population to around 3 000 animals. Selective poaching of elephants for trophies and ivory has almost eliminated the genetic trait for tusk formation in the Sri Lankan wild elephant population. Today only five per cent of the wild elephants in the country possess tusks – a substantially lower percentage than in the average Asiatic elephant population.

Selective removal has endangered some of the island's valuable timber trees. Calamander, *Diospyros quaesita*, a fine variegated timber tree, is rare today and is only present in a few restricted locations. Satinwood (*Chloroxylon swietenia*), ebony (*Diospyros ebenum*) and other valuable timber species like halmilla (*Berrya cordifolia*) and nedun (*Pericopsis mooniana*), once abundant, are now rare. *Diospyros oppositifolia* is now confined to small stands at Hinidum Kanda and Sinharaja while the madara tree, *Cleistanthus collinus*, seems to have been exploited to extinction.

Many species of medicinal and ornamental plants have also been over exploited. Some of the species endangered as a result are the orchids *Dendrobium maccarthiae*, *D. heterocarpum*, *Ipsea speciosa* and *Rhynchostylis retusa*. Sumithraarachchi (1986) has reckoned that, of the 170 species of orchids found in the island, 99 can be considered as rare, seven vulnerable, and 13 likely to become extinct. Medicinal plants such as ekaweriya (*Rauvolfia serpentina*), goda kaduru (*Strychnos nux-vomica*), rodanti (*Capparis moonii*), malitha (*Woodfordia fruticosa*), *Saraca asoca* and a host of others have become rare in the wild. Numerous plant species recorded in the island by earlier botanists have not been collected or observed subsequently, some for more than a hundred years, because of selective removal or the destruction or disturbance of their habitats.

Over the past ten years, there has been a growing demand for certain species for overseas markets. These include many plant species for use as ornamentals (including aquarium plants like *Cryptocoryne thwaitesii*, an endemic aroid) and others for use as medicine. Very recently there has been an attempt to export large quantities of the medicinal plant kotala himbutu (*Salacia reticulata*) collected from the wild. Among the fauna a growing trend is the demand for aquarium fish, and large scale collections are made both of fresh water species and coral reef species for the aquarium export trade. Collections from the wild on the scale needed for export will no doubt cause serious depletion of populations. Exploitation needs to be maintained at sustainable levels and in the case of fresh water species can be supported by culture-breeding.

Among the cultivated plants, particularly in the case of rice, the widespread use of high yielding varieties in preference to indigenous varieties continues to pose a threat to the survival of the wide spectrum of rice genes carried by the indigenous varieties. Similarly with animals, particularly cattle and poultry, the genes carrying useful traits such as resistance to diseases, may eventually disappear due to the strong preference for imported germplasm.

Lists of threatened species in Sri Lanka were compiled, commencing with the list of threatened plants of Sri Lanka (Abeywickrama, 1987). This was followed by lists of threatened fauna and flora published in Wijesinghe (1993). IUCN prepared a global list of threatened animals, replacing the earlier Red Data Book (IUCN, 1998). In the new listing the degree of threat was based on quantitative data. This list contains 43 entries for Sri Lanka, only two of which are invertebrates. Had quantitative data been available, many more species would have qualified for inclusion in the global list of threatened species.

Other than the species considered to be globally threatened, it is necessary to have a scientifically compiled list of species that are under threat in the country. The lists of nationally threatened species referred to above are largely based on the observations of scientists who have done field studies and not on defined criteria. Teams of scientists commissioned by IUCN Sri Lanka, using quantitative data wherever available and adopting defined criteria, have recently drawn up fresh lists of threatened animals and plants. The lists have now been published (IUCN Sri Lanka, 2000). Of the indigenous fauna, 1 243 species in selected taxonomic groups were evaluated and 560 fell into the Highly Threatened or Threatened category. These were 117 species of land snails (52 per cent endemic), 43 species of crustaceans, 70 species of dragon-flies, 76 species of butterflies, 39 species of fishes, 33 species of amphibians, 87 species of reptiles, 61 species of birds and 34 species of mammals. Among the plants, 807 indigenous species of flowering plants were evaluated and 690 of them fell into the Highly Threatened or Threatened category.

As an island Sri Lanka has a high percentage of endemic species that have evolved because of its isolation and in the southwest quarter of Sri Lanka they are particularly vulnerable. When their natural habitats are destroyed they are unable to recolonize the degraded soils. Over 200 naturalized aliens (Abeywickrama, 1956) include some of the most invasive plants. They have successively established themselves, most often at the expense of natural flora. Among the fauna too, the endemics represent a highly vulnerable group. At present the lists of invasive species of plants and animals are being compiled under the direction of the Ministry of Forestry and Environment.

Even in the case of indigenous biota that are not endemic to Sri Lanka, the genetic stock of the populations would no doubt have evolved many unique features during the long period of isolation from the populations elsewhere. The disappearance of any such species in Sri Lanka would represent a significant degree of genetic erosion of the species concerned.

CONSERVATION OF BIOLOGICAL DIVERSITY

One of the world's first wildlife sanctuaries dates back to the reign of King Devanampiyatissa, after Buddhism was introduced in the third century BC. Later, in the twelfth century AD King Kirthi Nissanka Malla prohibited the killing of animals within a radius of what would have been 35 km of his kingdom of Anuradhapura. Sri Lankan Kings who followed protected large tracks of forests as reserves, for example the Uduwattekele Reserve and the Sinharaja Forest.

In modern times, the enactment of the Forest Ordinance in 1907 marked the beginning of legal provision being made for the protection of forests. In 1938 Sri Lanka established six categories of protected areas, under the Fauna and Flora Protection Ordinance: -

> Strict Natural Reserves, National Parks, Nature Reserves, Jungle Corridors, Intermediate Zones and Sanctuaries.

All these were administered by the Department of Wildlife Conservation. The forests under the jurisdiction of the Forest Department were the Reserves, Proposed Reserves and 'Other Crown Forests'. The Forest Department's function was to ensure that there would be a steady supply of timber and other forest products to serve the needs of the country.

In the late 1980s world wide attention began to be directed to the problem of rapid loss of biological diversity. In Sri Lanka, the fragmented rain forests of the southwest were recognized as requiring special protection because of their high levels of biodiversity and endemism and the high level of threat to the species. Biodiversity assessments were carried out in these forests which were reserves and proposed reserves under the Forest Department, and these assessments confirmed the high conservation value of these forests. Simultaneously, the Forest Department imposed a moratorium on logging in the natural forests. This was followed by the introduction of a new category of forests – Conservation Forests – through an amendment to the Forest Ordinance. Up to now it has been decided to declare 30 forests in the wet zone as conservation forests, in view of their critical importance for biodiversity conservation. These forests, together with the Sinharaja forest which had earlier been declared a National Wilderness Area under a legislative enactment, the National Wilderness Areas Act, are 'protected areas' under the jurisdiction of the Forest Department. With the inclusion of these forests, the total extent of protected areas legally recognized as such under both the Department of Wildlife Conservation and Forest Department is nearly 14 per cent of the land area. What is important then is to ensure that these areas are adequately protected from encroachers, poachers and illegal loggers.

In addition to the *in situ* programmes that have played a major role in the conservation of Sri Lanka's biological diversity, *ex situ* genetic conservation efforts have been carried out in botanic, zoological and medicinal plant gardens. Sri Lanka has three botanic gardens, a single zoological garden and a number of medicinal plant gardens. The Botanic Gardens at Peradeniya, established in 1822, contain 10 000 flowering plants belonging to 1179 different species (Gunatilleke and Wijesundera, 1982), including about 14 per cent of the endemic species.

An important development in *ex situ* conservation in the last decade was the setting up of the Plant Genetic Resources Centre (PGRC)in Gannoruwa, Peradeniya. This institution has facilities for the cryo-preservation of plant germplasm. Germplasm of many species of plants, mainly crop plants, have been included in its collection already.

Policy, Legal and Institutional Aspects

The conservation of biological diversity is essentially a multi-sectoral activity. It is important, therefore, that clear policies are defined so that all institutions whose actions have an impact on biodiversity may identify their role in conserving this resource and take appropriate action.

In March 1994 the government of Sri Lanka ratified the Convention on Biological Diversity and shortly thereafter appointed a National Experts' Committee on Biological Diversity to advise the ministry in charge of the environment on matters relating to the conservation of biological diversity. The ministry spearheaded the action that led to the ratification by Sri Lanka of the Convention, and it therefore, took on the mantle of the national focal point for the Convention.

As an initial step towards taking action to implement the Convention, the Ministry set up a network of institutions:-

(a) which are responsible for the conservation and use of biodiversity and
(b) whose activities have an impact on biodiversity.

Countries that have ratified the Convention are expected, in terms of Article 6, to prepare national strategies, plans or programmes for the conservation of biological diversity. Accordingly the ministry, obtaining technical support from IUCN Sri Lanka, prepared a Biodiversity Conservation Action Plan (BCAP) entitled, 'Biodiversity Conservation in Sri Lanka – A Framework for Action' (MFE, 1999).

The duty of coordinating and promoting the implementation of the BCAP rests with the Ministry of Forestry and Environment. Although it has taken some initiatives so far, the Ministry is as of now, inadequately equipped to play the dynamic role expected of the national focal point for moving ahead in implementing the BCAP. While many actions for the conservation of biological diversity fall within the functions of one institution or another, there are many others that require coordinated action by several institutions. The Ministry of Forestry and Environment must play a lead coordinating role in this context.

There are many gaps in the data on biological diversity in Sri Lanka, particularly in respect of the fauna. The National Science Foundation has commenced work on a Zoological Survey of Sri Lanka, and this effort needs to be supported, on a sustained basis, through the provision of financial, human and institutional resources.

The import of microorganisms and of genetically modified organisms is a matter for the highest concern. Movement of these organisms across national barriers is rising sharply, and though they are imported on the basis of the benefits that could be derived, they could be potentially a grave danger to the biodiversity of the country and even to the health of the people. It is also possible that multinationals use developing countries where import regulations are lax to test newly developed genetically modified organisms. Current legislation – the Plant Protection Ordinance and the Animal Diseases Act do not make provision for controlling the import of these organisms. Further, it is doubtful whether the proposed amendments to the Plant Protection Ordinance will serve the purpose, adequately. While new legislation is urgently needed it is also necessary to develop regulatory guidelines which, as an immediate measure, could be used with the existing legislation relating to imports and subsequently, with the new legislation that would be enacted.

Another problem that is rearing its head and threatening to reach crisis proportions is the export of genetic material – plants and animals. Recently there was a reported attempt to export a consignment of the medicinal plant *Salacia reticulata* and another attempt to send out a consignment of plant extracts. These are but two examples of a practice that is quite common. Bioprospecting for pharmaceuticals, cosmetics, etc. is taking place on a large scale in the developed countries. A tropical country without adequate laws to control access to its genetic resources faces, under these circumstances, threats to its biodiversity. Moreover, the country faces the distinct possibility of deriving no benefits from products that may be developed using indigenous genetic resources. The Convention on Biological Diversity states that countries should "endeavour to create conditions to facilitate access to genetic resources for environmentally sound uses by other Contracting Parties". But it also specifies that:-

(a) a state has sovereign rights over its natural resources and
(b) access shall only be on mutually agreed terms and with prior informed consent.

There is, therefore, an urgent need to draft legislation and supporting regulations for controlling access to Sri Lanka's genetic resources.

Another matter that requires attention by more than one institution is the danger of spread of invasive species. In the dry southeast of the country there is the prolific growth of *Opuntia* and *Prosopis juliflora*. In the upcountry there is the prolific growth of *Ulex*. There are signs of an invasive spread of *Mimosa pigra*. It is important for institutions that import plants and animals to obtain full information on the species concerned and to screen them before release in order to ensure that there will be no danger of their reproducing aggressively and displacing indigenous biota.

The Forestry Master Plan of 1995, in sharp contrast to its predecessor of 1986, attaches a great deal of importance to aspects of conservation. The first of the revised national forestry policy objectives reads:-

"To conserve forests for posterity, with particular regard to biodiversity, soils, water, and historical, religious, cultural and aesthetic values".

In other words conservation takes precedence over supplying timber, which is just as well for a forest estate that has for far too long been intensively exploited for timber. A good part of the plan is devoted to action to be taken for the conservation of biological diversity. What is needed is to move from planning to action.

The Forest Department is responsible for the protection of biodiversity in the forests under its charge. It is adequately supported by technical staff, but it has to depend on donor financing for the implementation of its biodiversity conservation programme which includes the management (with community participation) of its newly declared protected areas, the conservation forests.

The major part of the protected area network is within the jurisdiction of the Department of Wildlife Conservation. A project was launched in 1991 with financial support from the Global Environmental Facility for strengthening the technical capacity of the Department and placing the wildlife reserves under sound management. Seven years on, the gains fall well short of expectations, particularly as regards the management of the reserves. One of the biggest pitfalls in the Department's administration is the rapid turnover of departmental heads many of whom are not wildlife professionals but transferable officers of the administrative service. The Department is embarking on another project with support from the Asian Development Bank, and the success of this project will depend in large measure on the establishment of a stable institutional structure within the Department.

With regard to the export of live fish and other aquatic life, there was some inconsistency between the Fauna and Flora Ordinance and the Fisheries Ordinance. The Fisheries and Aquatic Resources Act of 1996 has replaced the old ordinance, and one of the objectives of the new legislation is to give greater protection to selected species of fish. The Fauna and Flora Ordinance is also to be revised, and it is important to ensure that any inconsistencies with the Fisheries and Aquatic Resources Act are avoided and that maximum protection is given to the threatened species of fauna.

In the agricultural sector, attention being focused on increased production, aspects of conservation of biodiversity of both flora and fauna tend to get neglected. It would be shortsighted to give step-motherly treatment to conservation, as sustainable agriculture will only be possible if a broad spectrum of genetic resources is conserved. The best possible use must be made of the PGRC, and field gene banks should be expanded. Captive breeding and tissue culture should be more widely practised so as to reduce the pressure on wild stocks.

The Biodiversity Conservation Action Plan that has now received government approval provides the blueprint for the wide-ranging action needed to be taken to conserve the nation's biological diversity, to ensure that it is used sustainably for the benefit of the people, and to avoid causing irrevocable damage to our rich biological heritage. Its implementation should receive the highest priority by the government and the people.

REFERENCES

1. Abeywickrama B.A. (1956) The Origin and Affinities of the Flora of Ceylon. *Proc. 11th Annual Session, Ceylon Ass. Adv. of Sci.* **2** : 99-121.

2. Abeywickrama B.A. (1987) *The Threatened Plants of Sri Lanka.* Natural Resources, Energy and Science Authority of Sri Lanka (now the National Science Foundation), Colombo.

3. Abeywickrama B.A. and Jansen M.A.B. (1978 a) *A Checklist of the Liverworts of Sri Lanka.* UNESCO Man & Biosphere National Committee for Sri Lanka No 1. National Science Council of Sri Lanka, Colombo.

4. Abeywickrama B.A. and Jansen M.A.B. (1978 b) *A Checklist of the Mosses of Sri Lanka.* UNESCO Man and Biosphere National Committee for Sri Lanka No 2, National Science Council of Sri Lanka, Colombo.

5. Arulpragasam K.D. (1984) Ecology of Rocky Shores and Estuaries of Sri Lanka. In: *Ecology and Biogeography in Sri Lanka.* (Ed. C.H. Fernando) Dr W. Junk Publishers, The Hague.

6. Ashton P.S. and Gunatilleke C.V.S. (1987) New Light on the Plant Geography of Ceylon I – Historical Plant Geography. *Journal of Biogeography,* **14:** 249 – 285.

7. Baldwin M.F. (Ed.) (1991) *Natural Resources of Sri Lanka – conditions and trends.* Natural Resources, Energy and Science Authority of Sri Lanka, Colombo.

8. Bandaranaike W.M. and Sultanbawa M.U.S. (1991) *A List of the Endemic Plants of Sri Lanka.* Forest Department, Battaramulla, Sri Lanka. As cited in IUCN (1997).

9. Central Environmental Authority - CEA (1994) *Wetland Site Report: Walauwatta Waturana Swamp Forest.* Central Environmental Authority, Colombo.

10. Costa H.H. (1984) The Ecology and Distribution of Free-living Meso- and Macro-Crustacea of Inland Waters. In: *Ecology and Biogeography in Sri Lanka.* (Ed. C.H. Fernando) Dr W. Junk Publishers, The Hague.

11. Crusz H. (1984) Parasites of Endemic and Relict Vertebrates; a biogeographical review. In: *Ecology and biogeography in Sri Lanka.* (Ed. C.H.Fernando) Dr W. Junk Publishers, The Hague.

12. Dayaratne P. L. O. and De Silva R. N. (1995) *Ambio,* **24**: 391-401.

13. Erdelen W. (1989) Aspects of the Biogeography of Sri Lanka. In: *Forschungen Auf Ceylon III,* (Ed. Herausgegeben von) Ulrich Schweinfurth Franz Steiner Verlag, Stuttgart.

14. Erwin T.L. (1984) Composition and Origin of the Ground Beetles. In: *Ecology and Biogeography in Sri Lanka.* (Ed. C.H. Fernando) Dr W. Junk Publishers, The Hague.

15. Green M. and Jayasuriya M. (1996) Lost and Found – Sri Lanka's Rare and Endemic Plants Revealed. *Plant Talk,* January, pp 18-21.

16. Gunatilleke I.U.A.N. and Gunatilleke C.V.S. (1990) Distribution of Floristic Richness and Its Conservation in Sri Lanka. *Conservation Biology,* **4** (1): 21-31.

17. Gunatilleke C.V.S. and Wijesundera D.S.A. (1982) *Ex situ* Conservation of Woody Plant Species in Sri Lanka. *Phyta, Journal of the Botanical Society of the University of Peradeniya,* **2.** As cited in Baldwin, 1991.

18. IUCN (1996) *IUCN Red List of Threatened Animals.* IUCN, Gland, Switzerland.

19. IUCN Sri Lanka (1997) *Designing an Optimum Protected Areas System for Sri Lanka's Natural Forests, volume 1* (mimeo). IUCN Sri Lanka, Colombo.

20. IUCN Sri Lanka (2000) The 1999 List of Threatened Fauna and Flora of Sri Lanka IUCN Sri Lanka, Colombo.

21. Johnson P. and Johnstone R. (1995) Productivity and Nutrient Dynamics of Tropical Sea Grass Communities in Puttalam Lagoon, Sri Lanka. *Ambio*, **24**, 411-417.

22. McKay G.M. (1973) *Behaviour and Ecology of the Asiatic Elephant in South-eastern Ceylon.* Smithsonian Contribution to Zoology No. 125

23. Ministry of Forestry and Environment – MFE (1999) *Biodiversity Conservation in Sri Lanka- A Framework for Action.* Ministry of Forestry and Environment, Battaramulla, Sri Lanka. In Print.

24. Ministry of Agriculture, Lands and Forestry – MALF (1995) *Sri Lanka Forestry Sector Master Plan.* Ministry of Agriculture, Lands and Forestry (now Ministry of Forestry and Environment), Battaramulla, Sri Lanka.

25. Myers N. (1988) Threatened Biotas – "Hotspots" in Tropical Forests. *The Environmentalist*, **8:** 187-208.

26. Myers Norman (1990) The Biodiversity Challenge: Expanded Hotspots Analysis. *The Environmentalist*, **10:** 243-256.

27. Neale J.W. (1984) The Freshwater Ostracoda. Green, Michael (1996). In: *Ecology and Biogeography in Sri Lanka.* (Ed. C.H. Fernando) Dr W. Junk Publishers, The Hague.

28. Rajasuriya A. De Silva R.M.W. and Ohman M. C. (1995) Coral Reefs of Sri Lanka: Human Disturbance and Management Issues. *Ambio*, **24:** 428-437.

29. Senanayake F.R. and Moyle P.B. (1982) Conservation of Freshwater Fishes of Sri Lanka. *Biol. Conserv.* **22:** 181-195. Sumithraarachchi B. (1986) A Report on Steps Taken to Conserve Orchidaceae in Sri Lanka. *Phyta, Journal of the Botanical Society of the University of Peradeniya*, 3(1): 26-41. As cited in Baldwin, 1991.

30. Sumithraarachchi B. (1986) A Report on Steps Taken to Conserve Orchidaceae in Sri Lanka. Phyta, Journal of the Botanical Society of the University of Peradeniya, 3(1): 26-41. As cited in Baldwin, 1991.

31. WCMC (World Conservation Monitoring Centre) (1994) *Biodiversity Data Sourcebook.* World Conservation Press, Cambridge, UK. As cited in IUCN, 1997.

32. Wijesinghe L.C.A.de S., Gunatilleke I.A.U.N., Jawardena S.T.G., Kotagama S.W. and Gunatilleke, C.V.S. (1993) *Biological Conservation in Sri Lanka – A National Status Report (revised).* IUCN Sri Lanka, pp 100.

Photograph by Chandima Kahandawala.

Courts Complex at Hulftsdorp

LEGAL FRAMEWORK FOR NATURAL RESOURCES MANAGEMENT

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Summary

While each chapter of this publication may deal with specific legal provisions, a holistic view of the legal framework, relevant laws, primary legal responses, institutional arrangements for management and tools for conservation of Sri Lanka's Natural Resources is presented in this chapter.

Constitutional provisions, relating to environment, including fundamental rights and duties are discussed. Legal tools such as Environmental Impact Assessment (EIA), Environmental Protection Licenses and Public Trust Doctrine are analysed. Laws relating to landbased resources such as, forests, wildlife and minerals are discussed, as well as laws relating to fresh and marine waters, including pollution and quality.

Sri Lanka's obligations and rights under various International Agreements, Conventions and Laws are presented. The Conventions, relating to the Environment, to which Sri Lanka has subscribed are listed. A list of statutes relating to various natural resources is given. Some important judgments handed down in cases relating to the environment are listed, as well.

INTRODUCTION

This chapter seeks to bring together in one place:

a) the various aspects of the legal framework governing the management of natural resources;

b) The primary legal responses and tools for natural resources management and conservation;

c) A description of the various laws dealing with the environment and with different natural resources.

The reader may find specific legal aspects concerning a particular natural resource referred to and discussed in the chapter dealing with that resource. This is inevitable, since those legal aspects would be directly relevant to the management regime applicable to that resource. However, this chapter seeks to give a holistic view of the legal framework and the institutional arrangements *vis-à-vis* natural resource management, as well as the legal tools available for such management. The chapter also gives a brief description of the various laws specifically applicable to different natural resources.

Legal System – General Aspects

Sri Lanka's environmental law is a curious mixture of civil law and common law principles derived from Roman-Dutch and English law, statute law, juristic writings and judge-made law. As a result, there is a multiplicity of jurisdictions and institutions in the environmental arena. In turn, this leads to weak enforcement, lack of coordination and inefficiency.

The Judiciary on the other hand has shown a keen interest in the development of environmental law. The minor judiciary in particular has taken an active (and in some cases an activist) role in developing environmental law, especially by expanding the scope of public nuisance law. Recent Court of Appeal and Supreme Court judgements have extended *locus standi* to environmental Non Governmental Organizations (NGOs) to sue for writs in the public interest and have not hesitated to hold government institutions accountable for their environmental and developmental decisions.

There is a common misconception that natural resources are managed **by** laws. Such is not the case. Natural resources are managed **through** the law. Laws provide the tools and the framework for management. The numerous tasks of management, including policy making, enforcement, application of management techniques and tools and the making of specific decisions have to be performed within that framework. This chapter seeks to set out that framework.

Another trend that should be noted is the interpolation of a new level of provincial government after the 13th amendment to the Constitution in 1987. The constitutional amendment introduced a new level of institutions between the central government and local governments. Provincial governments also have legislative and executive power over environmental matters[1]. This area of the law is influx and it is near impossible to predict with any certainty how legal issues in this area would be resolved.

The enactment of the National Environmental Act in 1980[2] and its amendment in 1988 (NEA) has brought two important regulatory tools into the regulator's hand. These are Environmental Impact Assessment (EIA) procedures and Environmental Pollution Licensing (EPL). These regulatory tools govern almost all aspects of development.

Among the new initiatives, are the transparent and participatory processes adopted by the government in drafting a new National Environmental Protection Act (NEPA) and a new draft Forest Conservation Act. The drafting of NEPA was supported by the United Nations Environment Programme (UNEP). Both these laws are in draft form and the draft NEPA is before a cabinet sub-committee. The draft NEPA is a comprehensive draft law which updates existing legislation and introduces many new concepts including the "polluter pays" principle, environmental tribunals, enforceable rights to a healthy environment, administrative penalties, green marking etc. The new draft forest law contains provisions for tenure agreements between communities and the government to be registered and re-orients the classification and regulation of forests in keeping with modern trends.

Constitutional Provisions

The Constitution of Sri Lanka contains several provisions, relating to the environment. For example, Article 27 (14) of the Constitution of Sri Lanka states that it is the duty of the State "to protect, preserve and improve the environment for the benefit of the community". In addition, Article 28 (f) of the Constitution makes it a "fundamental duty" of every person to "protect nature and conserve its riches". These provisions, however, are not set out in the chapter on fundamental rights: they are to be found in the chapter entitled "Directive Principles of State Policy and Fundamental Duties" and are not enforceable in a court of law since the Constitution specifically states so[3].

[1] At least one provincial council has exercised it's powers in the area of environmental protection under the concurrent list of subjects set out in the 13th amendment to the Constitution. The northwestern provincial council adopted the Northwestern Provincial Environmental Statute No. 12 of 1990 and several other provincial councils have drafted such statutes. With a view to preventing the proliferation of statutes at variance with the NEA, the Ministry of Forests and Environment has established a Committee, consisting of provincial council representatives and other government officials to draft a model statute on the environment. This effort is funded by the UNEP.

[2] The National Environmental Act No. 47 of 1980 as amended by Act No. 56 of 1988.

[3] Article 29 of the Constitution states that "The provisions of this chapter do not impose legal rights or obligations, and are not enforceable in any court or tribunal. No question of

Although the constitution contains an enforceable chapter of fundamental rights, it does not contain an express right to a healthy environment, nor an express right to life. Nevertheless, environmental disputes involving mining and quarrying have reached the Supreme Court on the basis that they involved the violation of other declared fundamental rights including the freedom from cruel, inhuman and degrading treatment, the right to equality, the right to choose one's residence and the right to carry on a lawful occupation.[4] Most of these cases have been settled out of Court. There was however, litigation in the Supreme Court which had a potential for setting a precedent, inferring the right to life and a right to a healthful environment[5].

Overview of Institutional Framework

Environmental law in Sri Lanka has evolved in piecemeal fashion over the years. As a result responsibility for environmental protection is shared by a number of institutions at both local and national levels. At the local level, local authorities and the police have from the earliest times been engaged in environmental planning, protection and dispute resolution. These local authorities are armed with powers to abate nuisances. In addition, local authorities also perform zoning, public health and numerous other duties involving the built environment and solid waste collection and disposal.

At the national level, authority for environmental matters is divided among a variety of different departments, commissions, and agencies. The lack of coordination among these various authorities has inhibited the development of a coherent and effective environmental strategy in Sri Lanka. Recent efforts, however, to improve cooperation hold promise for improved environmental management. The Forest Department[6], headed by a Conservator, is perhaps the oldest government agency responsible for management of the national forest estate. The Department of Wildlife Conservation, established in the early 1950s, is responsible for management of approximately 10 per cent of the nation's land area, constituted as parks and reserves. It also has a mandate for the protection of endangered species.

New institutions for environmental management were not established until the 1980s. The Central Environmental Authority (CEA), the apex environmental agency, was established by the National Environmental Act (NEA) in 1980[7]. Its functions include environmental standard setting, pollution control and environmental planning including EIA. In the early 1990s a cabinet ministry for the Environment was established and has since functioned as the national environmental planning and policy making body.

In 1981, the Coast Conservation Act[8] established the Coast Conservation Department with primary responsibility for prevention of coastal erosion and management of the coastal zone. The Fisheries Department is another agency with a long history and oversees the management of both inland and marine fisheries resources. It currently operates under the Fisheries Act of 1996[9].

Marine pollution falls within the purview of the Marine Pollution Prevention Authority (MPPA) established by the Marine Pollution Prevention Act of 1981.[10]

Approximately 80 per cent of the land area of Sri Lanka is titled to the state. The management and disposal of these lands is in the hands of the Land Commissioner's Department, and the Land Reform Commission. These functions are performed under a number of laws which are discussed more fully

inconsistency with such provisions shall be raised in any court or tribunal"

4 See for example the cases of Environmental Foundation Ltd vs. AG *et al.* 1 SAELR 17.

5 Lalanath de Silva vs. Nandimitra Ekanayake, Fundamental Rights Application 569/98. The case was decided infavour of the Petitioner on the basis of the violation of equality and the Court did not rule on the question of the right to life and environment. Supreme Court minutes of 2.11.99.

6 The exact date on which the Forest Department was established is uncertain. Nihal Karunaratne, in *"Forest Conservation in Sri Lanka"*, 1987, (p. 88), having examined the question states that the Department was established in the middle of 1887.

7 Section 2 of the NEA.

8 The Coast Conservation Act No. 57 of 1981 as amended by Act No. 64 of 1988.

9 The Fisheries Act No. 02 of 1996

10 Act No. 59 of 1981.

below. The Geological Survey and Mines Bureau is responsible for controlling mining activities.

GENERAL ENVIRONMENTAL LAW AND POLICIES

The key environmental law is the National Environmental Act (NEA) [11] which introduced both EIA and EPL procedures. Apart from this Act, there are many other sectoral statutes that deal with specific areas of resources or developmental activity.

> The powers and functions of many of the institutions overlap with one another in the area of environmental management. The need for coordination amongst these agencies has become a compelling necessity. The Ministry of Environment, the CEA and other agencies have established *ad hoc* coordinating mechanisms. However, there is no permanent statutory coordinating mechanism as yet. The only overacting law is the NEA which deals with pollution control and EIA.

The National Conservation strategy was adopted in December 1988. Following the Strategy a National Environmental Action Plan (NEAP) was adopted in 1991. NEAP is presently under revision. Certain actions from NEAP have been identified and developed into the Environmental Action 1 Project (EAIP) which has been funded by the World Bank beginning in 1997. The EAIP seeks to assist the government of Sri Lanka by strengthening the Ministry of Forests and Environment and the Central Environmental Authority. The project also creates a Community Environmental Improvement Facility (CEIF) through which the Ministry of Forests and Environment can make grants to community environmental initiatives. There is also a component on land and agriculture where new experiments on soil conservation and environmentally better land use practices in critical watersheds will be piloted.

There have been several efforts to draft a comprehensive national environmental policy without success. However, a National Policy on Industry and Environment was issued in 1996 with the participation of three relevant Ministries. The Coastal Zone Management Plan of 1990 (since revised) contains policy statements regarding the coastal zone. In the area of forestry, a National Forest Policy was adopted in 1996 and a new Forestry Master Plan, adopted in 1995. The Biodiversity Action Plan was published in 1998. Policy and statements relating to public lands, fisheries, air and water may be found scattered in numerous documents and decisions. These are not well known or understood, nor consistently applied. In most cases these plans and policies are administrative initiatives which do not necessarily have legal authority. In a few cases, such as the Coastal Zone Management Plan and the Colombo Development Plan, the documents have legal effect since they are authorized and given legal effect through an Act[12].

Public Participation

There is no law that generally requires the notification of potentially affected parties prior to the making of developmental decisions. However, developmental decisions that affect the rights of particular citizens may attract the common law principles of natural justice. The administrative law applicable in Sri Lanka is the same as that applicable in England and the prerogative writs of *certiorari*, *mandamus*, prohibition and *quo-warranto* are available in Sri Lanka through the High Courts and the Court of Appeal. These principles would in many cases require notification and the granting of an opportunity of being heard.

Developmental decisions, such as the compulsory acquisition of private land[13], would be in this category. Less obvious instances may include the granting of Environmental Protection Licences (EPL)[14] for the discharge of waste, and approval of land use incompatible with zoning. In the latter situation, public notifications are not made in practice. However, decisions rendered by the Secretary to the Ministry of Environment on EPL appeals have made it clear that neighbourhood

[11] Supra (Note 1)

[12] For example the Coastal Zone Management Plan is authorized under the Coast Conservation Act, and the city of Colombo Development Plan is authorized under the Urban Development Authority Law No. 41 of 1978.

[13] Under the Land Acquisition Act (Cap.460).

[14] Under Section 23A of the NEA.

objections must be heard in considering EPL applications[15] and the Supreme Court has recently affirmed this principle.

A number of statutes however, specially provide for public participation. For example, the Town and Country Planning Ordinance[16] requires public notification and subsequent hearings on draft zoning plans. The Coast Conservation Act [17] requires public notification and hearings on permit applications for development activity within the coastal zone where an EIA has been required. Notification periods range from 30 to 60 days and are usually published in the government gazette.[18]

Elaborate provisions are contained in the NEA for the notification and participation of the public in project design and approval.[19] Every EIA or Initial Environmental Examination (IEE) in respect of listed projects is required to be made public through notifications in the press and the gazette for 30 days.[20] A public hearing thereafter is optional. The public has a right of access to the EIA and IEE documents.

Similar provisions apply under the Coast Conservation Act[21] for major development projects for which an EIA has been requested. Guidelines issued by the CEA encourage the involvement of the public at the earliest stages of the project design including the scoping stage.[22] In practice however, this has not happened. As yet the EIA process is an addition at the end of the developmental decision making process. Industry, it seems has yet not sufficiently appreciated the need to begin the process early. The public has rights to compulsory notification only at latter stages of the process. At the early stages, involvement of the public is the discretion of the Project Approving Agency (PAA).[23] Cases have been brought before the courts in respect of disputes involving the interpretation of EIA regulations but these cases have so far been settled out of court.

Public interest groups have successfully litigated non-disclosure and issues of bias through the use of writs and constitutional provisions regarding fundamental rights.[24] Administrative decisions made by the Secretary to the ministry-in-charge of the subject of environment in appeals under the NEA have also recognized the right of the neighbourhood to make representations when the CEA is considering EPL applications.[25]

There is no clear legal provision for public participation in implementation, monitoring compliance and enforcement. Efforts to include public involvement in these areas by way of permit conditions have been extremely limited. Affected members of the public, however, are increasingly accessing the legal system for environmental laws, and approvals and permit conditions.

Resource Management - Legal Tools and General Procedures

Environmental Impact Assessment (EIA)

Currently, three laws impose EIA obligations: the NEA, the Coast Conservation Act No. 57 of 1981 (CCA), and the Fauna and Flora Protection Ordinance (Cap. 469) as amended by Act No. 49 of 1993.

A number of ministries and other government agencies have been designated under the NEA as Project Approving Agencies (PAA) with authority over the conduct of the EIA process.[26] For the purposes of the Coast Conservation Act (CCA), the Director of Coast Conservation exercises EIA authority.[27] For the purposes of the Fauna and Flora

[15] See the Appeal under Section 23 E of the NEA by E.M.S. Niyaz, 2 SAELR 1. Also Gunaratne vs. Homagama Pradeshiya Sabha *et al*., FR No. 210/97 Supreme Court Minutes of 3/4/98.

[16] (Cap. 269). Section 27.

[17] Supra (Note 8)

[18] Section 16 of the Coast Conservation Act (Supra).

[19] Chapter IV C of the NEA.

[20] Section 23BB(3) of the NEA.

[21] Section 16.

[22] Clause 2.2 of "*Guidance for implementing the environmental impact assessment process*" CEA, 1993.

[23] Clause 4.1 of the CEA Guidelines (note 22)

[24] See the case of Environment Foundation Ltd. vs. the Secretary to the Ministry of Transport and Highways *et al.*, Court of Appeal Writ application No. 549/94.

[25] See the Appeal of E.M.S. Niyaz under Sec. 23E of the NEA2 SAELRI.

[26] See the Gazette Extraordinary No 857/14 of 23.02.95.

[27] Section 16 of the CCA.

Protection Ordinance, the Director of Wildlife Conservation exercises EIA authority.[28]

Under the NEA and regulations made thereunder[29], an EIA or IEE is required for every listed project referred to as Prescribed Projects. There are currently some 52 projects listed by generic description, magnitude and location. Among these are river basin development and irrigation projects, construction of hydroelectric power stations exceeding 50 MW, thermal power plants exceeding 25 MW, hotel projects of over 99 rooms or resorts of more than 40 ha, projects involving the involuntary resettlement of more than 100 families, port development, construction of highways of more than 10 km etc.

Under the CCA, the Director of Coast Conservation has the discretion to require an EIA with respect to permit applications for development activities within the coastal zone. The current Coastal Zone Management Plan[30] states that the Director will call for an EIA when such activities may have potentially significant impacts on the coastal zone.

Under the Fauna and Flora Protection Ordinance, an IEE or EIA is required 'for carrying out a development activity of any description within a distance of one mile from the boundary of any National Reserve declared under the Ordinance. The procedure applicable for the conduct of the EIA, however, is the same as under the NEA.

An IEE is defined[31] as a written report where possible environmental impacts of the projects are assessed, with a view to deciding whether or not the impacts are significant. The purpose of an IEE is to decide whether or not an EIA is required.

The contents of an EIA[32] include:

i) predicted environmental impacts;
ii) description of avoidable and unavoidable adverse environmental impacts;
iii) description of alternatives to the project, less harmful to the environment;
iv) reasons why such alternatives were rejected;
v) an environmental cost benefit analysis, if prepared.

The decision making process under all three laws is similar.[33] The process begins with the developer lodging Preliminary Information (PI) with the relevant agency. The agency conducts a 'scoping' and issues Terms of Reference (TOR) for an EIA/IEE. The developer then hires consultants, produces an EIA/IEE and submits it to the agency. If the agency considers the EIA adequate, the agency publishes notices in the press and the gazette, opening the EIA/IEE for public comments for 30 days. Under the CCA, the EIA is also referred to the Coast Conservation Advisory Council for comments during a 60 day period. Comments received are forwarded to the developer for response, after which the agency makes a decision to approve or disapprove the project. Approval is usually conditional. The developer has a right of appeal to the Secretary of the Ministry in charge of the subject of Environment (for EIAs under the NEA) and to the Secretary of the Ministry of Fisheries and Aquatic Resources (for EIAs under the CCA). It is unclear whether there is any right of appeal against decisions made under the Fauna and Flora Protection Ordinance.

Under all three laws, a 'scoping' is conducted by the lead agency to determine the issues that ought to be addressed in an EIA/IEE[34]. The developer, related agencies and affected parties may be invited to the 'scoping'. The 'scoping' usually determines whether an EIA or IEE is required, forms the basis for issuing Terms of Reference (TOR) to the developer, and defines the scope of the EIA/IEE.

Post-decision-monitoring is a duty of the PAA. However, the power to enforce approval conditions is with the CEA in respect of decisions made under

[28] Section 9A of the Ordinance (Cap 469) as amended by Act No. 49 of 1993.

[29] Regulations are contained in Gazette Extraordinary No. 772/22 dated 24.06.93.

[30] The current Plan adopted in 1990 received Cabinet approval as required by the CCA but was not Gazetted. Further to this there was a 1996 revision that was finalized and submitted to the Cabinet but not Gazetted yet.

[31] Section 33 of the NEA.

[32] Section 33 of the NEA.

[33] The process is set in the EIA Regulations.

[34] Regulation 6(ii) of the EIA regulations.

the NEA.[35] The CEA has delegated this power of enforcement to some of the PAAs. Post-decision-monitoring, however, is less than satisfactory.

Since the EIA regulations were gazetted in 1993, a number of cases involving their interpretation have reached the Court of Appeal and Supreme Court. Even prior to the EIA regulations being Gazetted, the Supreme Court in Amarasinghe *vs.* AG *et.al*.[36] drew attention to the availability of provisions in the NEA[37] empowering the CEA to subject development projects to environmental assessments. The Court observed that when the regulations were gazetted, statutory provisions for public participation would be available.

In a recent case[38] which was filed after the EIA regulations, the question arose as to whether it was adequate to make the EIA report available to the public in the English language alone. The Court granted leave to proceed for violation of language rights guaranteed by the Constitution. The case was later settled with the PAA agreeing to make the EIA report available in Sinhala and Tamil as well. In Environmental Foundation Ltd. vs. the Secretary Ministry of Transport and Highways *et al.* [39] a PAA that demonstrated an overt interest in the project under review, was disqualified by reason of bias from functioning as the PAA under the EIA regulations. The Petitioner, a non-governmental organization, had applied to the Court of Appeal for a writ or prohibition. After the Court issued notice on the Respondents, the case was settled with the PAA being changed and the CEA being appointed as the new PAA.

Environmental Protection Licensing (EPL)

Environmental Protection Licensing (EPL) is another important regulatory tool introduced by Act No. 56 of 1988 to the NEA. The NEA states that "No person shall discharge, deposit or emit waste into the environment which will cause pollution except under the authority of a licence issued by the [Central Environmental] Authority and in accordance with such standards and other criteria as may be prescribed under this Act".[40]

The regulations necessary to implement these provisions were gazetted in February 1990 and became effective from the 1st of July 1990.[41] These regulations set down the procedure for applications for EPLs, the manner in which such applications should be assessed, and the criteria that should be applied in granting or refusing an EPL. The regulations also establish discharge standards for effluent into inland surface waters, onto land for irrigation purposes, and into marine coastal areas. The regulations further establish tolerance limits for effluent from textiles, tanning and rubber industries.

The terms "waste" and "pollution" are defined in the NEA and raise difficult questions of science.[42] For instance, "waste" is defined as "liquid... discharged ... into the environment in such volume, consistency or manner as to cause an alteration of the environment". This definition requires evidence that the liquid waste being discharged will cause an alteration of the environment.

Standards fixed under the NEA take into account a number of factors including the nature of the effluent, human health, impact on other living organisms, technology available for pollution control and cost benefits of such controls. Generally, standards are a compromise between these competing factors. They may not be adequate protection in a certain context while in others they may provide ample safeguards.

Nuisance Law - The Common Law Response

Common law principles of nuisance are part of the law of Sri Lanka. Although nuisance is a tort developed in England, the concept has found it's way into Sri Lankan and South African law. The law of nuisance allows owners and occupants of land who are victims of environmental pollution to sue for declarations, injunctions and damages. The Sri

[35] Section 24B of the NEA.
[36] 1 SAELR 17; 1993 (1) SLR 376.
[37] Section 10(h) of the NEA.
[38] Supreme Court Fundamental Rights Case No. 413/93.
[39] Court of Appeal Writ Application No. 549/94.
[40] Section 23 A of the NEA.
[41] National Environmental (Protection and Quality) Regulations No. 1 of 1990 published in Gazette Extraordinary No. 595/16 dated 2nd February 1990.
[42] Section 33 of NEA.

Lankan courts have even recognized that one does not need to wait till the nuisance manifests itself and that potential victims could bring a *quia timet* action to prevent nuisances.[43] The Law makes a distinction between private and public nuisances.[44] Public nuisance is an offence punishable under section 261 read with section 283 of the Penal Code.[45] More importantly, chapter IX of the Criminal Procedure Code Act No. 15 of 1979 provides for the abatement of nuisances through appropriate proceedings in the Magistrate's Court. The procedure for the abatement of a public nuisance can be initiated by any person by lodging information with the Magistrate.[46] The Magistrate may then if necessary, after taking evidence, issue a conditional order for the abatement of the nuisance. The Respondent on whom the order is served may then show cause against the order or comply with the same. If the Respondent chooses to show cause, the court may take evidence and decide to discharge the order or vary the same or make the same absolute. The Court also has a limited power to issue injunctions pending the determination of the case.[47]

In Elal Jayantha vs. OIC Panadura Police[48] the Court of Appeal pointed out that this special procedure should be followed in cases filed for the abatement of public nuisances and that the procedure for summary trial of offences should not be resorted to. In Greena Fernando vs. Tekla Saparamadu[49] the Court of Appeal held that once a conditional order is issued, the burden of adducing evidence and starting the case was on the Respondent.

An important question that arises in Public Nuisance cases is the effect of an EPL and arguments that the industry is acting within the terms of the EPL and within environmental standards. In Keangnam Enterprises vs. Abeysinghe[50] the Court of Appeal was called upon to decide whether the Magistrate's jurisdiction was ousted if the Respondent has obtained an EPL from the CEA. The Court did not decide this issue since it transpired that the Respondent in this case did not have the EPL on the date the conditional order was made but had obtained the same subsequently. The court did however, make a distinction between an EPL and licences issued by other agencies including local authorities, and emphatically stated that other licences could not be equated to an EPL.

Over 200 public nuisance cases relating to environmental pollution have been filed in the last two years. In about 60 per cent of these cases the courts have fashioned an appropriate remedy to abate the nuisance.

The Evolving Public Trust and Guardianship Doctrine

Another useful principle in balancing environmental and developmental interests is the Public Trust doctrine. The state holds all its property including natural resources in trust for the public. The state may therefore not dispose of natural resources titled to it as if it were a private person, but only for legitimate purposes and in keeping with procedure established by law.

Although there has never been a case directly raising the issue in respect of the use or disposal of natural resources, the Supreme Court has recognized the public trust in several recent judgements. In the recent case of Smithkline Beecham Biologicals S.A. vs. State Pharmaceuticals Corporation of Sri Lanka *et al.*[51] the Supreme Court held that in the area of government procurement, the state and its agencies are not "on the same footing as a private individual".[52] It also held that the State should be held to its own guidelines, *inter alia*, requiring transparency in the tender process, and recognizing a duty to obtain financially the most advantageous and qualitatively the best services and supplies for the country.

In the case of Premachandra vs. Jayawickrema[53] and Bandara vs. Premachandra[54] the Supreme Court

[43] Arlis Appuhamy vs. Kavidane 1983 (2) SLR 493.
[44] For a detailed discussion of these differences see, Salmond Law of Torts, 17th ed. 1977 page 49 et seq.
[45] (Cap. 19).
[46] Section 98 of the Criminal Procedure Code No. 15 of 1979.
[47] See Section 104 of the said Code.
[48] 1986 (1) SLR 334.
[49] 1990 (1) SLR 270.
[50] 1 SAELR 1.

[51] Supreme Court Fundamental Rights case No. 89/97 S.C. Minute of 20th May, 1997.
[52] *Ibid.* Page 19.
[53] 1994 (2) SLR 90.

held that powers vested in public officials and agencies of the state were held **in trust** to be exercised for the lawful purposes for which they were given. In the Environmental Foundation Ltd. vs. The Land Commissioner *et al.*[55] the Court of Appeal, granting interim relief in a public interest writ application concerning the leasing of state lands to a hotel company, was critical of the Secretary to the Ministry of Lands and Mahaweli Development for having placed the company in possession of state land without complying with legal procedure. These provisions required public notification of the proposed lease and a consideration of public objections thereto.

In the recent case of Bulankulama *et al* vs. Secretary, Ministry of Industrial Development *et al.* 2000, 7 SAELR 1, the Supreme Court was not inclined to apply the public trust doctrine to the Eppawala Phosphate deposits. Instead the court expressed the view that the legal concept applicable was one of state guardianship of natural resources for the benefit of the public. The court took the view that the guardianship of resources was the joint responsibility of the state and the public.

PROPERTY RIGHTS AND ENVIRONMENT

Broadly speaking, land in Sri Lanka is divided into private and state lands. With respect to private property there is no system of **title** registration. However, **deeds** relating to land may be registered at the Land Registry. Such registration confers priority for land transactions supported by consideration.

State Lands may be disposed of by the President of the Republic by way of grant or lease and by other public officers such as the Land Commissioner and the Divisional Secretaries acting under the provisions of the State Lands Ordinance[56] or the Land Development Ordinance.[57]

Private property may be acquired by purchase, exchange, gift, inheritance, accession or prescription. State property may be acquired by grant under the provisions of one of the above laws. The State also has power to compulsorily acquire private land on the payment of compensation calculated at market value under the provisions of the Land Acquisition Act.[58]

Common/Community Property Rights have, for the most part disappeared. There are however, cases in which such rights have been asserted on the basis of customary rights but almost always denied by the Courts (during colonial times).[59] There is a move to recognize the rights of communities to manage forest resources.[60] However, apart form the area of forestry and some experiments done under the Shared Control of Resources (SCOR) – project of the USAID, there is no trend to reinvent communal property rights. The trend is in the opposite direction – to recognize and expand the right of private ownership of land and other resources. There are also scattered provisions in laws, including the Land Settlement Ordinance[61], which allow the recognition of certain common property rights.

LAND USE PLANNING AND MANAGEMENT

Land use planning is an area which is highly politicized and has met with little success. There are three institutions charged with this responsibility. The Town and Country Planning Department functions under the Town and Country Planning Ordinance.[62] The Urban Development Authority acts under the Urban Development Authority Law of 1978.[63] Finally, local authorities have limited land use planning and zoning powers.

[54] 1994 (1) SLR 301.
[55] 1 SAELR 53.
[56] (Cap. 454).
[57] (Cap. 464)

[58] (Cap. 460)
[59] See the cases of Fernando *et al.* vs. Fernando *et al.* 22 NLR 260; Baba Appu vs. Aberan *et al.* 8NLR 160; Rowel Mudliyar vs. Pieris *et al.* 1 NLR 81; Fernando vs. Fernando *et.al* 42 NLR 279.
[60] The draft Forest Conservation Act (1997) has been made public by the Ministry of Forests and Environment in June 1997. The draft Act contains provisions for the negotiation, conclusion and registration of "tenure" agreements relating to state lands. Such tenure agreements may contain provisions relating to common property rights or joint management regimes (i.e. state and community).
[61] See the provision to section 10 of the Land Settlement Ordinance (Cap. 464).
[62] (Cap.269)
[63] Law No. 37 of 1973 as amended by Acts No 4 of 1982 and 44 of 1984.

The Town and Country Planning Ordinance provides for the declaration of planning areas. It empowers the Town and Country Planning Department to embark on land use planning and zoning.[64] The process stipulated is highly participatory and transparent. Several areas of the country have been planned in this manner but the plans are not enforced.

The Urban Development Authority has power to engage in the preparation of development plans for areas declared as urban development areas under the relevant Act.[65] Although several areas have been so declared, the UDA has prepared a development plan only for the city of Colombo. This plan is operative and is enforced to a reasonable degree. The law requires development within Colombo to be covered by a development permit from the UDA. Such a permit will only be issued if the development conforms to the zoning in the plan and the conditions and criteria specified in the plan.

Zoning, when legal and effective, does limit the use of private land. The Town and Country Planning Ordinance provides for the payment of compensation for injurious affection. 'Injurious affection' is a term used to denote losses to property value caused by restrictions on its use or adverse impact upon its potential use. The UDA has power to compulsorily acquire private land when the same is required under the Act for development purposes.[66] Compensation is payable on the basis of market value when such acquisitions take place.

Incentives for conservation of private land are almost non-existent. In fact, incentives are for exploitation of private land. Subsidies are given for short term and medium term crops by way of fertilizer subsidies.

Environmental Management of Public Lands.

Approximately 80 per cent of the land area of the country is titled to the state and is managed through state agencies. Numerous state agencies are involved in the management of state lands. Primary responsibility for disposition of state land is with the Land Commissioner. The Land Commissioner exercises powers under the State Lands Ordinance[67], the Land Development Ordinance[68] and the Land Settlement Ordinance.[69] The powers and functions of the Land Commissioner are exercised through delegation, namely to the Divisional Secretaries and District Secretaries.

During the period 1972 to 1975, the government implemented Land Reforms.[70] Private ownership of agricultural land was limited to a maximum of 50 acres (20 ha). Excess land was taken over on the payment of compensation calculated by a statutory formula. Some of these lands were then distributed to landless people and utilized for other public purposes. Privately owned tea and plantation lands were also vested in two government corporations. Some of these lands are managed by private companies although still tilted to the state, while others have been completely privatized.

The environmental management of public lands has been very sporadic. There are some guidelines issued by the Land Commissioner on environmental impacts of dispositions and leases but these are not strictly enforced.[71] The EIA regulations however, do cover some aspects of public land management.[72] These aspects include the removal of forest cover of more than 1 ha, clearing of land areas exceeding 50 ha and conversion of wetlands of more than 4 ha. Any of the 52 projects listed in the EIA regulations if located within 100 m of any forest reserve, or wildlife sanctuary requires approval under the EIA process, irrespective of its magnitude. Thus a small industrial plant or irrigation project within 100 m of a forest reserve would require an EIA.

Protected areas and parks involving public lands are declared under three statutes, namely the Fauna and Flora Protection Ordinance and the National Heritage Wilderness Areas Act.[73] Protected areas under the Fauna & Flora Protection Ordinance fall

[64] See section 6 and 38 of the Town & Country Planning Ordinance.
[65] Section 8 of the UDA Law.
[66] Section 16 of the UDA Law.

[67] (Cap 286)
[68] (Cap 300)
[69] (Cap. 299)
[70] This was achieved through the Land Reform Law No. 1 of 1972 as amended by Act No 39 of 1975, 18 of 1986.
[71] See the Land Orders issued by the Land Commissioner, now consolidated in one volume (1985).
[72] EIA regulations. 1993.
[73] Act No. 3 of 1988

into two broad categories: National Reserves (declared over public lands) and Sanctuaries (declared over public/or private lands). Forest Reserves and Village Forests may be declared over public lands under the Forest Ordinance. National Heritage Wilderness Areas may be declared over public land only.

The regime over most of the reserves includes controlled access (via permits), protection of fauna and flora and management of habitat etc. The Wildlife Department manages all areas under the Fauna and Flora Protection Ordinance while Forest Reserves, Village Forests and Wilderness Areas are managed by the Forest Department.

Cultural monuments and archaeological sites receive protection under two main statutes: the Antiquities Ordinance[74] administered by the Archeological Department and the Central Cultural Fund Act[75]. Most archaeological sites and monuments are declared under these laws and receive protection. There are however no laws to protect monuments and building of more recent origin (less than about 150 years old). Sri Lanka is a party to the World Heritage Convention and a number of sites are listed as world cultural and natural heritage sites. A recent proposed amendment to the Antiquities Ordinance will require an archaeological impact assessment in addition to an EIA for development projects impinging on cultural and historic sites.[76]

CONSERVATION AND MANAGEMENT OF NATURAL RESOURCES

Biological diversity falls within the purview of several institutions. The Wildlife Conservation Department and the Forest Department have responsibility for *in situ* conservation of biodiversity. The *ex situ* conservation of biodiversity is covered by both departments in respect of listed species. The current law protects all species of mammals, reptiles and birds other than those listed as unprotected[77]. In the case of amphibians and invertebrates, positive listing is required for protection. Transport of forest produce requires a permit from the Forest Department. Similarly development activity impacting on Forest reserves, Sanctuaries, Wilderness Areas and National Reserves requires an EIA[78].

There is currently no legal regime applicable to the protection of intellectual property rights relating to biodiversity or indigenous knowledge concerning the same. Other agencies such as the Agriculture Department and the Plant Genetics Resources Centre have some jurisdiction over plant materials and livestock.

Sri Lanka is a party to the Biological Diversity Convention and the focal point for the purpose of the convention is the Ministry in charge of the subject of environment. The Ministry has prepared a Biodiversity Conservation Action Plan (BAP).

Wildlife is protected *in situ* within national reserves and sanctuaries declared under the Fauna and Flora Protection Ordinance. Species that are protected under the negative and positive lists of the ordinance receive protection *ex situ* as well as *in situ.* Entry into reserves requires permits while entry into sanctuaries do not. Human intervention within these areas is regulated. Regulation varies from very strict to minimal, depending on the category of reserves. National Reserves could be Strict Natural Reserves, National Parks, Nature Reserves, Intermediate Zones, Jungle Corridors, Refuges, Buffer Zones, or Marine Refuges.[79] The Department of Wildlife Conservation also administers the provisions of the Convention on the International Trade in Endangered Species (CITES).[80]

The Fisheries Act of 1996 governs ocean fishery resources. The Act provides, amongst others, for the declaration of fisheries conservation areas.

[74] Cap. 394

[75] Act No. 57 of 1980.

[76] See page 287 et seq.

[77] See sections. 30 and 31 of the Fauna and Flora Protection Ordinance as amended by Act No 49 of 1993.

[78] EIA regulations. 1993 read with Section 9A of the Fauna and Flora (Amendment) Act No. 49 of 1993 and the Regulations published in Gazette Extraordinary No. 859/14 dated 23.02.1995.

[79] See sections 6 of the Fauna and Flora Protection Ordinance.

[80] See page 287 et seq.

Minerals

Mining falls within the purview of the Geological Survey and Mines Bureau (GSMB): The Mines and Minerals Act No. 33 of 1992 established the GSMB.

The ownership of all minerals is vested in the state even though the soil may be owned by a private person[81]. Mining and exploration for minerals must be licensed under the Act by the GSMB. Mining licences are issued only to qualified individuals and companies registered to do business in Sri Lanka. Mining is not permitted within Archaeological Reserves and within specified distances of monuments.[82]

New mining licences are subject to the EIA process if the type and extent of mining is listed under the EIA regulations. Additionally the GSMB has power to stipulate conditions including the taking of deposits and insurance for the protection of the environment. Regulations made by the GSMB under the Act cover a variety of environmental stipulations, criteria and conditions for licensing and operating mines. They also cover the disposal of mine wastes. The Act also deals with the health, safety and welfare of miners.

The Regulations under the Act as well as the regulations under the NEA dealing with wastes and environmental standards apply to mining wastes. Enforcement in this area is however, weak.

Reclamation of mines is a major problem in Sri Lanka. Current practice requires the mining enterprise to make a deposit to cover costs of recovery. This deposit however is inadequate for the purpose. Large extents of mined areas, particularly areas mined for clay, sand and gems remain open. A recent study was commissioned by the GSMB and CEA to investigate economic costs and benefits of these deposits.[83] The results identified incentives and disincentives for restoration. The GSMB is currently involved in reforming these practices. The Act gives power to the GSMB to enforce restoration.

Mining rights on public and private land are subject to licensing by the GSMB and all minerals wherever situated belong to the state. Royalties are payable in respect of minerals recovered and license fee is required as well. The right to mine particular parcels of public lands may be subject to EIA procedures as well to lease for permit conditions.

Individuals affected by mining activities, may have resources to the common law remedies of injunctions and damages. The GSMB also has power to prosecute and recover damages in a civil suit. Public liability insurance coverage may be available in the case of large mines. Miners have special workmen's compensation packages covering health and occupation injury and a Special Workmen's Compensation Commissioner Acts to help injured recover compensation.

Agriculture

Institutions and laws for the protection and development of agriculture are fairly advanced primarily because Sri Lanka is predominantly an agricultural society. The Agrarian Services Department headed by a Commissioner is responsible for the Administration of the Agrarian Services Act 1979.[84] The Department of Agriculture, headed by a Director Genaral, is responsible for the administration of a number of laws including the Fertilizer Ordinance, the Control of Pesticides Act, the Soil Conservation Act[85] 1951, Botanic Gardens Ordinance 1928 and the Plant Protection Ordinance.[86] The Department of Animal Production and Health also headed by a Director is responsible for nationwide veterinary services and for the administration of a number of laws including the Diseases of Animals Ordinance and the Animals Act. Overall supervision of these agencies falls under the Ministry of Agriculture and Lands.

Soil Conservation is covered by the Soil Conservation Ordinance of 1951. The Ordinance was not operative for decades, but in the 1980s

[81] Section 2 of the Mines and Minerals Act.
[82] Section 30 of the Mines and Minerals Act No. 33 of 1992.
[83] The Clay mining study was done for the GSMB by Dr M Ranasinghe of the University of Moratuwa in October 1995 titled "*Feasibility and Environment Impacts of Clay Mining in Sri Lanka:* Final Report to the Economy and Environment Programme for South East Asia.

[84] Act No. 58 of 1979
[85] Act No. 25 of 1951 (Cap. 279)
[86] Cap. 276

public agitation resulted in the activation of the law. Since then several areas have been declared as erodible areas under the Act and landowners are required to take specified soil conservation measures. The Ordinance also provides for the compulsory acquisition of erodible lands and for the enactment of regulations in respect of areas and lands declared under the Ordinance.[87] The Department of Agriculture enforces the Ordinance, but this has been weak. Regulations under the Ordinance can cover flood control, pasturing and grazing, soil conservation measures, agricultural practices, draining and cambering. Soil erosion in the hills, due to bad agricultural practices, has become a major environmental problem. Tobacco, Tea and Potato cultivation are three of the biggest contributors to the problem.

Agricultural land, in particular rice paddy lands, receive protection under the Agrarian Services Act. Such lands cannot be converted to other uses without the prior permission of the Commissioner of Agrarian Services. Tenant cultivators also receive protection and may not be evicted from their paddy lands without a proper order from the Commissioner. There are elaborate hearing and appeal procedures for eviction, termination of tenancy, collection of rents and for action regarding non-cultivation. Other specific statutes also deal with protection for rubber, coconut and tea lands.

The discharge of non-point source agricultural pollutants is covered by the EPL scheme under the NEA. However, non-point source agricultural pollution is an area that is not dealt with by the existing framework . Although there are laws on Pesticides and Fertilizers, there is no law dealing with runoff, nor are these Acts enforced very well in the field. As a result, agricultural runoff is a serious factor in water pollution in Sri Lanka.

The Control of Pesticides Act 1980 as amended from time to time and the regulations made thereunder govern pesticide imports, formulation, distribution, sale and use. Pesticide poisoning in Sri Lanka has reached crisis proportions with most suicides being the result of pesticide poisoning.

The Registrar of Pesticides, an Officer within the Agricultural Ministry is responsible for licensing the formulation of pesticides. The Registrar was responsive to public appeals for banning the "dirty dozen" and other such pesticides with adverse human and environmental impacts. The problem lies in the lack of qualified staff and laboratory facilities for enforcement.

Forests and Forest Management

The Forest Department is the main institution having authority over forestry. Other agencies – such as the Mahaweli Authority, the Wildlife Conservation Department, the Coast Conservation Department, the Irrigation Department, the Urban Development Authority (in respect of urban forests) and the Land Commissioner – have special authority over areas under their control.

Forest management over public lands is in the hands of the Forest Department. The Forest Ordinance provides for the declaration of areas of state lands as Forest Reserves. Public lands may also be declared as Conservation Forests or Village Forests. Village Forests are meant for use by village communities. Although such Village Forests have been declared, scarcely any exist on the ground. Village Forests declared over the years have been denuded, in some cases by the villagers, in others by utilization for development schemes and settlement schemes. The law regulates entry, logging, hunting etc. within these reserved areas.

There are also provisions applicable to the removal of timber and forest produce from state lands in general. Such action requires a permit from the Conservator of Forests. Transport of timber, whether from public or private lands, also requires a permit. The Forest Department has prepared a Forestry Master Plan and a National Policy on Forestry. The law is currently being revised by a National Task Force with a view to bringing it into conformity with national policy. The new policy encourages commercial forestry and also home

[87] A Number of areas have been declared erodible areas under the Act from time to time. For example, see Gazette Extraordinary No. 10 524 of 8.05.53; No. 12 250 of 16.12.60; No. 1 618 of 19.12.58; No. 11590 of 21.11.58 and No. 523/21 of 16.09.88. However, no regulations have been gazetted under the Act though recommended to the relevant Minister by the Director of Agriculture.

gardens. Home gardens are a traditional concept in which Sri Lankans culturally and historically have created analog forests around their homes. These home gardens consist of short term vegetable and grain crops, medium high fruit trees, legumes, fodder plants and large shade giving timber trees. Studies have demonstrated that these home gardens are good analog forest systems.[88] It allows the state to concentrate its efforts at conservation and protection in areas of high biodiversity. It also seeks to liberalize the transport regime with a view to encouraging home gardens.

A private landowner is free to plant and fell trees in his land subject to two regulations. The first is that if forest cover over the limit specified in the EIA regulations is being felled, the owner must comply with the EIA process under the NEA. Secondly there are few species that receive special protection under the Forest Ordinance and the Felling of Trees (Control) Act. Logging that may affect a listed species requires a permit. The owner is required to obtain a permit for the transport of such timber. It has been recognized that this area of the law requires strengthening and the task force is seeking to do just that.

As a result of public and NGO agitation, provisions relating to social and community forestry are being included in the new forest law. They do not currently exist. The new law will provide for tenure agreements between the state and communities and these agreements may include the eventual transfer of ownership of public lands. A system for registration and enforcement of these agreements will also be included.[89]

Air Resources

Protection of the Atmosphere

The primary responsibility for air quality lies with the CEA. The Board of Investment (BOI) has limited authority for air quality within Industrial Promotion Zones. The BOI has been established by law for the purpose of promoting foreign investment in the country. For this purpose it has power to establish Industrial Promotion Zones over which it has wide ranging powers including the provision of infrastructure and environmental pollution control. The BOI has also power to grant tax and other investment incentives to foreign investors. Local authorities also have limited powers to abate nuisances relating to air pollution.

The ministry in charge of the subject of environment is responsible for establishing air quality standards. The ministry has established ambient air quality standards for the country.[90] There are interim stationary source emission standards, which are currently applied by the CEA whenever an Environmental Protection Licence (EPL) is granted to stationary sources. EPLs are not issued in respect of mobile sources. There are draft stationary and mobile source emission standards which are yet to be finalized.

Stationary sources which emit waste into the atmosphere are required to obtain an EPL from the CEA or other delegated local authorities. These include both existing and new sources. Emission of air pollutants into the atmosphere without a valid EPL is illegal.[91]

Although Section 23A of the NEA as currently worded requires mobile sources emitting pollutants into the atmosphere to obtain an EPL, no such EPL has ever been issued. There are draft emissions and smoke standards for vehicles. Smoke standards have been established under the Motor Traffic Act[92] and the Police have been equipped with smoke meters; however, enforcement is far from satisfactory. The new standards will be implemented through periodic checks on motor vehicles and certification of air pollution levels through authorized garages.

Both civil and criminal liabilities are attached to air pollution. Air pollution not covered by an EPL is an offence punishable with fine or imprisonment.[93] Compensation for damage caused by air pollution is

[88] See page 158 et seq., of the *Forestry Master Plan*, July 1995. Forestry Planing Unit, Ministry of Agriculture, Lands and Forestry.

[89] The draft Forest Conservation Act (June 1977). This draft has just been made public by the Ministry of Forests and Environment.

[90] Standards contained in Gazette Extraordinary No. 850/4 dated 20.12.94

[91] Section 23 A read with Section 31 of the NEA.

[92] Standards published in Gazzette Extraordinary No. 817/6 of 03 May 1994.

[93] Section 23 A of the NEA read with Section 31. Also Section 23 K of the NEA.

recoverable in a civil suit. However, enforcement of criminal liability is almost non-existent due to lack of trained personnel and lack of testing facilities. Enforcement through the use of nuisance laws, however, are popular and effective.[94]

Fresh Water and Marine Resources

Protection and Management of Water resources

There are several institutions having authority for water resources. The Water Resources Board has general responsibilities for the assessment, protection and development of water resources.[95] The Water Supply and Drainage Board has responsibilities for the supply of water for drinking and industrial uses.[96] The Irrigation Department is responsible for the construction, maintenance, operation and development of minor and major irrigation tanks, canals and schemes.[97] The Mahaweli Authority has wide powers in respect of the management of the Mahaweli river system and water resources within the Mahaweli development area.[98]

The Mahaweli is Sri Lanka's longest river and has become the principal source for irrigation and hydropower development. The Mahaweli Authority was established two decades ago for the purpose of undertaking the rational development and management of the river basin that is defined as the Mahaweli Development Area. Since then four major hydropower dams and reservoirs have been built and a large extent of land irrigated. Large numbers of people have been settled in areas opened to agriculture by the Mahaweli Scheme. Responsibility for water quality is with the CEA and local authorities and other agencies, to which this responsibility has been delegated. Additionally there were numerous other agencies performing special or limited functions with respect to identified water bodies, rivers or watersheds. As a result there is more confusion about agency functions duties and powers. The government has established a National Water Secretariat at the Ministry of Irrigation. New legislation is currently being drafted to overcome these difficulties.

The ministry in charge of the subject of environment is responsible for establishing both water discharge standards as well as ambient water quality standards. Discharge standards have been established for inland surface water and marine coastal areas.[99] Industry specific discharge standards have been established for rubber factories, textile industries, and tanning industries for discharge into inland surface water. There are also standards for industrial effluents discharged on land for irrigation purposes.[100] There are currently no ambient water quality standards.

Point sources discharging waste (as defined in the NEA) into the aquatic environment or onto land must have an EPL.[101] Generally, an EPL may be obtained from the CEA, however, the power to issue EPLs for 19 minor industries has been delegated by the CEA to the local authorities. EPLs are subject to a set of general conditions and case specific conditions. Existing point sources may be allowed to exceed discharge standards for a limited period, on condition that they implement a time bound programme of pollution control. An EPL is renewable annually. Failure to comply with EPL conditions may subject the facility to sanctions.[102]

There is no clear legal basis for the control of non-point sources. There are laws dealing with use and applications of pesticides and fertilizers. Non-point source pollution, however, may be assessed in projects subject to the EIA process and could always become the subject of nuisance abatement procedures.

The Water Supply and Drainage Board and Water Resources Board are responsible for the provision of drinking water. Water supply schemes and pipe borne water are only found in the major urban centres. The majority of people obtain drinking water from wells (ground water) or from streams and irrigation channels. The law provides

[94] The most popular is that found in the sections 98 et seq. of the Criminal Procedure Code Act No. 15 of 1979.
[95] Act No 29 of 1964.
[96] Act No. 2 of 1974.
[97] The Irrigation Ordinance (Cap. 312)
[98] The Mahaweli Authority Act No. 23 of 1979.

[99] Standards found in Gazette Extraordinary No. 595/16 of 2.2.90.
[100] *Ibid.* Industrial effluents meeting these standards may be used for irrigated crops and plantations.
[101] Section 23A of the NEA and the regulations contained in the Gazette Extraordinary No. 595/16 of 2.2.90 (hereinafter called the EPL regulations).
[102] Sections 31 of the NEA and EPL regulations 14.

for the protection of reservoirs established for the purpose of water supply. While discharge standards could be enforced against point sources polluting streams and irrigation channels, no such enforcement is possible against the most serious problem of non-point source pollution.

There is no clear regime for the protection of ground water. Even the common law does not provide adequate protection for ground water supply. There appears to be a lacuna in the law.

Common law principles regulate to some extent, water allocation and user conflicts. However, this does not appear to be an efficient way to deal with water quantity. There are provisions in the State Land Ordinance requiring a permit from the District/Divisional Secretary for the withdrawal of water for non-domestic purposes from public streams and public lakes.[103] This provision, however, is not enforced. The Irrigation Department controls the quantity and usage of irrigation water under an elaborate system of decision making and operational controls under that Ordinance.

Until recently the only law available for the protection of fresh water ecosystems was contained in the Fauna and Flora Protection Ordinance. Such bodies of water could be declared a National Reserve or Sanctuary, giving it a protected status.[104] Recent legislation has expanded the authority available to protect water resources. The recent Fisheries and Aquatic Resources Act (1996) provides for establishment of Fisheries Reserves.[105] The Forest Ordinance allows for the establishment of conservation of forests which extends to mangroves on state lands.[106] The protection of such reserves varies from law to law ranging from the protection of wildlife to the withdrawal of water.

In most cases violation of legal requirements relating to water pollution carry penalties.[107] There is also common law liability for compensation in damages for pollution and loss of water quality and quantity. There are also numerous agencies exercising special or limited powers over defined water bodies. For instance, the Wildlife Department has power over water bodies within national parks and the Ports Authority has power over water bodies connected to harbours.

Protection of Oceans and Coastal Areas

The Coast Conservation Act of 1981 places the administration, control, custody and management of the coastal zone in the hands of the state.[108] The Coast Conservation Department is the agency with authority over the Coastal Zone. The coastal zone is the area lying within 300 m landwards of the mean high water line and the area within 2 km seawards of the mean low water line. In the case of water bodies connected to the sea, the landward boundary extends 2 km from the natural entrance points.[109]

The Marine Pollution Prevention Authority (MPPA) was established by the Marine Pollution Prevention Act in 1981.[110] The purpose of this Act is to give effect to the several international conventions of marine pollution and civil and criminal liability to which Sri Lanka has become a signatory.[111] The MPPA was inactive until 1995. Since then it has commenced a programme of work to implement the Act. This includes regulations and surveillance. The MPPA has authority over Sri Lanka waters which includes the territorial sea, contiguous zone, the exclusive economic zone, the continental shelf and pollution prevention zone as defined in the Marine Zone Law.[112]

The Fisheries Department exercises authority over fisheries resources in Sri Lankan waters and for this purpose exercises powers under the Fisheries and Aquatic Resources Act No. 2 of 1996.

The law requires a Coastal Zone Management Plan(CZMP) to be prepared following a transparent participatory process.[113] Such a plan was prepared and made operative in 1990 as required by law, and is in the process of being revised (1995). The plan,

[103] Section 77 of the State Lands Ordinance (Cap. 454).

[104] Gazetted declarations are required under Sections 2 of the Fauna and Flora Protection Ordinance.

[105] Section 36 of the Fisheries Act No. 02 of 1996.

[106] Section 3 and 3A of the Forest Ordinance(Cap. 451)

[107] Section 23 A of the NEA read with Section 31. Also special penalties are provided in Section 23 H of the NEA for pollution of inland waters, and Section 23 V provides penalties for discharging oil into inland waters.

[108] Section 2 of the CCA.

[109] Section 42 of the CCA.

[110]. Act No. 59 of 1981.

[111] See International Convention listed on page 285

[112] Law No. 22 of 1976.

[113] Section 12 of the CCA.

among other things, sets out guidelines with respect to the development activities in the coastal zone.

Development activities in the coastal zone requires a permit from the Director of the Coast Conservation Department.[114] Any activity likely to alter the physical nature of the coastal zone is treated as 'development activity'.[115] However, certain activities described in the CZMP, including fishing, do not require a permit. Regulations further specify activities which do not need a permit.[116] A permit will be granted only if it is consistent with the CZMP and does not have adverse effects on the stability, productivity and environmental quality of the coastal zone.[117]

The Director of Coast Conservation retains discretion to call for an EIA before permit applications are considered.[118] The Director of Coast Conservation has also wide powers to demolish unauthorized buildings and structures.[119] The exercise of these powers has resulted in challenges in courts from time to time.[120]

The Marine Pollution Prevention Act of 1981 gives effect to the following five International Conventions:[121]

1. the International Convention on the Prevention of Pollution of the Sea by Oil 1954, as amended;
2. the International Convention on Civil Liability for Oil Pollution Damage, 1969;
3. the International Convention on the Establishment of an International Fund for Compensation for Oil Pollution Damage, 1971;
4. the International Convention relating to Intervention on the High Seas in Case of Oil Pollution Casualties, 1969; and
5. the International Convention for the Prevention of Pollution from Ships, 1973 and the Protocol of 1978.

The Act provides for compulsory insurance for vessels carrying more than 2000 tonnes of oil in Sri Lanka waters.[122] Civil liability is limited to Rs. 7 210/- for each tonne of the vessels tonnage with respect to any one incident. The maximum limit of liability is an aggregate of Rs. 750 million. Criminal liability for dumping oil carries a maximum penalty of Rupees one million, as does the offence of pollution. The law also deals with preventive measures, reception facilities and maritime casualties.[123]

Enforcement of coastal zone law might be regarded as reasonably effective considering the short history of the active Coast Conservation Department. The MPPA has become active albeit recently. The Fisheries Department has a longer history of enforcement and is reasonably active. Its functions include the prevention of illegal fishing, the allocation of fisheries resources, the resolution of fisheries disputes and the assessment and management of fisheries resources.

Sri Lanka is a party to the Law of the Sea Convention[124] and exercises jurisdiction over the territorial sea, continental shelf, the exclusive economic zone and the contiguous zone in keeping with the definitions laid down in that convention.

CHEMICAL SUBSTANCES & PRODUCTS

There is no comprehensive law that governs the import, export, manufacture, use, sale and disposal of chemical substances and products. Instead there

[114] Section 14 of the CCA.
[115] Section 42 of the CCA.
[116] Regulations contained in Gazette Extraordinary No 260/22 of 2.9.83.
[117] Section 15 of the CCA.
[118] Section 16 of the CCA.
[119] Section 31 of the CCA.
[120] See the cases of L. Escale Pvt. Ltd. vs. Dir. CCD and Secy. Ministry of Fisheries & Aquatic Resources SARLR 3 and order dated 25.07.96 in Galle High Court Revision application No. HCR 79/95 G.M. de Silva vs. Director CCD and Hon. AG.
[121] Section 17 of the Marine Pollution Prevention Authority Act No. 39 of 1981.
[122] Section of the MPPA.
[123] Section 3, 13, 15 of the MPPA
[124] United Nations Conventions on the Law of the Sea: acceded to by Sri Lanka on 10th December 1982.

are a number of statutes that govern different chemicals and compounds. As a result there are also a number of institutions with authority over different chemicals and substances. One of the negative features of this legislative approach is that there are a number of toxic or hazardous chemicals and substances that are not subject to any regime with respect to importation, exportation, sale, advertisement etc. Disposal of all substances by way of waste, however, is covered by the EPL provisions of the NEA. The establishment of chemical plants exceeding specified capacity is required to go through the EIA process.

The Food Act of 1980[125] established a Food Authority and a Food Advisory Council which have authority over the importation, production, consumption, sale, advertisement etc. of food. The Cosmetics, Devices and Drugs Act of 1980[126] controls these substances and authority is vested in a Director of Health and a Cosmetics, Devices and Drugs Technical Advisory Committee. The Explosives Ordinance[127] controls explosives and substances of a like kind. The Poisons, Opium and Dangerous Drugs Ordinance[128] controls listed poisons and drugs. Pesticide formulations are governed by the Control of Pesticides Act 1980[129] and the Act is administered by a Registrar of Pesticides. There is a similar Act governing Fertilizers (1961).[130]

General government policy regarding the import and export of chemicals and substances are to be found in the regulations made under the control of Imports & Exports Act.[131] A number of substances and chemicals are subject to tariffs and duties as well as to permit procedures. This Act is enforced by the Customs Department and the Controller of Imports and Exports.

The production of cigarettes and its impact on human health has given rise to a number of cases in the United States and the rest of the developed world. There appears to be gradual extension of the liability of tobacco companies in respect of human health impacts where adequate warnings have not been given on the product to potential consumers. There also appears to be a trend to recognize the liability of employers towards employees who may become unwilling passive smokers. The multi-million dollar settlement arrived at recently in the USA in such a case, is an indication that even tobacco companies are recognizing the existence of such liability. A recent action filed in a Sri Lankan District Court by a lung cancer patient against a leading tobacco company shows that increasing attention is being given to this issue.

Apart from the above statutes there is no law specifically governing the manufacture of new chemicals or substances. The formulation of new pesticides would require a permit from the Registrar of Pesticides.

The manufacture, import and distribution as well as storage and transport of named or gazetted substances are covered under the above statutes. For instance, import, labelling, formulation, transport, storage and sale of pesticides is governed and controlled by the Pesticides Act. Similar provisions apply to food, drugs etc. as well as to explosives . However, there is no general law governing these matters with respect to new or unlisted chemicals and substances.

Consumer protection is provided by the Consumer Protection Act[132], which has special provisions covering labelling, advertisement, packaging, sale, distribution etc. of the above listed substances. The Consumer Credit Act[133] specifically deals with hire-purchase agreements and protects consumers who take goods on such agreements. Other specific Acts such as Food Act requires standards to be complied with and consumers are entitled to information with respect to declaration on labels etc.

Enforcement of these statutes are with the institutions having authority. Local authorities enforce food regulations and consumer protection regulations through Public Health Inspectors and Food Inspectors. Enforcement may not be very strong, but is nevertheless visible. The enforcement of the Pesticide Act has been hampered by the lack

[125] Act No. 26 of 1980
[126] Act No. 27 of 1980
[127] The Explosives Ordinance (Cap. 140)
[128] Cap. 549(218)
[129] Act No. 33 of 1980
[130] Act No. 21 of 1961.
[131] Cap 236

[132] Act No. 1 of 1979 as amended by Act No. 37 of 1980.
[133] Act No. 29 of 1982

of staff at the Registrar's office. Consumers affected by products are entitled to sue for damages through normal common law depict (tort) actions. Liability regimes are similar to those applicable in other common law countries.

Waste Management

There are three key agencies responsible for waste management. They are the CEA, the Board of Investment (BOI) and the relevant local authorities. Responsibility for licensing waste disposal and the enforcement of environmental standards is with the CEA.[134] The control and management of waste within industrial promotion zones is with the BOI.[135] The scavenging and disposal of solid waste and general sanitation is the responsibility of the relevant local authority. Major urban centres are governed by Municipal Councils, smaller centres by Urban Councils, and village and rural areas by Pradeshiya Sabhas.

Responsibility for the collection and disposal of household and non-hazardous solid waste, is with the local authority. There are elaborate legal provisions in the local government Acts with respect to this matter. Local authorities are expected to establish dumps/landfills and provide for scavenging services. Dumps are required to be authorized by a license issued under the NEA by the CEA.[136] This requirement is however, not enforced. Solid waste disposal sites exceeding 100 tonnes per day require approval under the EIA process.[137]

Hazardous Waste is regulated through a set of regulations adopted in 1996 by the Ministry of Environment under the NEA.[138] The regulations provide for generators and importers to report on the quantity, chemical make up etc. of hazardous waste. Collection, storage, transport, disposal, recovery and recycling, of hazardous waste requires a licence. Licences could be a single or multiple operation licence. The regulations provide for safety signs, the training of personnel, emergency response and public access to hazardous waste information. The regulations also provide for absolute liability[139] insurance. The regulations, though in force, have not yet been enforced by CEA. The regulations are currently being revised.

Sri Lanka is party to the Basel Convention on the control of Transboundary Movement of Hazardous Wastes and their Disposal (1989).[140] In keeping with its obligations, regulations have been gazetted under the Control of Imports and Exports Act requiring import-export permits for hazardous waste. Such permit would be issued following prior-informed-consent principles and an examination of the application by the CEA. While the export-import regulations follow the Basel Convention definition of Hazardous Waste, the internal regulation is limited to a smaller list of hazardous wastes.

Radioactive waste is specially dealt with under the Atomic Energy Authority Law.[141] The Atomic Energy Authority regulates all imports and exports of radioactive substances including wastes. It also regulates disposal of such substances and waste and the use of such substances. Sri Lanka generally does not permit the importation of radioactive waste and has no nuclear power plants or major nuclear devices. Radioactive substances are only used for beneficial purposes, such as in medical diagnosis and treatment, agriculture assessments, teaching and in laboratory conditions.

Sri Lanka and Her International Environmental Obligations

Sri Lanka has become a party to a number of environmental conventions and treaties. These are:

a) Conventions for the Protection of the World Culture Heritage and Natural Heritage (1972).[142]

[134] Under the provisions of the NEA.

[135] Under Section 20 A of the Greater Colombo Economic Commission Law No. 4 of 1978 as amended by Act No 49 of 1992.

[136] Sections 23A and 23 N of the NEA

[137] Item 18 of Part I of the EIA regulations.

[138] Regulations contained in Gazette Extraordinary No. 924/13 of 23.05.96

[139] The concept of "absolute liability" (i.e liability that does not admit of exceptions or defence) is distinct and separate from strict liability as expounded in the English case of Rylands vs. Fletcher (1868) L.R. 3 H.L. 330:The concept was first stated by the Indian Supreme Court in the case of M.C. Metha vs. Union of India, 1987 AIR (SC) 952]; 1987 AIR (SC) 965; AIR (SC) 982; 1987 AIR (SC) 1086.

[140] Sri Lanka acceded to this convention on 22.08.92.

[141] Act No. 19of 1961

[142] Adopted on 16.11.1972. Sri Lanka acceded on 06.09.1980.

b) Convention on Wetlands of International Importance Especially as Waterfowl Habitat, Ramsar (1971).[143]

c) Convention on International Trade in Endangered Species of Wildlife and Flora (1973).[144]

d) Convention on the Conservation of Migratory Species of Wild Animal (CMS) (1979).[145]

e) UN Convention on the Law of the Sea (1982).[146]

f) Vienna Convention for the Protection of the Ozone Layer (1989).[147]

g) Montreal Protocol on Substances that deplete the Ozone Layer (1987).[148]

h) Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal (1989).[149]

i) Convention on Biological Diversity (1992).[150]

j) UN Framework Convention on Climate Change (1992).[151]

k) Stockholm Declaration of the UN Conference on the Human Environment (1992).

l) Rio Declaration on Environment and Development (1992).

The question of global equity looms large in a number of these conventions. For instance the Montreal Protocol requires parties to reduce the use and manufacture of chloro-fluoro-carbon(CFC) by certain deadlines. Sri Lanka, in pursuance of her obligations, has gazetted the necessary orders prohibiting the use of CFCs after 2005.[152] However, Sri Lanka has not yet received the promised financial assistance or technology transfer that would enable local industry to switch to non-CFC substances. The Framework Convention of Climate Change as well as the Biodiversity Convention raise the issue of shared responsibility between the North and the South.

Though Sri Lanka is a party to the above international conventions, several of them have not yet been given proper legal status through the enactment of appropriate legislation. The Biodiversity Convention and the Ramsar Convention are two such instances.

List of Acts, Statutes and Ordinances

Air

Motor Traffic Act No. 14 of 1951 as amended from time to time.

Cultural Heritage

Antiquities ordinance (Cap 188).
Central Cultural Fund Act No. 57 of 1989.

Environment

Constitution of the Democratic Socialist Republic of Sri Lanka.

National Environment Act No. 47 of 1980 as amended by Act No. 56 of 1988.

National Environment Act (draft).

Northwestern Provincial Environment Statute No. 12 of 1990.

Fauna & Flora

Botanic Gardens Ordinance No. 31 of 1928 as amended by Act No. 33 of 1973.

[143] Adopted on 02.02.1971. Sri Lanka acceded on 1990.
[144] Adopted on 03.03.1973, Sri Lanka acceded in 1990.
[145] Adopted on 23.06.1979, Sri Lanka acceded on 02.08.1979.
[146] Adopted on 10.12.1982, Sri Lanka acceded on 10.12.1989.
[147] Adopted on 22.03.1985, Sri Lanka acceded on 15.12.1989.
[148] Adopted on 16.09.1987, Sri Lanka acceded on 15.12.1989.
[149] Adopted on 22.03.1989, Sri Lanka acceded on 22.08.1992.
[150] Adopted on 22.05.1992, Sri Lanka acceded on 21.03.1994.
[151] Adopted in June1992, Sri Lanka acceded on 23.11.1993.

[152] Order under section 23W of the NEA published in Gazette Extraordinary No. 850/4 dated 20.12.1994.

Animals Act No. 29 of 1958 as amended from time to time.
Diseases of Animals Ordinance No. 25 of 1909 as amended from time to time.
Fauna and Flora Protection Ordinance (Cap.469) as amended especially by Act No. 49 of 1993.
Felling of Trees (Control) Act No. 9 of 1951 as amended by Act No. 30 of 1953.
Fisheries Act No. 2 of 1996.
Plant Protection Ordinance (Cap. 447).

Fresh Water & Marine Resources

Coast Conservation Act No. 57 of 1981 as amended by Act No. 64 of 1988.

Irrigation Ordinance (Cap. 453).

Marine Pollution Prevention Act No. 59 of 1981.
Maritime Zones Law No. 22 of 1976.

National Water Supply and Drainage Board Act No. 2 of 1974.

Water Resources Board Act No. 29 of 1964.

Land

Agrarian Services Act No. 58 of 1979.
Forest Conservation Act (draft).
Forest Ordinance (Cap. 451).
Greater Colombo Economic Commission Law No. 4 of 1978 as amended by Act No. 49 of 1992.
Land Acquisition Act No. 9 of 1950.
Land Development Ordinance (Cap. 464).
Land Reform Law No. 1 of 1972 as amended by Act No. 39 of 1975 and No. 18 of 1986.
Land Settlement Ordinance (Cap 463).
Mahaweli Authority Act No. 23 of 1979.
Mines and Minerals Act No. 33 of 1992.
National Heritage Wilderness Areas Act No. 3 of 1988.
Soil Conservation Act No. 25 of 1951 as amended from time to time.
State Lands Ordinance (Cap. 269).
Urban Development Authority Act No. 41 of 1978 as amended from time to time.

Occupational Health & Public Health

Consumer Protection Act No. 1 of 1979 as amended from time to time.
Factories Act No. 543 of 1961 (Cap. 128).

Substances

Atomic Energy Authority Act No. 19 of 1969.
Control of Pesticides Act No. 33 of 1980.
Cosmetics, Devices and Drugs Act No. 27 of 1980
Explosives Ordinance (Cap. 183).
Poisons, Opium and Dangerous Drugs Ordinance (Cap. 218).
Fertilizers Act No. 21 of 1961.
Food Act No. 26 of 1980.
Imports and Exports Control Act No. 1 of 1969.

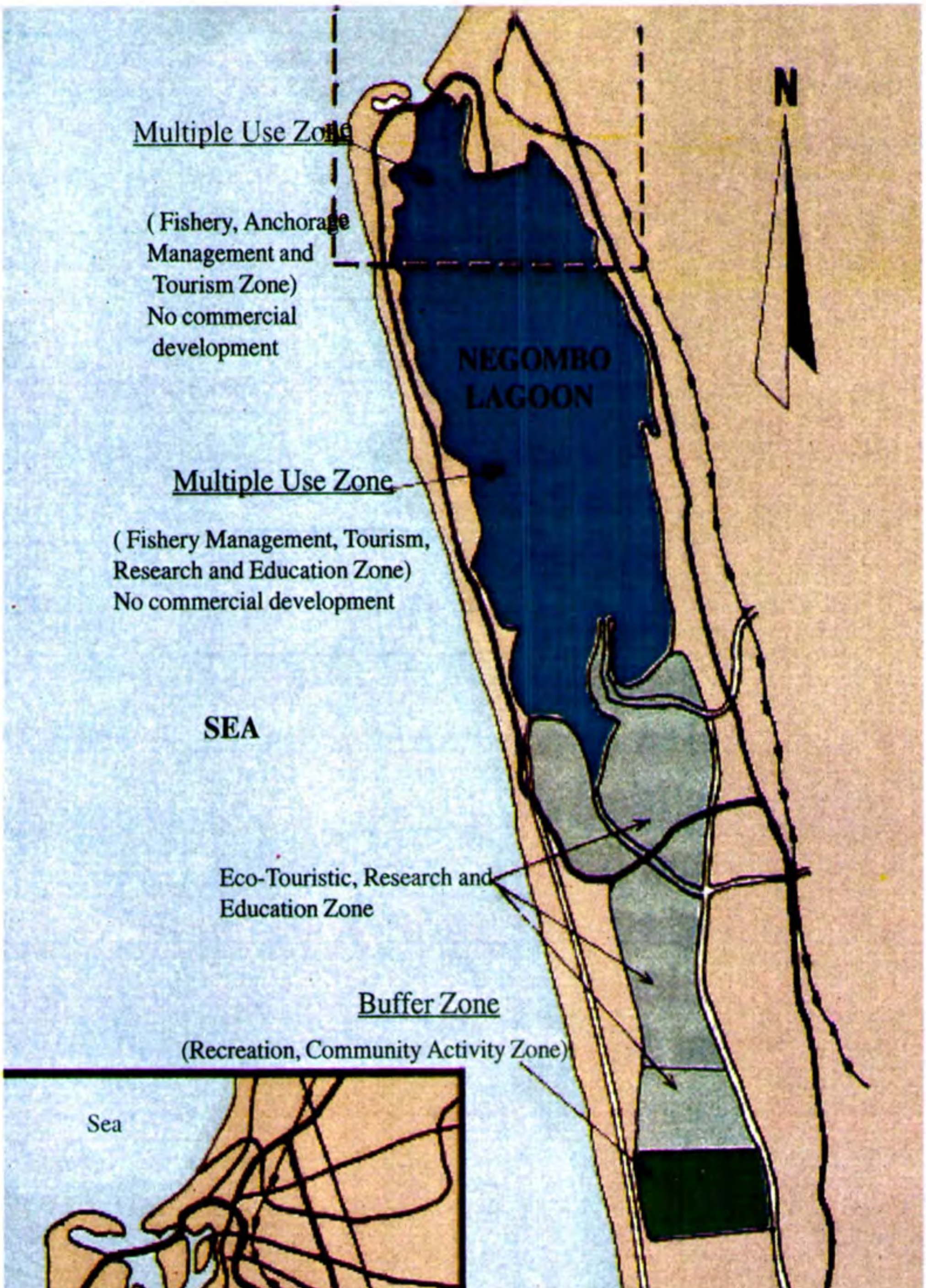
CASES

Appeal of E.M.S. Niyaz under Sec. 23E of the NEA, 2 SAELR 1
Arlis Appuhamy vs. Kavidane, 1983 (2) SLR 493
Baba Appu vs. Aberan, 8 NLR 160
Bandara vs. Premachandra, 1994 (1) SLR 301
Elal Jayantha vs. OIC Panadura Police, 1986 (1) SLR 334
Environmental Foundation Limited vs. Attorney General *et al.*, 1 SAELR 17
Environmental Foundation Limited vs. Secretary to the Ministry of Transport and Highways *et al.*, Court of Appeals Writ Application, No. 549/94
Environmental Foundation Limited vs. The Land Commissioner *et al.*, 1 SAELR 53
Fernando vs. Fernando *et al.*, 42 NLR 279
Fernando *et al.* vs. Fernando *et al.*, 22 NLR 260
G.M.de Silva vs. Director, Coast Conservation Department and Honorary Attorney General, Galle High Court Revision application No. HCR 79/95
Greena Fernando vs. Teckla Saparamadu, 1990 (1) SLR 270
Harinda *et al.* vs. Ceylon Electricity Board *et al.* Fundamental Rights Application No. 323/97, (pending in courts)
Keangnam Enterprises vs. Abeysinghe, 1 SAELR 1
L. Escale Pvt. Ltd. vs. Director Coast Conservation Department and Secretary, Ministry of Fisheries & Aquatic Resources, 3 SAELR 3

M.C. Metha vs. Union of India, 1987 AIR (SC) 952; 1987 AIR (SC) 965; 1987 AIR (SC) 982; 1987AIR (SC) 1086
Mohamed Faizz vs. Attorney General, 1 SAELR 62
Premachandra vs. Jayawickrema, 1994 (2) SLR 90
Rowel Mudliyar vs. Pieris *et al.*, 1 NLR 81
Rylands vs. Fletcher, (1868) L.R. 3 H.L. 330
S.C. Amarasinghe vs. Attorney General *et al.*, 1 SAELR 17; 1993 (1) SLR 376
Smithkline Beecham Biologicals S.A. vs. State Pharmaceuticals Corporation of Sri Lanka *et al.*, Supreme Court Fundamental Rights case No. 89/97 S.C. Minutes of 20th May 1997
Supreme Court Fundamental Rights Case No. 413/93
Weragama vs. Indran *et al.*, 2 SAELR 02

List of Abbreviations

BAP - Biodiversity Action Plan
BOI - Board of Investment
CCA - Coast Conservation Act
CCD - Coast Conservation Department
CEA - Central Environmental Authority
CEIF - Community Environmental Improvement Facility
CFC - Chloro –Fluoro-Carbons
CZMP - Coastal Zone Management Plan
EAIP - Environmental Action 1 Project
EIA - Environmental Impact Assessment
EPL - Environmental Protection Licence
IEE - Initial Environmental Examination
MPPA - Marine Pollution Prevention Authority
NEA - National Environment Act
NEAP - National Environmental Action Plan
NEPA - National Environmental Protection Act (draft)
NGO - Non-Governmental Organization
NLR - New Law Reports
PAA - Project Approving Agency
PI - Preliminary Information
SAELR - South Asia Environmental Law Report
SLR - Sri Lanka Law Report
UDA - Urban Development Authority
UNEP - United Nations Environmental Programme



Source: Wetland Conservation Project, CEA.

TOWARDS SUSTAINABLE DEVELOPMENT

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PREAMBLE

No country big or small can survive without economic development. Historically, the development processes of the countries of the world have created, in today's context, groups of countries, some described as developed, others as developing. Inevitably, any development activity has impacts on the environment, which may be localized but can also have global overtones. It is generally accepted that global impacts of the past and present economic development activities of developed nations have been the principal causes of major environmental damage, in global terms. By and large, this situation has changed but little. On the other hand, it is also generally accepted that developing and under-developed countries, many of which had suffered economically under foreign rule, need rapid economic development, in order to ensure that their people shall have an optimum and satisfying means of life.

In common, these countries face the spectre of overpopulation, which continues to become more acute and abject poverty with all its attendant ills, such as, malnutrition, lack of basic amenities, poor health and unemployment. These problems are compounded by lack of expertise, limited trained and educated human resource base and, the inability to generate adequate levels of income, whereby the living conditions of people may be uplifted. Moreover, many of these countries have economies based on primary products, which are of low economic rating, with little value addition and very limited competitive advantage, in international markets.

That is the backdrop against which the concept and practice of sustainable development has to be considered in countries such as ours. It is axiomatic that poverty and poor levels of education and of general awareness go hand in hand with many aspects of environmental degradation. Therefore, if any attempt at balancing the quality of the environment against essential economic development is to succeed, the twin problems of poverty alleviation and providing a sound educational base must be addressed, in developing and under developed countries.

SUSTAINABLE DEVELOPMENT

It was not until about the middle of the twentieth century that concern about the environment and adverse anthropogenic impacts on it, began to take hold in the minds, even of scientists. Governments and bureaucrats were slow to follow. But concern did grow, first among the developed countries and spread less rapidly to all countries. Recognition of different kinds and extents of environmental damage and deterioration began to be given some consideration in the planning and policy making processes of developed countries and to a lesser extent among other countries. Discussion and debate, planning and action led also to the framing of legislation by various countries and the imposition of environmental quality standards.

It must be stated that the community of scientists, subsequently supported by concerned Non-Governmental Organizations (NGO), were the trail-blazers in opening up the pathways to general public understanding of the problems relating to environmental degradation and the major disasters that mankind will have to face, in the course of the 21[st] century.

As realization grew that it is essential to pay close attention to environmental aspects of any development activity, it also began to be realized that many of the looming problems are common to all countries and that planned, concerted and coordinated action by the global community had become an urgent imperative. The first Global Conference on the Human Environment, the Stockholm Conference on the Human Environment, was held in 1972 and attended by delegates from 113 nations. Following on this, in 1983, the United Nations created **The World Commission on Environment and Development.** This Commission ,which came to be known as the **Brundtland Commission,** after its Chairperson, **Gro Harlem Brundtland** of Norway, produced a Landmark Report, entitled **'Our Common Future'.** The **Concept of 'Sustainable Development'** emerged out of these initiatives. The concept is best defined, as follows, in terms set out in that report itself :-

> **"Humanity has the ability to make development sustainable – to ensure that it meets the needs of the present without compromising the ability of future generations to meet their own needs."**

In 1989, the United Nations began preparations for the **United Nations Conference on Environment and Development,(UNCED)** to be held in Rio in 1992. This conference was meant to spell out to the nations of the world the paths to sustainable development. The preparatory phase involved not only government officials but also NGOs, groups from business and education, indigenous and women's groups. Like all other participating nations, Sri Lanka too produced a Country Report for the Conference , the **'Sri Lanka National Report'.**

Held in 1992, the Rio Conference produced **Agenda 21,** a blueprint on how to make development socially, economically and environmentally sustainable and the **Rio Declaration on Environment and Development,** the 27 principles of which define the rights and responsibilities of nations as they pursue human development and well being. Another statement laid down principles relating to the management, conservation and sustainable use of forests. Two important conventions, the **'Convention on Biological Diversity'** and the **'Framework Convention on Climate Change'** were also approved at Rio. Sri Lanka took part in the preparatory phases (Prepcoms) , was well represented at Rio and is a signatory to the Conventions and Declarations.

THE PATH TO SUSTAINABLE DEVELOPMENT

It is a fallacy to think that the lay public, by themselves, are the main agents of unsustainable development practices and of degradation of the environment. The most extensive and serious damage has been caused, in every country, largely, by **Governments, Public Institutions** and major **Private Sector** concerns. These are the authorities and institutions, that direct policy and planning and engage in large scale development activities that, in turn, have major environmental impacts. What better example can be quoted than that of the failed economic and industrial development of the USSR and major environmental disasters that resulted, as illustrated by the ruin that is the remnant of the Ural Sea.

It is often stated that there is an urgent need to create greater awareness in the public mind about resource use and the protection of the environment. This might have been true some years ago but is no longer a valid view. Through the efforts of NGOs, Scientists and Education Systems, understanding of problems, possible approaches and individual and community responsibilities, relating to the environment have gained much ground in the public mind, in this country and in all developed countries and most developing countries. However, the power to direct economic development along appropriate channels does not lie in the unofficial domain. The will and commitment of governments and government agencies are the keys to sustainable development. This will and commitment are often lacking, particularly in the developing world, where short term political goals often override long term national and global environmental interests. Politicians and bureaucrats, who stride the stage for short periods of time, often consider themselves the arbiters of our destiny and have on occasion caused serious damage, by paying little attention to environmental concerns, while they pursue pet projects.

A prime example of such folly, in our own country, was the development of potato farming on Horton Plains. In retrospect, that appears utterly ridiculous but, at that time, the arm of authority considered the potato and the potato farmer as being more valuable than the Horton Plains ecosystem. It took all the pleadings and persuasive powers of a committed group of scientists to 'cry halt' to the project. The Plains are still recovering from the ravages of that incredible onslaught. A similar case in point was the proposal to log the Sinharaja, now a **World Heritage Site,** in order to provide raw material for a mere *Plywood Factory,* an act of absurdity. The powers that launched these disasters have passed into the limbo, the damage they caused will long remain.

It is lamented, often, that the forest cover of this country has declined to less than 25 per cent, during the period following independence. The major cause for this decline was the clearing of forests on a large scale in order to create settlement schemes based on irrigated agriculture, such as the Gal Oya and the Mahaweli Projects. Needless to say the economy of the land and the needs of the people demanded rapid and large scale development but environmental concerns were not addressed from the angle of sustainability. There are mitigating circumstances in respect of Gal Oya, in that knowledge, understanding and concern had not developed to any great extent, on these matters, at that time. The same cannot be said, however, in respect of the Mahaweli. In the latter case, the development was backed by the first ever **Environmental Impact Assessment** (EIA) carried out in this country, by TIPPETS, a competent group of foreign consultants. The fault lies in the fact that many of the palliative measures that were recommended and should have been implemented in parallel with the development exercise, were never implemented. In terms of results, two decades into the Project, the settlers still live at subsistence level and land degradation is rampant. A cost benefit analysis and an environmental audit will show startling results. Settlers were encouraged to take up pig farming, in order to supplement relatively meagre incomes, without taking into account the fact that pigs are multiplier hosts of the causal agent of Japanese Encephalitis. That disease has reared its ugly head in the country, adding to the woes caused by malaria, also a disease, now, again on the increase and carried by a mosquito that once contributed to the downfall of the ancient hydraulic civilization. Such is not the nature of sustainable development, and such are not the paths that we should follow as we expand our economy for the betterment of the living standards of our people.

Chena cultivation, too, is a contributory factor to land degradation. This is an age old practice which did not do major damage when there was sufficient land, much fewer people and long fallow periods, between successive cultivations. Today, chena cultivation causes very considerable damage. Yet, in the agricultural economy of the country, subsidiary crop production is largely based on chena cultivation, which practice has the sanction of governments. The continuation of the practice of chena cultivation, too, comes back to roost at the doorstep of the policy maker and planner. Their efforts at poverty alleviation have failed to find more sustainable means of income generation. Even the provision of an important component of the food needs of the nation have to be met by subsistence farmers using unsustainable means of production.

SRI LANKA AND AGENDA 21

The lack of political will and commitment on the part of successive governments to follow the path of Sustainable Development is easily demonstrable if we consider the aftermath of the Earth Summit of 1992, as manifested in follow up activity in Sri Lanka. Agenda 21, the main outcome of the Earth Summit, is a heavy tome, running to 40 chapters. These lay down agreed approaches that countries may follow in order to achieve Sustainable Development, in the 21st Century. Seven years from that time, there is little evidence that governments of this country have taken serious note of what we agreed should be done. It would not be unreasonable to state that many of those who should be carrying the process forward are unaware of the existence of such a document and fewer have read it. Actions for implementation of the proper approaches for integrating development actions with environmental measures which are essential for sustainable development have not come to the forefront of planning and policy making. The UNDP did sponsor a short preliminary study on Agenda 21 in relation to Sri Lanka for the Ministry of Environment but little else has happened.

On the positive side, it is encouraging to note that important follow up activities are being taken in relation to the two conventions. A **Biodiversity Action Plan** has been prepared for the Ministry of Environment by IUCN, Sri Lanka, with wide participation. An Experts Committee on Biodiversity advises the Ministry of Environment. A red list of fauna for Sri Lanka has been compiled by IUCN. With respect to the Framework Convention on Climate Change a Steering Committee is functioning, carrying out requirements of the Conference of Parties. What is lacking is actual action on ground to do the things that we need to do for ourselves, apart from producing reports for the international bodies, which also needs to be done.

WHERE DO WE GO FROM HERE?

The economy of this country is determined by its heritage of natural resources, its geographical location and the will and ingenuity of its peoples. At one of the Annual Sessions of the Sri Lanka Association for the Advancement of Science, the Chief Guest, a Nobel Laureate advised our scientists to direct their interests and energies along directions within our capacity and suited to our particular needs, rather than trying to ape the money gobbling technologies of the developed world. This advice applies equally to the directions that we could follow in the sustainable development of our economy and the fashioning out of an appropriate 21st Century lifestyle for our people.

The preceding chapters of this book have laid out the natural resource base and have identified how these resources may best be employed for the well being of our people and the preservation of our environment. Development planning has to revolve around these basic resources.

THE HUMAN RESOURCE

It has already been emphasized that our human resources are amongst the most valuable of our resources. It has been demonstrated that education policies practised in years after independence have enabled us to create a literate, easily trainable population. One major benefit has been the remarkable slowing down of the rate of population growth. It has been possible, also, to achieve and maintain a reasonably healthy population. This too is attributable to the quality and level of the education system, of that time.

We need to mobilize our human resource to the fullest extent possible, both for contribution to productivity within the country, as well as for generating trained personnel for skilled employment beyond our shores. Therefore, the education system has to be geared to serve these goals. We cannot be satisfied simply with introducing the study of environment and conservation into the curricula. Teaching and learning at school and university and subsequently as a lifelong process must confer on the learner the ability to develop for himself and for his society a life style which is entirely sustainable, in the long term. The new generation of planners, policy makers, politicians and decision makers who will emerge from the education system must be steeped in a true understanding of man's total dependence on a balanced and healthy environment. The earth system existed for four billion years without man, who appeared on the stage a mere 500 000 years ago. The earth system will continue to exist for many more billions of years. We need to understand that Mother Earth needs a helping hand to survive. It is man's continued existence on earth that is at stake and Earth will rapidly find a new and better equilibrium once we are gone. As we enter the 21st Century our insurance of continuing survival lies in our capacity to achieve sustainable life styles supported by sustainable development.

In recent decades the education system progressively went into decline. It did not achieve the whole and wholesome personality development, nor the appropriate and adequate training of young minds to meet the challenges of the future. Neither did it keep pace with expanding frontiers of knowledge and technology, nor was it attuned to national development needs. No society can prosper in the absence of a carefully designed system of education which allows for rapid adaptation to changing needs. When all is said and done, it is the output from the education system that must guide the country along the pathways to a prosperous and successful future. Fortunately, the present government has realized that primacy of place must be given to the quality of education and has committed itself to a comprehensive overhaul of the system at all levels with precisely these goals in mind.

HOW DO WE USE OUR RESOURCES?

First we need to know the nature, content and value of our resources. The chapters in this book give such an overview. Next we need to develop integrated plans for sustainable use of our renewable resources and efficient and optimum use of those that are non-renewable, while searching for alternate materials for the future. In actual terms, we should develop a long term National Plan for Sustainable Development. Such a plan would be a consensus document which should not be subject to the vagaries of political whims and fancies.

As a sequel to Rio and Agenda 21, this country should by now have developed such a plan. A major arm of government, for instance, the Ministry of Planning and Plan Implementation should establish an Agenda 21 Implementation Unit and guide the destinies of this country into the 21st Century.

SOME LEAD AREAS FOR SUSTAINABLE DEVELOPMENT

Education as the keystone on which the entire future of the country will rest has already been stressed. The human resource base thus adequately served, land and water are prime resources. The land/man ratio is already below the required minimum. Therefore very careful attention needs to be paid to maintaining and enhancing the quality of the land and to ensuring that every plot of land is put to its proper and optimum use. However, even today, we do not have a National Land Use Policy or National Land Use Plan. There have been attempts at making out Land Use Plans, for instance, by the Urban Development Authority, Local Government Agencies, various Ministries and plans for Coastal Zone Management by the Coast Conservation Department. The major drawback in this multi-pronged approach to land use planning is the lack of coordination and often the implementation of programmes that adversely affect one another and the environment.

Sustainable development requires as its first base a National Land Use Plan and a National Land Use Policy. These must define in broad terms the particular uses to which land may be put based on sound ecological, geological, geographical and social considerations. Under a devolved system of government such a plan and policy become even more important. We need to know the extents of watersheds that need to be conserved, stream bank and reservoir bank reservations, natural wetlands that must remain inviolate to serve land drainage and biodiversity conservation and how our great variety of ecosystems, including coastal ecosystems should be managed.

Land and Water

Land, soil and water management are everyday concerns of the individual farmer and of an agricultural economy. Though our tradition as a country with an agro-based economy is ancient we do not seem to have retained and developed basic elements essential for sustainable production. The history of concern for Soil Conservation in this country is a chequered one. This is discussed elsewhere in this book. Soil is a renewable resource but not in terms of human life spans. Loss due to soil erosion is enormous and corrective measures do not operate anywhere near the levels at which they should. At long last, we have an acceptable Soil Conservation Act, but will its provisions be implemented or will it join the numerous other pieces of legislative enactments that are mere pieces of paper couched in high sounding legal jargon?

Our farmers, for the most part, have little understanding of the value of water and the importance of its proper use. Most farmers use up much larger quantities of water than is really needed, resulting not only in wastage of water as a resource but also leading to degradation of the land itself. We are told that a considerable area of land in the Mahaweli is already subject to water-logging and salinization. Much of the Lunugamvehera acreage has been badly degraded, as well. Too much water, poorly designed and maintained drainage systems, a pre-occupation with paddy farming where the original plan called for crop diversification, have all served as pillars of failure, compounding geologic and engineering flaws of the scheme itself as conceived.

Combined with the damage caused by the lack of sensitivity to proper soil and water management are the increasing levels of pollution that have come down the years as a heritage from the Green Revolution. As is the case with water use, our farmers are using far larger quantities of agro-chemicals than are actually required. This leads to soil pollution, pollution of surface waters and of ground waters and pollution of the very food materials that are produced. Some chemicals being applied to give longer shelf life and better appearance can become health hazards. The case of the 'nitrate bomb' and the 'blue baby syndrome' in the underground waters of the Jaffna Peninsula and the Kalpitiya area have been described elsewhere. Uncontrolled use of agrochemicals lead to the development of resistant strains of pests and the vicious upward spiral of the application of stronger pesticides in increasing quantities, leading to newer resistant strains of pests. Are our agricultural practices sustainable in their present form? They are not. The farmer is poverty stricken in spite of huge investments on irrigation schemes and extensive transformation of land cover. We do not know how much longer the tea that we produce, virtually by sand culture buttressed by agro-chemicals, can remain a keystone of our economy. Rubber that no longer commands the position it once did can now be put to new uses in the rubberwood furniture industry after appropriate treatment. Coconut plantations, the nut now classed as a cardio-vascular risk factor, is giving place to highly priced residential properties, for there is much land hunger in the country.

Water as has been pointed out is a renewable resource but its availability is not uniform across space and time. In areas where it is plentiful it is wasted. In areas of scarcity obtaining water for basic daily needs is a major problem. As part of the National Agenda 21 Policy we need a Water Policy. There are now a Water Resources Secretariat (WRS) and Water Council, the establishment of which constitute important initiatives. A clear set of actions need to be developed to ensure the quality of water, its availability and the protection of our sources.

Connected to this is a clear Policy covering Wetlands. There is now a programme that is designed to help in Wetland Management and Conservation, referred to in earlier chapters. In this area too there have been short-sighted policy errors. For instance a government agency, The Low Lying Areas Reclamation Board, was set up for the filling up of wetlands and reclaiming them for use as buildable land. This has had disastrous results. We experience frequent floods because the natural drainage systems have been blocked out by these property developments, in addition to which much damage has been done to natural habitats and biodiversity.

Transport

Sustainable development demands a comprehensive and rapid overhaul of the country's transport system. We have an outmoded, dilapidated and utterly inefficient railway system. Very little addition has been done to the rail tracks laid down by the British and even those tracks are in a very bad state. Our rolling stock is piteous. While our neighbour India produces her own rolling stock, which would suit us admirably, we have turned to countries whose designs and systems make our travelling public severely stressed. While High Speed Trains operate at speeds in excess of 200 km/h in various parts of the world and even in India trains run at speeds in excess of 100 km/h, our trains keep to a leisurely average of about 40 km/h.

Another interesting feature of our railways is that commuter trains overflow with people at rush hours, morning and evening, and run practically empty during most of the day. On the other hand, road transport is in shambles. Too many small buses, ply on our roads, packed with passengers, breathing down each others necks. Many of these vehicles are not roadworthy and cause massive congestion on major roads. The roads, themselves, have changed little over the years and cannot cater to the massive increase in vehicles.

In terms of environmental costs, city transport is a major source of air pollution. In traffic jams, travellers are forced to inhale exhaust fumes which include Carbon monoxide, among other obnoxious and harmful gases posing the cumulative effect of respiratory ailments. In economic terms, there is unnecessary increase in burning of petrol and diesel and losses caused by the inability of people to move rapidly from one place to another. Haulage of goods by road adds to the problems both environmental and economic. In short, our transport system is operating on an entirely unsustainable base which has multiple impacts on the economy, on health and on the quality of life of our people. This is a state of affairs that cannot be allowed to continue into the first decades of the new millennium. Major policy initiatives and measures for rectification should take priority position within a carefully planned and realistically integrated set of actions for an Agenda 21 for Sri Lanka.

Rapid Mass Transit Systems

The main commuter services for Greater Colombo and other major towns in the country should be converted to modern electric railway systems carrying large numbers of individuals, frequently at high speed. The first such conversion could be the Colombo – Katunayake line with an easily accessible terminal at the Bandaranaike International Airport and a new terminal in the city of Colombo. This would serve an expanding tourist industry and the Industrial Zone. Such a venture could be a landmark Millennium 2000 initiative. A phased conversion to (the new millennium, incidentally, commences on January/01/2001) Rapid Mass Transit (RMT) systems should follow along the busier lines. At the same time travellers must be drawn away from the road services to railways by comparative superiority of the services offered by the latter and the development of a coordinated rail-road system which places one within easy access of the other. In fact, road transport in and around cities should serve as feeder services for the railways with buses delivering passengers to the doorstep of important railway stations. The best such system in the world operates in the City of Toronto in Canada, a system worth emulating.

Given the incontrovertible fact that no major re-structuring of the existing road network in the main cities is possible, the only practicable approach to solving congestion is the development of one way traffic flow systems, even along the main roads. The only traffic flow system that one can recall with pride is the Uniflow system that still operates in the Fort.

In constructing our so-called Highways, we have made the error of routing them through city centres thus defeating the primary objective of rapid passage from Point A to Point B. Here corrective action is possible by constructing appropriate by-passes that do not permit ribbon development along such stretches.

Urban Development And Satellite Towns

Very few of our people can afford to live in Greater Colombo or in and around other major cities. The answer lies in a planned development of satellite towns, such planning being integrated with planned expansion of the economy including Tourism, Industrial Parks, Diversified Agriculture. There was once talk of a 'Parallelogram of Development'. It seems to have been the victim of infanticide, but such planning is essential. If it goes hand in hand with the development of rapid mass transit systems, people can live in healthy affordable areas and continue to work in the cities.

The future status of Trincomalee is worth considering in the context of integrated urban development. Trincomalee has one of the best, natural deep water harbours in the world. Given Sri Lanka's location. *vis-a-vis* major global sea routes and air traffic routes, it can be developed as a transit hub with an international airport.

Trincomalee has a number of other unique features which can be subject to sustainable development, to great advantage. The location has been identified as one with high potential for the development of Ocean Thermal Energy Conversion (OTEC). The Trincomalee area is one of great scenic beauty with headlands and bays and palm-fringed sandy beaches. In fact, this area attracted much of the tourist trade before the ethnic conflict. Historically, as well, there is Fort Frederick, a remnant of British colonial rule. Within the confines of the Fort is an ancient Hindu temple, Thirukoneswaran. During the Second World War, Trincomalee served as the main Naval Base of the South East Asia Command, under Lord Louis Mountbatten. Various cultural features are located in the environs of Trincomalee including the Kantalai tank and famous 'hot springs'. Obviously in planning integrated development a proper balance has to be struck between development imperatives and environmental losses. We have had experience of extreme positions taken up by environmental lobbies which have hindered essential development activities on flimsy grounds. One such example is the coal fired power plant that was planned for Trincoimalee. Any plan that is drawn up for the future development of this unique heritage would necessarily have to take into account this wide range of attributes. Ocean and harbour, bays and beaches, culture, possible industrial development, the potential to serve as a transhipment hub and a number of other factors should go into a planning exercise of innovative and ambitious dimensions, an Agenda 21 exercise.

Tourism as a Major Economic Base

It is well known that we launched into the development of the tourist industry in the late 70s. There was rapid expansion, but in the early stages, as on other fronts little pre-planning went into the development. Inevitably, there were immediate and undesirable environmental and cultural impacts. That false start should not deter us from developing tourism in this country as one of the potential sustainable cornerstones of the national economy.

As was indicated in the introductory chapter, this country is blessed with great beauty, a long cultural heritage, rich biodiveristy and ecosystems that can form the firm foundation of a truly sustainable and environment friendly tourist industry. Tourist interest is centred on coastal resorts, the hill country and our cultural artefacts. There is great potential to add ecotourism to these traditional attractions. A friendly people, absurdly cheap facilities (when dollars are converted to Sri Lankan Rupees) and a string of hotels that compare favourably with the best in other tourist centres of the world, all combine to make tourism an arena for sustainable economic activity.

One great advantage in the expansion of tourism is that it is not primarily based in the Metropolis of Colombo. Its tentacles will spread across the country to the remotest reaches of the land, carrying with it opportunity for jobs, entreprenuership, and income generation by individual effort and initiative. Our youth have already taught themselves languages such as German, French and Japanese, in an education milieu that, until the current Education Reform process came into force, did not even provide them with formal means to acquire an adequate knowledge of English.

There is a lobby that would discourage tourist expansion on the grounds of possible cultural and environmental erosion. If expansion is carefully planned, building in the necessary safeguards our people are intelligent enough to understand that one does not 'kill the goose that lays the golden egg'. If one visits many of the tourist resorts that have developed recently the contrast between the developed area and the surroundings is clearly visible, the former being much more environment friendly. Who pollutes the beaches? Certainly not the tourist.

Ecotourism is in its infancy in this country. The Muthurajawela Project and its Conservation aspect is a prime example of how we can exploit our ecosystems and biodiversity, sustainably to great advantage. Horton Plains and Worlds End, Bird sanctuaries, Nature trails, Whale watching off Trincomalee, Skin diving to view our undersea wealth are all examples of directions of sustainable ecotourism development, which have considerable potential for income generation.

Any major activity has in-built qualities many of which are good, others bad and yet others ugly. This applies to the growth of the tourist industry as well. The growth of child prostitution and especially of boy prostitution is one facet that has reared its ugly head and given this country an unenviable reputation. However, here if the truth be told, the tourist who is so inclined finds a ready able and willing supply. The children are not press-ganged into the trade. They offer themselves and mothers are known to place their young daughters, on offer. These people are poverty stricken and in these pursuits they find easy ways of earning considerable sums of money, with little effort, time or capital outlay. No account is however, taken of the damage in human terms to the long term future of the subjects of such abuse and exploitation. The answer is in drawing these families into support systems for the tourist trade in more acceptable services and supply ventures.

The argument that tourists are a threat to the purity of our culture is untenable. The many TV channels now bring into the homes of most people the entire gamut of desirable and less desirable experience. It is for us to be discriminate in how we educate our children. We need to instil moral and human values through our education system, the home environment and religious and cultural values. The fault lies in us, not in our stars or in transient aliens who come to our shores.

SUSTAINABLE DEVELOPMENT AND THE GOVERNMENT OF SRI LANKA

Sustainable Development is the responsibility of governments because of the major dimensions of Policy Initiatives, Integrated Planning, Project Implementation on a prioritized programme and major investments. The process involves people participation at every level and NGOs have an important role to play as monitors and watchdogs.

An Agenda 21 for Sri Lanka, using the broad guidelines of the UNCED Agenda 21 needs to be given top priority. Because of recent historical factors, an understandable lack of information on economic development *vis-a-visa* stable environment, a haphazard and *ad hoc* approach to planning, we operate today in a rather diffused system of management of basic resources, environmental degradation and a pace of economic development that cannot, yet, uplift the quality of life of too large a proportion of our people. Lines of command and control are multiple, diffuse and therefore, and often ineffective. There are many excellent pieces of legislation on the Statute Books but they are not effectively enforced due to lack of commitment and political will.

A major drawback has been the unwillingness of the establishment to exploit to the fullest the wide range of local expertise existing in the minds of the community of scientists, professionals and intellectuals coupled with an excessive dependence on foreign consultants. A major policy shift is required here. Our engineers have demonstrated that they can carry out major projects as effectively or better than their foreign counterparts and at much lesser cost to the national exchequer. The same applies to our experts in most fields related to national development imperatives.

An in-built defect in coalition governments which we have now and have had in the past is the distribution of subjects among ministers and ministries and groupings that militate against integrated development planning and implementation. We have had the subject of Environment handled together with Parliamentary Affairs.

One would like to see more rational groupings determined mainly on the needs of the country and integrated planning and sustainable economic development, than ones that cater to the whims and fancies of individuals, whose demands must be satisfied in order that a government may survive. For instance, the subjects of Forests, Wild Life and Environment make a logical and viable grouping, as also would the grouping of Higher Education, Science and Technology. Similar groupings serving the needs of an Agenda 21 would be Lands, Agriculture and Irrigation and Education, Culture and Social Affairs.

The world of the 21st Century will be ruled by Science and Technology. No successful business enterprise or company is run by groups of amateurs. This applies in much larger measure when it comes to the governing of a nation. Inevitably, final decisions have to be taken by ministers and cabinets. But, if we are to prosper, the decision making process must take on board the best available inputs from scientists and technocrats on possible options. This could be achieved, best, by attaching a 'brains trust' to each ministry made up not of political favorites and hangers on but of men and women who are accepted in the country as competent and knowledgeable in their own fields. Our land is not poor in such talent.

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